ACCM 12

12TH ASIAN - AUSTRALASIAN CONFERENCE ON COMPOSITE MATERIALS

ORGANIZERS

Zhejiang University
Chinese Society for Composite Materials

Blossom Water Museum Hotel, Hangzhou, PR China
25-28 April, 2023

Chairs' Welcome

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Prof. Shanyi DU

Harbin Institute of Technology

On behalf of the Asian-Australasian Association for Composite Materials (AACM), we sincerely welcome you to join us at the 12th Asian-Australasian Conference on Composite Materials (ACCM12) to be held from 25th to 28th April 2023 in Hangzhou.

Under the leadership of the AACM established in 1997, ACCM series has developed as one of the largest composites conference in the world promoting scientific research, technological development and industrial applications in the field of composite materials.

The theme of ACCM12 is "Composites for Quality of Life". ACCM12 will feature a 3-day program of divergent range of themes in composite research, and will showcase plenary and keynote talks, academic exchange, international networking, topical sessions/symposia and social activities including Banquet and Awards Ceremony. It promises to provide a valuable platform for scientists, engineers, postgraduates and other professionals to share, discuss and critically examine the most recent progress and trends in Composites Materials, Design Manufacturing and Applications.

Hangzhou, the home for ACCM12, renowned as "Paradise on Earth", is also preparing to host The 19th Asian Games.

We look forward to welcoming you at ACCM12 in Hangzhou in April 2023 !

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25th April	Day 1 26th April		Day 2 27th April		Day 3 28th April	
14:00-20:00 Registration	08:00-17:00	Registration Poster/ Trade Exhibition	08:00-17:00	Poster / Trade Exhibition	08:00-12:00	Poster / Trade Exhibition
	08:30-09:00	Opening Ceremony	08:30-10:00	Keynote Session 1 / Keynote Session 2 / Keynote Session 3	08:30-10:00	Keynote Session 4 / Keynote Session 5 / Keynote Session 6
	09:00-10:20	Plenary Session 1				
	10:20	Tea Break	10:00	Tea Break	10:00	Tea Break
	10:40-12:00	Plenary Session 2	10:20-12:00	Concurrent Sessions 1	10:20-12:00	Concurrent Sessions 4
	12:00	Lunch	12:00	Lunch	12:00	Lunch
	13:30-14:50	Plenary Session 3	13:30-15:00	Concurrent Sessions 2	13:30-15:00	Concurrent Sessions 5
	14:50-15:10	Tea Break	15:00	Tea Break	15:00	Tea Break
	15:10-16:30	Journal Session	15:20-17:30	Concurrent Sessions 3	15:20-16:40	Concurrent Sessions 6
	16:40-18:00	Industry Session	17:30-18:30	Poster Session	16:40-17:00	Closing Ceremony
	18:00	Dinner	18:30-20:00	Conference Banquet		

Plenary Session

	Time	Talk Title	Speaker	Affiliation	Room	Moderator
April 26	09:00-09:40	Behaviour of Thin-ply Hybrid Composites	Michael R WISNOM	University of Bristol	Main Venue	**Dongsheng LI** Commercial Aircraft Corporation of China Ltd **Ning HU** Hebei University of Technology
	09:40-10:20	Programmable Shape Memory Composites and 4D Printing: from Aerospace to Biomedical Applications	Jinsong LENG	Harbin Institute of Technology		
	10:40-11:20	Construction of Functional Composite Materials via Organic-Inorganic Hybrid Strategy and their Applications	Meifang ZHU	Donghua University		**Limin ZHOU** Southern University of Science and Technology **Yan LI** Tongji University
	11:20-12:00	Dedicate to Professor Adrian Mouritz: Professor Adrian Mouritz's Life-long Contribution to the Composites Society	Chunhui WANG	University of New South Wales		
	13:30-14:10	Dissolving Diamond, Growing Diamond in New Ways, Protonating Diamondoid Molecules, Zeolite Templated Carbons	Rodney S. RUOFF	Ulsan National Institute of Science and Technology		**Yanwu ZHU** University of Science and Technology of China **Ning HU** Hebei University of Technology
	14:10-14:50	Open Molding Technology for Continuous Fiber Reinforced Thermoplastic Composites	Asami NAKAI	Gifu University		

Keynote Session

	Time	Talk Title	Speaker	Affiliation	Room	Moderator
April 27	08:30-09:00	Development of Function-integrated Structural Composites for Aerospace Application	Xiaosu YI	University of Nottingham Ningbo China	Room 1	**Quanhong YANG** Tianjin University **Xitao ZHENG** Northwestern Polytechnical University
	09:00-09:30	A 1000 Wh/L Lithium-ion Battery Enabled with Shrinking Graphene Caged Microparticulate Silicon Anodes	Quanhong YANG	Tianjin University		
	09:30-10:00	Control of Hierarchical Structure of Polymer Articles via "Structuring Processing"	Qiang FU	Sichuan university		

	Time	Talk Title	Speaker	Affiliation	Room	Moderator
April 27	08:30-09:00	Thermomechanical Treatment of Metal Matrix Composites	Sergey ZHEREBTSOV	Belgorod State University	Room 2	**Yusheng SHI** Huazhong University of Science and Technology **Lujun HUANG** Harbin Institute of Technology
	09:00-09:30	High-performance Fiber-reinforced Composite Materials Manufactured by Robotic Laser Additive Manufacturing Technology	Yusheng SHI	Huazhong University of Science and Technology		
	09:30-10:00	The Tsai-Wu Failure Criterion: Its Full Rationalization and Implications	Shuguang LI	University of Nottingham		

KEYNOTE SESSION

	Talk Title	Speaker	Affiliation	Room	Moderator
08:30-09:00	Application of Composite Materials in COMAC Aircraft Structures	Dongsheng LI	Commercial Aircraft Corporation of China, Ltd.	Room 3	**Jinglei YANG** The Hong Kong University of Science and Technology **Tao XIE** Zhejiang University
09:00-09:30	Green Manufacturing Technologies of Thermoplastic-based FRP Composites: Current Situation and Future Development	Jinglei YANG	The Hong Kong University of Science and Technology		
09:30-10:00	Construction, Propulsion and Applications of Micro-/nanomotors	Jianguo GUAN	Wuhan University of Technology		

	Talk Title	Speaker	Affiliation	Room	Moderator
08:30-09:00	High-performing Fiber Lithium-ion Batteries	Huisheng PENG	Fudan University, China	Room 1	**Jun MA** University of South Australia **Yongjin LI** Hangzhou Normal University
09:00-09:30	Evolutionary Polymer/Nanosheet Composites	Jun MA	University of South Australia		
09:30-10:00	Fifty Years of Carbon Fibre Composites and Their Future Opportunities	Hao WANG	University of Southern Queensland		

	Talk Title	Speaker	Affiliation	Room	Moderator
08:30-09:00	Mechanism Study on Advanced Lightning Strike Protection Composites Using a Miniature Tip Discharge Technique	Zhong ZHANG	University of Science and Technology of China	Room 2	**Yanwu ZHU** University of Science and Technology of China **Zhong ZHANG** University of Science and Technology of China
09:00-09:30	Surface Construction Technologies and Biomedical Applications of Zwitterionic Materials	Jian SHEN	Nanjing Normal University		
09:30-10:00	Analysing the Thermo-Mechanical Response of Natural Fibre Composites Under Fire	Raj DAS	Royal Melbourne Institute of Technology		

	TitleTalk Title	Speaker	Affiliation	Room	Moderator
08:30-09:00	Nano-micromechanical Analysis of the Fibre Reinforced Composites'Growth Resistance to Through-thickness Matrix Cracking	Chunhui WANG	University of New South Wales	Room 3	**Faxiang QIN** Zhejiang University **Chunhui WANG** University of New South Wales
09:00-09:30	Waves in Hyperelastic Material Structures and their Manipulations	Weiqiu CHEN	Zhejiang University		
09:30-10:00	Beyond the Wooden Table: Extending the Use of Natural Fibres and Biobased Materials to Airframe Interiors, Adaptive Structures, and Metamaterials	Fabrizio SCARPA	University of Bristol		

Room	April 27		April 28	
Room1	10:20-17:10	Session 1 Polymer Matrix Composites	10:20-16:35	Session 1 Polymer Matrix Composites
Room2	10:20-16:50	Session 2 Metal Matrix Composites	10:20-15:15	Session 2 Metal Matrix Composites
Room3	10:20-17:05	Session 3 Ceramic Matrix Composites	10:20-16:00	Session 3 Ceramic Matrix Composites
Room4	10:20-17:30	Session 4 Carbon Composites	10:20-12:10	Session 4 Carbon Composites
Room5	10:20-17:50	Session 5 Textile-Based Composites	10:20-12:00	Session 5 Textile-Based Composites
Room6	10:20-16:20	Session 6 Natural Fibers / Green Composites		
Room7	10:20-17:10	Session 7 Nanocomposites	10:20-14:50	Session 7 Nanocomposites
Room8	10:20-17:30	Session 8 Meta-Composites	10:20-15:10	Session 8 Meta-Composites
Room9	10:20-17:35	Session 9 Multi-Functional / Smart Composites	10:20-15:30	Session 9 Multi-Functional / Smart Composites
Room10	10:20-17:30	Session 10 Thermal / Fire Retardant Composites	10:20-15:20	Session 10 Thermal / Fire Retardant Composites
Room11	10:20-12:15	Session 16 Failure Criteria and Verification		
	13:30-16:20	Session 11 Automated Manufacturing		
	16:20-17:05	Session 12 Out-of-Autoclave Process		
Room12	10:20-17:10	Session 13 3/4D Printing and Emerging Technologies		
Room13	10:20-17:05	Session 14 Optimization Design/ Modeling and Simulation		
Room14	10:20-17:05	Session 15 Testing and Evaluations Simulation		
Room15	10:20-17:00	Session 17 Engineering Application		
Room16	10:20-17:40	Session 18 Biomedical Applications		
Room17	10:20-17:40	Session 19 Emerging Applications	10:20-16:45	Session 19 Emerging Applications
Room18	10:20-17:1	Session 20 Composites Repair, Self-healing, Recycling and Machining		

Abstracts

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Content

Plenary Lecture

Behaviour of Thin-ply Hybrid Composites

Michael R WISNOM*
Bristol Composites Institute, University of Bristol

Thin-ply composites have quite different behaviour from standard thickness materials, as matrix cracking and delamination are reduced or eliminated completely. Unnotched strength of thin-ply laminates is increased, but the lack of damage mechanisms to redistribute load around stress concentrations means that notched strength and fracture toughness are reduced. When thin plies are hybridized, new failure mechanisms can occur, with the possibility of plies fragmenting in tension, leading to pseudo-ductile stress-strain response and notch insensitivity. Fragmentation can also occur in compression with some materials, again producing a highly non-linear stress-strain response. In bending the different mechanisms in tension and compression lead to complex behaviour and the ability to tailor the response to produce gradual failure with high energy dissipation.

Plenary Lecture

Programmable Shape Memory Composites and 4D Printing: from aerospace to biomedical applications

Jinsong Leng*
Harbin Institute of Technology, China

As typical stimuli-responsive materials, shape memory polymers (SMPs) and their composites (SMPCs) can change shapes or sizes when exposed to an external stimulus and have advantages like a fast response, long lifetime, high resilience, light weights, stretchability, low cost, and easy processing. These special features make them promising materials for sensors and actuators, with broad application potential in deployable structures, self-healing systems, biomedical devices, 4D printing, etc. Under deliberate design, the deployable structures have been successfully verified in aerospace applications, especially Mars exploration projects. 4D printing is conventional 3D printing combined with the additional element of time as the fourth dimension. We have developed a series of shape-morphing structures through 4D printing, including a tracheal scaffold, occlusion device, vascular stent, and bone tissue scaffold. These materials offer significant promise for future smart products in many areas of science and technology.

Plenary Lecture

Construction of Functional Composite Materials via Organic-Inorganic Hybrid Strategy and their Applications

Meifang ZHU*
College of Materials Science and Engineering , Donghua University

Functional materials based on organic-inorganic hybrid strategy have demonstrated a remarkable capability in the integration of functions, structures and material properties, thus showing vast potentials in the fields of energy, environment, aerospace, photoelectric, sensing, and biomedicine. This talk will introduce functional fibers and their composite materials constructed via organic-inorganic hybrid strategy by our group. It will summarize our results and achievements in the design and construction of the functional units, regulation of the interface and surface of the organic and inorganic phases, as well as the fabrictaion technologies and industrilization of the functional fibers. The application propspects, challenges and future directions of the advanced functional fibers and their composite materials will also be provided.

Plenary Lecture

Dedicate to Professor Adrian Mouritz

Professor Adrian Morris was a plenary speaker for the conference. Sadly, he passed away on March.
Professor Chunhui Wang will give a talk at this plenary slot in memory of Professor Mouritz's life-long contribution to the composites society.

Biography

Adrian Mouritz was the Dean of Engineering and Distinguished Research Professor in Aerospace Materials at RMIT University (Royal Melbourne Institute of Technology). Professor Mouritz performed fundamental and applied research into fibre reinforced polymer composites covering a wide range of topics, including composites with through-thickness reinforcement, delamination toughening of composites, fire structural properties of composites, additive manufacturing of composites, energy storage composites, and novel joining techniques for composites. Professor Mouritz had conducted research with a large number of organisations, including Boeing, Airbus, Ford, US Office of Naval Research, and Defence Science & Technology Group (Australia).
Professor Mouritz was a Fellow of the Australian Academy of Technology and Engineering (FTSE), Fellow of Engineers Australia (FIEAust) and Certified Practising Engineer (CPEng). He was also a World and Life Fellow of the International Committee of Composite Materials. He was also the Editor of *Composites Part C* and *Composites Communications*, and an editorial board member of numerous journals including *Composites Part A*, *Polymer Composites*, *Materials & Design* and *Journal of Sandwich Structures & Materials*.

Plenary Lecture

Dissolving Diamond, Growing Diamond in New Ways, Protonating Diamondoid Molecules, Zeolite Templated Carbons

Rodney S. Ruoff*
Ulsan National Institute of Science and Technology (UNIST)

Dissolving single crystal diamond. Thin cobalt and nickel films are deposited onto single crystal diamond with orientations (100), (110), and (111), and the diamond is dissolved into the metal and removed from the thin metal film surface by water vapor. We discovered a kinetics regime in which the rate determining step is C-C bond breaking at the diamond-metal interface. To the best of our knowledge, this is the first measurement of the enthalpy of activation of this bond-breaking event, with subsequent diffusion of the C atom into the cobalt or nickel, for the D(100) and D(110) surfaces. D(111) was found not to dissolve [1].

Growing diamond in new ways. We have discovered methods to grow diamond under new growth conditions and I will describe these [2]. *Studies of protonation of diamondoid molecules in the gas phase.* We have explored the gas phase protonation using theoretical modeling of various diamondoid molecules, and discover thereby that larger diamondoids behave as superbases (have a gas phase basicity of about 10.5 eV or higher). I briefly describe this published work [3] and then turn to discussing our experiments in *mixing carborane superacids with diamondoid molecules* with the goal of making new types of ionic liquids and ionic solids [4]. Finally, I outline our work on zeolite templated carbons, where we introduce some new results. *Support from the Institute for Basic Science (IBS-R019-D1) is appreciated.*

[1] Dissolving Diamond: Kinetics of the Dissolution of (100) and (110) Single Crystals in Nickel and Cobalt Films; https://pubs.acs.org/doi/abs/10.1021/acs.chemmater.1c03809
[2] Homoepitaxial Diamond Grown in a Liquid Metal Solvent 10.26434/chemrxiv-2022-q8ppf
[3] Proton affinity and gas phase basicity of diamandoid molecules: aterial i to C131H116. DOI: 10.1039/d1cp04177k
[4] Work in progress.

Plenary Lecture

Open Molding Technology for Continuous Fiber Reinforced Thermoplastic Composites

Asami Nakai*
Gifu University

C-FRTP (Continuous Fiber Reinforced Thermoplastic) pipes are attracting attention, especially in the field of transportation equipment, from the viewpoints of productivity, secondary processing, and recyclability. Since the moldings of c-FRTP require high-cost intermediate materials such as prepreg, molding costs must be reduced. By molding c-FRTP pipe with open molding method using either male or female molds, it is possible to change the thickness with the same mold, thus reducing the molding cost.

In this study, two types of open molding technologies for c-FRTP were introduced; First, continuous molding of c-FRTP pipes by open molding, in which heating braiding molding and heating tape wrapping molding are continuously performed, was developed. Next, role forming processing was applied after manufacturing simple shape composites such as a plate with pultrusion molding and c-FRTP with a complex cross section was manufactured at high speed.

Keynote Lecture

Development of Function-integrated Structural Composites for Aerospace Application

Xiaosu YI*
1 University of Nottingham Ningbo China, UNNC
2 Yangtze River Delta Carbon Fiber & Composites Innovation Center, CCIC

To increase the efficiency of the system while reducing its structural weight, function-integrated structural composites are attracting more and more attention in the aerospace industry and composite community. Typical examples in aerospace industry can be considered as structural composites with highly electrical conductivity for electrical functioning of airframe of an airplane, and for its lightning strike protection as well, if the frame is made of carbon composites. Another meaningful function-integrated structural composite is sound-absorbing structural composite, a kind of dark acoustic structure or panel, which should be designed and characterized by lightweight, high-efficiency in noise reduction, while exhibiting good structural properties. The acoustic composite panel is typically used in interior of airplane and rail vehicles, and in aeroengine. Both structure-property relationship and function-integration mechanism for the two composite structures are introduced discussed in the presentation.

Keynote Lecture

A 1000 Wh/L lithium-ion battery enabled with shrinking graphene caged microparticulate silicon anodes

Quanhong Yang*
Tianjin University

High-capacity microparticle electrode materials, normally composited with carbons, promise to significantly improve the volumetric performance of lithium batteries. However, issues of mechanical instability and the induced interfacial reaction, which caused by the severe volume change and particle pulverization during cycling, prevent their practical use. In our research, based on a control of the capillary shrinkage of carbon networks, a strong yet ductile carbon cage analog to the stable structure of cells, is built for micro-Si anodes. In this composite, the inner carbon coating on the micro-Si like sieving cell membrane can isolate the electrolyte and transport the Li^+, and the outer dense graphene network like strong supportive cell wall can dissipate the local huge stress by the sliding of interlinked graphene in the anode. As a result, an ultra-stable micro-Si anode with a record-high 1000 cycle life and a pouch full cell using this anode with an ultrahigh volumetric energy density over 1000 Wh L^{-1} are achieved. This represents a critical step forward in building micro-Si composite materials approaching a real use in compact lithium batteries.

Keynote Lecture

Control of Hierarchical Structure of Polymer Articles via "Structuring Processing"

Qiang FU*
Sichuan university

The prevailing strategy of modern polymer processing has converted from traditional "shaping" processing, which is strongly depending on composition/formula design and processing technology, into the fashion of "structuring" processing characterized by realizing the customized structures and performances in polymer products. Two representatives on the "structuring" processing of polyolefin materials with high-performance will be elaborated in detail, by using the preparation of Li-ion battery separators and ultra-thin membrane of UHMWPE as examples.

Keynote Lecture

Nano-micromechanical analysis of the fibre reinforced composites' growth resistance to through-thickness matrix cracking

Chun-Hui WANG*
University of New South Wales

Transverse matrix cracks are a major issue for fibre composite laminates, as they can degrade the structural safety and link-up to form through-thickness cracks that cause fuel leaks in composite storage vessels. Transverse cracks are traditionally believed to form suddenly through the ply thickness and across the width, followed by tunnelling along the fibre direction. However, recent advances in high fidelity micromechanical models and high-resolution experimental observations reveal that matrix cracks first emerge as aterial between fibres and the matrix and propagate in a slow and stable manner in the thickness direction with increasing load, especially in thin ply composites.

This presentation reports a fundamental understanding of the phenomenon of increasing growth resistance of through-thickness cracking, as a function of crack length, in a constrained ply, i.e., an R-curve effect. A novel micromechanical model has been developed to obtain the R-curve for a given composite system, which is then used to analytically predict the propagation of through-thickness matrix cracks and the ply thickness effect on the transition from stable to unstable growth under increasing load. The analysis also reveals that, unexpectedly, the microcracking resistance decreases with fibre volume fraction and increases with microscopic thermal residual stresses caused by the mismatch of CTEs/stiffness between the fibre and the matrix.

A brief discussion is also presented of the role of nano-scale toughening in improving through-thickness matrix cracking resistance.

Keynote Lecture

Thermomechanical treatment of metal matrix composites

Sergey Zherebtsov *
Belgorod State University

One of the attractive ways to improve the strength-related properties of metallic materials is associated with the creation of metal-matrix composites (MMC) by inserting ceramic particles or fibers into the metallic matrix. The combination of a Ti-based matrix reinforced by boride particles (TiB) is a very promising example since this reinforcement has excellent thermodynamic stability, thermal expansion coefficients similar to the Ti matrix, a clean interface and excellent interface bonding between the TiB whiskers and the Ti matrix. The MMCs can be obtained using various methods, including traditional casting and various powder metallurgy techniques (e.g. spark plasma sintering or selective laser melting). Usually the composite preforms do not considered as an object for further thermomechanical treatment, however MMCs, along with the increased strength, demonstrate sometime poor room-temperature ductility. Thermo-mechanical treatment can improve mechanical properties of the MMCs however the effect of such treatment is not quite well known.

In present work the effect of thermomechanical treatment on structure and properties of Ti-based MMCs reinforced by boride particles is discussed. The mechanisms that control the mechanical behavior and factors contributing to strengthening are analyzed.

Keynote Lecture

High-performance fiber-reinforced composite materials manufactured by robotic laser additive manufacturing technology

Yusheng Shi*
Huazhong University of Science and Technology

Fiber-reinforced composite materials (FRCMs) are used in diverse fields due to the novel characteristics of low density, high specific strength, high-temperature resistance and corrosion resistance. Currently, FRCMs are developing in the direction of complexity, lightweight and integrated forming to meet the high-performance requirements. Additive manufacturing is an effective method for forming high-performance FRCMs with complex shapes. However, there is a bottleneck problem in the current additive preparation of FRCMs. Due to the serious fiber delamination phenomenon in the layered manufacturing process and the great influence of fiber orientation on the mechanical properties, the degree of anisotropy is high, especially the tensile strength along the Z-axial direction is low.

Our team have developed a new forming process for FRCMs based on the combination of laser melting and rolling. A multi-DOF robotic laser additive manufacturing equipment was established to form continuous carbon fiber composite components integrally. A laser beam was used to melt the carbon fiber prepreg tows, accompanied by a cold roll used to roll the prepreg in the molten state simultaneously and cool it to solidify. Conformal pressing roller increases the bonding force between layers of carbon fiber parts and the anisotropy of carbon fiber components can be relieved by employing surface conformal slicing and intelligent path planning algorithms. Experimental tests show that the mechanical properties of the as-built FRCMs are superior to those formed by other additive processes, especially the interlaminar shear strength has been greatly improved.

Keynote Lecture

Application of Composite Materials in COMAC Aircraft Structures

Dongsheng LI*
Commercial Aircraft Corporation of China, Ltd.

The use of composite structures on civil aircraft is to improve the performance of the aircraft and reduce the manufacturing and operation costs. As the only company in China engaged in the design and manufacturing of large commercial aircraft, COMAC (Commercial Aircraft Corporation of China, Ltd.) has dedicated to the development and application of high performance composite structures. In this presentation, composite structures used on ARJ21-700, C919 and CR929 are introduced. Some lessons learned are provided with suggestions for future work. It is intended to deliver to the conference a snapshot of the latest development of civil aircraft composite structures in China. It is also the intention of the author to communicate to the academic community the technical needs from the engineering application in the aerospace industry.

Keynote Lecture

Green Manufacturing Technologies of Thermoplastic-based FRP Composites: Current Situation and Future Development

Jinglei YANG*
The Hong Kong University of Science and Technology

This paper presents a review of the current situation of green manufacturing technologies of thermoplastic-based fiber reinforced polymer (FRP) composites. Developing thermoplastic FRP composites and its green manufacturing technology is of long-term significance on the sustainable aerospace, automotive, construction and other industrial field. Different types of technical solutions for green manufacturing of thermoplastic FRP composites are outlined. First, the existing thermoplastic resin systems that can be polymerized at room or low temperature compared with the traditional curing approaches are summarized. Compared with common commercial FRP composites, the overall mechanical performance and energy consumption of these novel thermoplastic-based FRP composites is analyzed and their research challenges and application status are discussed. On the other hand, latest non-traditional rapid energy-efficient manufacturing technologies are introduced, with a particular focus on frontal polymerization, which is considered as the most promising alternative to the traditional curing technologies for high-performance FRP composites. This review also provides a detailed introduction on the research progress in thermoplastic FRP composites frontal polymerization and analyzes its challenges in the further development. Finally, current research progress and challenges related to green manufacturing technologies of thermoplastic-based FRP composites is summarized and an outlook of the further research trends is discussed.

Keynote Lecture

Construction, Propulsion and Applications of Micro-/nanomotors

Jianguo Guan*
Wuhan University of Technology

In this presentation, I will begin with the definition and general information about micro/nanorobots before explaining why micro/nanorobots will bring us revolutionary technologies, especially in the fields of biomedicine (including drug delivery, cell separation and microsurgery), environmental sensing and remediation, and micro-nano manipulation. Then, after introducing how to make micro/nanorobots with strong propulsion by external physical fields or by chemical fuels, I will focus on how to make micro/nanorobots smart or intelligent for the micro/nanorobots at work in active drug delivery should move independently and coordinately in a swarm to target a disease site, and deliver drug with a high efficiency and significantly reduced systemic side effects. In the end, I make a brief summary, which includes:

1) Utilizing the Natural chemotaxis of biocells or bacteria, improving the Chemical Reaction Activity, incorporating stimuli-responsive matter and enabling Propulsion Mechanism Transformation all can realize biomimetic taxis of MNRs.

2) MNRs emitting signaling chemicals and strong hydrodynamic signals can communicate with one another.

3) With biomimetic communications, swarming MNRs can be formed that exhibit intelligent collective behaviors, such as adaptive reconfigurations, obstacle avoidance, leader-follower hierarchy and predator-prey biomimicry. This inspires the creation of the next-generation of intelligent drug delivery systems.

Keynote Lecture

Fifty Years of Carbon Fibre Composites and Their Future Opportunities

Hao Wang*
University of Southern Queensland

Carbon fibre reinforced polymer composites (CFRPs) are several times stronger and lighter than steel or aluminium alloy. As highly engineered materials they have been successfully used in aerospace and other areas. The year 2022 marks as the 50 years of the development and application of advanced carbon fibre composites. During the 50 years, initially CFRPs was extremely expensive, and only used in spacecraft and very high end sports equipment. Their lightweight and extremely high strength were quickly recognized by in aerospace industries. Large proportion of CFRP being accepted into commercial aircrafts. 50% of CFRP in Boeing 787 and Airbus 350, represented the first wave of carbon fibre composite in applications. Now we are seeing the second wave of carbon fibre composite in applications, which is expanding from aerospace to high-volume, low-cost and much wider industrial applications, including automotive, wind turbine, rail transportation, and infrastructure. The high-volume and low-cost offer significant opportunities for CFRP. They also bring new challenges and implications to the composite materials, their manufacturing, and the actual applications. As the leading journal in composites area, Composites Part B: Engineering, is working with academics and industry to address those issues. We also encourage young students and researchers to join us to be part of the new wave, making your contribution and fulfilling your dream.

Keynote Lecture

High-performing fiber lithium-ion batteries

Huisheng Peng*
Fudan University, China

Fiber lithium-ion batteries are pioneering as flexible power solutions because they can be woven into textiles. Textile batteries offer a convenient and seamless way to power future wearable electronics. However, current fiber lithium-ion batteries are only centimeters long because longer fiber lithium-ion batteries are difficult to produce and they are thought to have significantly higher internal resistances that compromise electrochemical performance. Here, we unexpectedly discovered that the internal resistance of fiber lithium-ion battery has a hyperbolic cotangent function relationship with fiber length, where it firstly decreases before leveling off as length increases. Systematic studies confirm this is true for different fiber batteries. We produced meters of high-performing fiber lithium-ion batteries via an optimized industrial process. Our mass-produced fiber lithium-ion batteries had a certified energy density of 85 Wh/kg based on the total weight of full battery including packaging. Over 80% capacity can be maintained after bending for 100,000 cycles. We show these fiber lithium-ion batteries woven into safe and washable textile by industrial rapier loom can wirelessly charge cellphones or power health management jackets integrated with fiber sensors and textile display.

Keynote Lecture

Evolutionary Polymer/Nanosheet Composites

Jun Ma*
University of South Australia

Graphene, as first mechanically exfoliated from graphite by Geim and Novoselov in 2004 [1], is a single atomic layer of sp^2 hybridized carbon atoms arranged in a hexagonal lattice. Referring to graphene that is oxidized by strong oxidizers and acids, graphene oxide is electrically insulating and can be conductive after reduction. Few-layer graphene is actually graphene (nano) platelets (denoted GNPs or GnPs; each platelet below 10 nm in thickness). Graphene nanosheets usually refer to monolayer or few-layer graphene who have large lateral dimension, in comparison with the small lateral dimension of GNPs. In polymer processing, GNPs are preferred over graphene nanosheets because (i) nanosheets are difficult to exfoliate and disperse in polymer melts and (ii) such a large lateral dimension cannot be fully utilized for reinforcement or toughening [2,3].

In comparison with metals and ceramics, polymers have been increasingly used in industries over the past five decades owing to their high specific strength yet low manufacturing costs. However, most polymers are inherently limited by low stiffness and lack of functionality such as electrical conductivity. In spite of extensive studies conducted to utilize carbon nanotubes and silicate layers to address the limitations, the rise of graphene now provides a more promising candidate due to its exceptionally high mechanical properties and electrical and thermal conductivities. This talk introduces the research conducted in Jun Ma's research team since 2008, i.e. the development of GNPs [2,3] and using them for processing of epoxy [4–7], elastomers [8–10] and conducting polymers [11,12], to produce multifunctional nanocomposites. These multifunctionalities include mechanical reinforcement, toughening, electrical and thermal conductivities, flame retarding, stretchable conductors, flexible strain sensing and energy storage. A new trend is to develop polymer/graphene nanoplatelet composites with no need of organic solvents [13,14].

Keynote Lecture

Mechanism Study on Advanced Lightning Strike Protection Composites Using a Miniature Tip Discharge Technique

Zhong ZHANG*
University of Science and Technology of China

Carbon nanotubes have advantages such as low density and high electrical conductivity, which show great potential to be used for lightning strike protection (LSP) of carbon fiber reinforced plastic (CFRP) instead of metallic meshes/foils. However, the LSP mechanism of CNTs is unclear, which limits their further refinement and applications. In addition, the general simulated lightning strike tests in previous reports are usually complex and expensive. They also use different test conditions (such as different sample sizes, different tip electrode sizes, etc.), leading to the direct comparison of the obtained conclusions being virtually invalid. Herein we design a miniature tip discharge system (TDS) to simulate the lightning strike environment in the laboratory and study the failure mechanism of CNT film-based advanced LSP systems. The main failure mechanism of the CNT film for LSP is thermal ablation, and the parameters affect LSP performance testing results include the electrical conductivity, specific heat capacity, film size, electrode tip diameter, electrical stress rates, etc. The isolation layer not only prevents electrochemical corrosion but also contributes to the LSP effect, mainly by insulation, thermal resistance, and thermal insulation.

Keynote Lecture

Surface Construction Technologies and Biomedical Applications of Zwitterionic Materials

Jian SHEN*
National and Local Joint Engineering Research Center of Biomedical Functional Materials, Nanjing Normal University;
Jiangsu Engineering Research Center of Interfacial Chemistry, Nanjing University;

Facing the key technical challenges of biomaterial in biocompatibility and biological functionality:

3. Proposed "Maintaining the Native Status" hypothesis.

Based on robust experimental data (such as biological evaluation, animal testing and molecular dynamics simulation calculations) and computer simulation, we have clearly proved that that zwitterionic structures could maintain the normal conformation and the native status of biomacromolecules.

2. Invented the surface zwitterionic modification technologies on diverse biomaterials

Designed new zwitterionic monomers (such as aterial-betaine, sulfo-betaine and carboxyl-betaine), new surface zwitterionic modification technologies on diverse biomedical materials (e.g. polymers, metals and inorganic non-metallic materials). Established robust relationship between the zwitterionic surfaces and surface properties (blood compatibility, andtifouling, antibacterial, anti-hyperplasia, and re-endothelialization) of materials.

3. Industrialization of zwitterionic materials on advanced biomedical devices.

Applied the technologies on stents, disposable leukocyte filtration and plasma virus inactivation blood transfusion devices.

Keynote Lecture

Analysing the Thermo-Mechanical Response of Natural Fibre Composites Under Fire

Raj Das *
Royal Melbourne Institute of Technology

Performance-based design strategy enables the use of composites in fire risk situations. In this approach, the fire behaviour of the composite materials and structural components can be comprehensively quantified and accurately evaluated. The number of tests required to quantify the fire properties of a composite material can be aterial by developing a robust model for predicting the thermal response of composites under realistic fire conditions. Large-scale fire tests, such as room corner test, are expensive and require special settings with advanced facilities to implement different fire scenarios. Hence, the development of robust models to predict ateria-structural response of a burning composite is of prime necessity to provide an insight into the fire-reaction properties and also understand the fire-induced damage processes of the composites.

In this paper, comprehensive experimental and numerical analyses using Fire Dynamics Simulator (FDS®) will be presented to compare the fire-reaction properties of natural fibre composites, namely wool and flax based polymer composites under different orientations. Two natural fibres, namely flax and wool, and two different matrices, namely polypropylene (PP) and epoxy, were used to prepare short and long fibre composites. Extensive numerical modelling results on the fire-reaction properties, burn time and surface temperature distribution will also be analysed. Next, the effects of composite sample (component) surface orientation on the ignitability, and heat and smoke production will be addressed. Finally, a coupled fire-structure model combining the finite volume and finite element methods that captures the essential aterial ics elements of the problem will be demonstrated. In this context, a relatively new concept of adiabatic surface temperature (AST) that has been introduced as a practical means to transfer data between fire and structural models at the gas-solid interface will be elucidated. The ability of the model to predict the temperature, deformation behaviour, and stress distribution in composite beams under combined thermal and mechanical loads will be evaluated.

Keynote Lecture

The Tsai-Wu failure criterion: Its full rationalization and implications

Shuguang LI*
University of Nottingham

The Tsai-Wu failure criterion for composite materials has undergone full rationalization recently. It has resolved the long-standing issue of the uncertainty associated with the coefficient F12 for the interactive terms between longitudinal and transverse stresses. The appearance of the failure envelope should take a form of elliptic paraboloid as the only rational choice as opposed to any closed envelope as Tsai and Wu suggested in their original paper. This has been subjected to systematic justification and fully elaborated mathematically. In addition, the formulation of the quadratic function as the failure function should show unbiased sensitivity to its coefficients of the similar nature as a basic logically requirement. Out of these considerations, not only is F12 determined, but also the transverse shear strength has been proven to be dependent of the transverse tensile and compressive strengths. The synergy of both findings delivers the complete consistency of the fully rationalized Tsai-Wu criterion. By achieving this, the fully rationalized Tsai-Wu criterion can be viewed as the extension of the Raghava-Caddell-Yeh criterion from isotropic materials of different tensile and compressive strengths to transversely isotropic materials in general, whilst the latter can be considered as the generalization of the von Mises criterion from isotropic materials of equal tensile and compressive strengths to those of different tensile and compressive strengths. This has fulfilled the vertical integration of a series of material failure criteria for different materials, such that under the assumption that the transversely isotropic material under investigation can be considered as homogeneous, the level of confidence in applying the fully rationalized Tsai-Wu criterion can match that for the Raghava-Caddell-Yeh criterion and the von Mises criterion for isotropic materials. The latter has been considered as fully established for isotropic materials in engineering.

Keynote Lecture

Waves in hyperelastic material structures and their manipulations

Weiqiu Chen*
Zhejiang University

Hyperelastic materials can repeatedly withstand large deformation, indicating a superior elastic behavior. The theory of hyperelasticity has already been established in the 1950s, and soon it has been applied to investigate the effect of large pre-deformation on the propagation behavior of elastic waves. More than a decade ago, Professor Katia Bertoldi at Harvard University, together with Professor Mary Boyce at MIT explored to use buckling and postbuckling deformation to tune wave propagation in phononic crystals, arousing again the research interests in waves in complex hyperelastic materials and structures. This report will summarize our achievements on the topic, including tuning of band structures in soft periodic structures, linear and nonlinear waves in dielectric elastomer bar, solitary waves in one-dimensional nonlinear periodic chains, strain engineering of acoustic topological states, etc. Due to the large deformation induced in hyperelastic materials, material nonlinearity as well as geometric nonlinearity should be both taken into consideration. Furthermore, in some cases, the characteristic of multi-field coupling should also be considered. These factors complicate the analysis, and hence except for a few special cases for which analytical solutions may be obtained, we have to resort to numerical simulations, and if possible to experiment for verification.

Keynote Lecture

Beyond the wooden table: extending the use of natural fibres and biobased materials to airframe interiors, adaptive structures, and metamaterials

Fabrizio Scarpa*
Bristol Composites Institute, University of Bristol, UK

When we look at a wooden table, we see a simple passive object of inanimate material. Wood and plant-based materials have however fascinated generations of engineers and technologists trying to mimicry their behavior or making use of their properties to develop sustainable products within the local supply chains. In this talk we will describe the use of biobased natural fibre (flax, hemp) materials with special focus on applications for aircraft interiors and show how these biobased composites can then be used to develop novel lattice structures, and adaptive metamaterials with shape changing characteristics due to relative humidity and temperature. We will also examine how 3D/4D printing techniques can be used to make adaptive structures using flax/hemp systems, and general criteria to develop smart composites using natural fibres and hygrmorphs principles.

Session: Polymer Matrix Composites

Presenting Type: Oral-Invited

Relationship between the co-continuous morphology with asymmetric composition in the immiscible polymer blends and the structure of the compatibilizer: in situ formed graft copolymer

Dean Shi*
Hubei University

The polymer blends with co-continuous structure can maximize the advantages of each phase of polymer and obtain excellent polymer materials. However, preparing stable co-continuous morphologies in immiscible blends within a wide range of composition ratios or with low minor phase contents remain a challenge. These co-continuous morphologies are thermodynamically unstable and can become coarsened or even degrade to the droplet/matrix morphology under high-temperature annealing or secondary processing. The commonly used method is to add interface compatibilizers to the polymer blends that can meet the following two requirements: (1) to promote the flatness of the two-phase interface; (2) it does not hinder the aggregation of dispersed phase. Hence, whether the co-continuous morphology can be obtained in immiscible polymer blends is determined by the graft copolymer itself should have a co-continuous structure thermodynamically. In other words, whether the graft copolymer itself has a co-continuous structure, it must be able to form a co-continuous structure of polymer blends?

Based on this idea, polystyrene (PS, Mw=330,000 g/mol) and nylon 6 (PA6 Mn=20,000 g/mol) are used as the research objects, and styrene-maleic anhydride copolymer (SMA) with moderate molecular weight (Mw=110,000 g/mol) and relatively high MAH content (28 wt%) is used as the initial compatibilizer. SMA11 compatibilizers with lower MAH contents (11 wt%) are gained from pretreatment by aniline (ANL). Then the according PS/PA6/SMA ternary blends are prepared and their morphologies are investigated in detail. The main results are as follows: (1) Although SMA28-g-PA6 itself tends to form a co-continuous structure in thermodynamics, when the rotor speed of the mixer is 105 rpm, the blending system is an island structure regardless of whether PA6 is a matrix phase (70 wt.%) or a minor phase (30wt.%). The continuities of a minor phases are CCI (PS) =6% and CCI (PA6) =43%, respectively. This is mainly because the SMA28-g-PA6 copolymer containing more PA6 branch chains will be pulled out from the interface of the two phases during the processing process, thus losing the compatibilization effect. On the contrary, when SMA11-g-PA6, which is an island structure, is used as the compatibilizer, the co-continuity of the system is relatively high, CCI (PS) =97% and CCI (PA6) =99%, respectively. The reason may be that larger shear stress can elongate a minor phase in favor of a flat interface.

Key words Co-continuous morphology, PA6, In-situ formed graft copolymer

Session: Polymer Matrix Composites

Presenting Type：Oral−Invited

Thermally Conductive Phase Change Composites with Conical Graphene Aerogels for Solar-Thermal-Electric Energy Conversion

Zhong-Zhen Yu*、Hao-Yu Zhao
Beijing University of Chemical Technology, China

Although organic phase change materials can reversibly store and release latent heat during their phase change processes, their weak solar-thermal conversion ability, low thermal conduction, and poor structural stability seriously hinder their applications for solar-thermal energy conversion and thermal energy utilization. Herein, high-quality conical graphene aerogels (HCGAs) with concentric annular structures are constructed to enhance thermal conduction, solar-thermal energy conversion, and shape stability of the phase change material of tetradecanol for solar-thermal-electric energy conversion application. An optimal HCGA/tetradecanol phase change composite with 7.05 wt% of graphene achieves a high through-plane thermal conductivity of 4.54 W m^{-1} K^{-1}. Benefiting from the low graphene loading, the phase change composite achieves a high phase change enthalpy of 206.1 J g^{-1} and a high latent heat retention of 94.5%, indicating its excellent energy storage performances. For solar-thermal energy conversion, the conical surface of the conical phase change composite is exposed to the simulated solar light, and the anisotropic high-quality-graphene structure enables the heat generated from the solar light to be rapidly transferred to the entire phase change composite, achieving a high solar-thermal energy conversion and storage efficiency of 84.0%. A solar-thermal-electric generator assembled with the conical phase change composite array and the thermoelectric device exhibits maximum output voltages of 261 and 1214 mV under solar light intensities of 100 and 500 mW cm^{-2}, respectively. Even after the removal of the solar light, the voltage output can still be continued by releasing the thermal energy stored in the phase change composite.

Key words phase change composites; graphene aerogels; thermal conductivity

Session: Polymer Matrix Composites

Presenting Type: Oral-Invited

Interfacial structure and properties of one-dimensional reinforcement-filled polymer composites

Ling Zhang*、Tianbo Deng
East China University of Science and Technology

The one-dimensional reinforcement including fibers and nanotubes modified high-strength polymer composites with lightweight and high performance are the key materials for the development of the national economy. The structural defects and hydrophilicity of the traditional reinforcements lead to the weak interfacial interaction and poor dispersion in the composites during processing, which are great challenge restricting their engineering amplification. In this report, hybrid fibers were constructed by introducing the organic macromolecular-nano aterial network structure or nucleating agents on the surfaces of glass fibers to obtain high surface activity and the growth of the tanscrystallization, resulting in enhanced interfacial adhesion of the composites. Based on the fiber fracture model, the impregnation rollers configurations of melt impregnation equipment were designed and optimized to control the dispersion of glass fibers effectively and to achieve good impregnation in high viscosity melt. The composite material prepared by continuous impregnation of hybrid fibers exhibits greatly improved performance, which is several times that of short fiber reinforced composites, has great potential to replace metal parts. Carbon nanotubes are considered as one of the best reinforcement materials due to their outstanding properties. A structurally controllable "soft-rigid" block polymer-functionalized MWCNTs (MWCNTs-g-BP) was designed to enhance and toughen chitosan (CS) biodegradable materials through a solvent evaporation method. When the composite is stressed, the soft segment poly(ε-caprolactone) (PCL) could deform and absorb energy, which acts as a buffer layer and also provides space for MWCNTs to move. While the rigid segment poly(glycidyl methacrylate) (PGMA) could generate covalent bonds with CS molecular chains, which significantly enhances the interfacial interaction of the composite. Benefiting from the synergistic effect of soft segment PCL and rigid segments PGMA, the MWCNTs-g-BP can strengthen and toughen nanocomposites simultaneously. By changing the ratio of block polymers, the composite exhibits a stronger increase of mechanical properties with only 1 wt% MWCNTs loading. The tensile strength of the composite is increased by 53.8%, as well as the elongation is enhanced by 3.5 times compared with pure CS. This study provides a new approach for designing high-performance composites with one-dimensional reinforcement and giving great promise to various applications.

Key words polymer composites, structure and properties, reinforcement, interfacial interaction

Session: Polymer Matrix Composites

Presenting Type: Oral-Invited

Quasi-Solid Polymer Electrolyte Based on Lithium-Rich Porous Aromatic Frameworks

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Northeast Normal University

The development of solid polymer electrolytes (SPEs) with high ionic conductivity, wide electrochemical window, and high mechanical strength is the key factor to realize high-energy-density solid lithium ion batteries (SLIBs). Porous aromatic frameworks (PAFs) have the advantages of high porosity, easily functionalized molecular structure, and rigid stable framework, which fully meet the requirements of solid polymer electrolytes with high Li+ capacity, fast Li+ transport, and safety. Herein, lithium-rich PAF-170-AO was obtained through the absorption of LiTFSI by amidoxime groups and abundant pores, then compounded with poly(vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP) to prepare a PAF-based quasi-solid polymer electrolyte (PAF-QSPE) with only tiny amounts of plasticizer. The amidoxime groups of PAF-170-AO restricted the movement of the anions of LiTFSI through hydrogen bonding, which effectively promoted the dissociation and migration number of Li+, reduced the concentration polarization, and inhibited the growth of lithium dendrites. PAF-QSPE exhibited high ionic conductivity of 1.75×10-4 S cm-1 and of 0.55 at room temperature. The activation energy was as low as 0.136 eV. Furthermore, the assembled SLIBs with PAF-QSPE presented a discharge capacity of 163 mAh g-1 at 0.2 C and a capacity retention rate of 96% after 350 cycles, illustrating a stable cycling performance. This work demonstrated the great application potential of lithium-rich PAFs in QSPEs.

Key words Quasi-Solid Polymer Electrolyte; Lithium-Rich; Porous Aromatic Frameworks

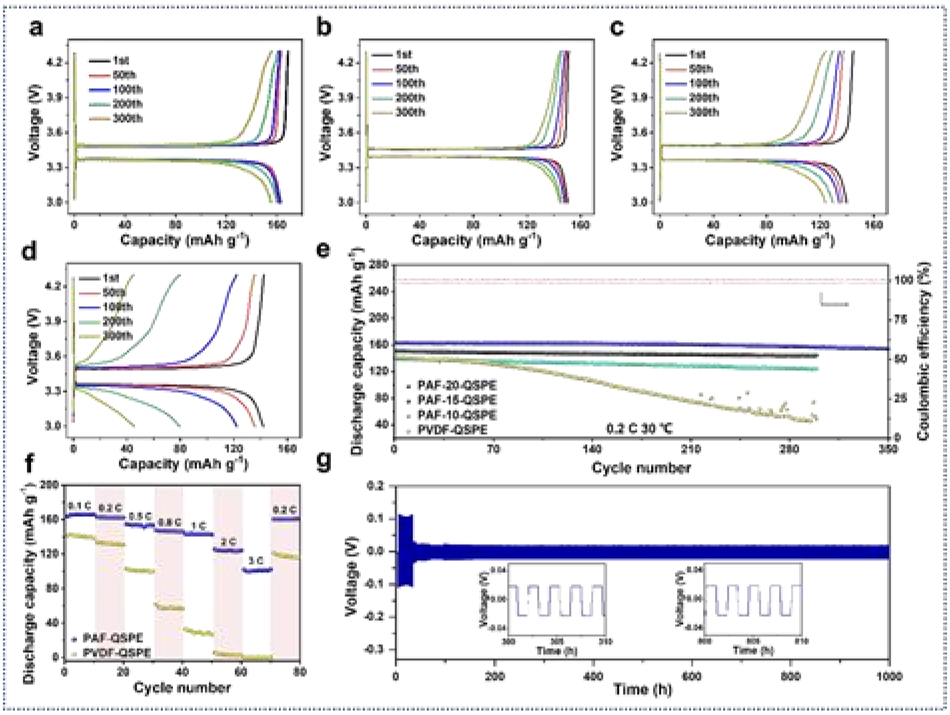


Fig. 1. (a-d) Discharge/charge voltage profiles of Li/PAF-x-QSPE (x%, x=20; 15; 10; 0)/LFP cell at 0.2 C; (e) Cycling performance of Li/PAF-x-QSPE (x%, x=20; 15; 10; 0)/LFP cell at 0.2 C; (f) Rate capability of Li/PAF-QSPE/LFP and Li/PVDF-QSPE/LFP cell; (g) Voltage profile of galvanostatic lithium plating/stripping of the symmetric Li/PAF-QSPE/Li cell at 0.25 mA cm^{-2}.

Session: Polymer Matrix Composites

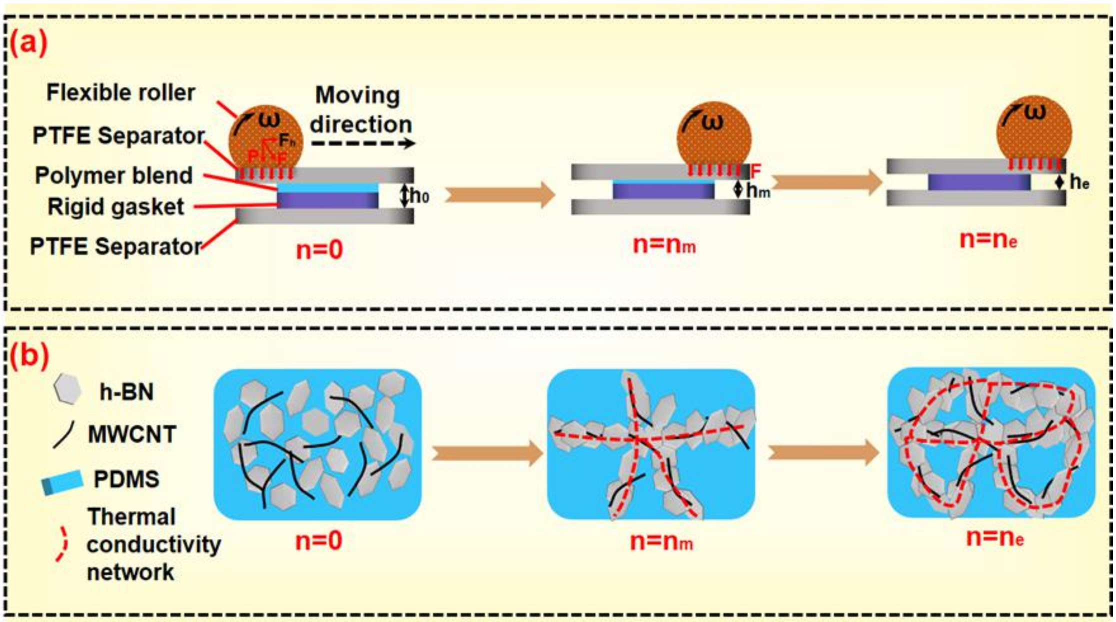
Presenting Type：Oral-Invited

Enhanced thermal conduction of hybrid filler/polydimethylsiloxane composites via a continuous spatial confining process

Jingyao Sun*、Daming Wu
Beijing University of Chemical Technology

Owing to the rapid development of the electronics and aerospace industry toward high integration and power, the growing demand for heat dissipation management materials was urgent. However, the continuous fabrication of thin highly thermally conductive polymer composites at a large scale remains challenging, especially requiring control of the filling content of fillers. Herein, the continuous spatial confining forced network assembly (CSNA) method was applied to realize the continuous construction of thermally conductive networks of hexagonal boron nitride (h-BN) and multi-walled carbon nanotubes (MWCNT) in polydimethylsiloxane (PDMS) matrix. The thermal conductive composites presented thickness-dependent in-plane thermal conductivity (K), reaching 4.28 W m-1 K-1 for h-BN (30 wt%)/MWCNT(2 wt%)/PDMS in 0.15 mm thickness. The h-BN/MWCNT/PDMS composite represented a 1543.5% increase compared to the pure PDMS thanks to the CSNA method and the bridging connection of MWCNT. This work provided a facile method to prepare the thin high thermal conductive composites, which might promisingly advance the industrialization of thin thermosetting thermal conductive composite films.

Key words Polymer-matrix composites; Thermal conductivity; CSNA method



Session: Polymer Matrix Composites

Presenting Type: Oral-Invited

MXene functionalized CF/PEKK composites with integrated EMI shielding performances and mechanical properties

Xueqin Yang[1,2]、Jiamei Luo[1,2]、Hongliang Ren[1]、Yi Xue[1]、Chenxi Yang[1]、Ting Yuan[1]、Zehao Yang[1]、Yong Liu[1]、Hui Zhang*[1,3]、Jianyong Yu[2,3]

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The development of carbon fiber-reinforced thermoplastic (CFRTP) composites is gradually changing from a focus on the usage as a mechanical material to an emphasis on the potential as an integrated mechanical and EMI shielding material. However, poor interfacial interactions between carbon fibers (CF) and thermoplastic matrix, coupled with rather inferior electrical conductivity of thermoplastic matrix are unfavorable for the design of CFRTP composites with combined EMI shielding performances and mechanical properties. Herein, the two-dimensional MXene ($Ti_3C_2T_x$) nanosheets were employed to increase the shielding effect of carbon fiber-reinforced polyetherketoneketone (CF/PEKK) composites and endow the strong interfacial interactions between CF and polyetherketoneketone (PEKK). As expected, the resultant CF/PEKK composites possessed outstanding EMI shielding performances, while the mechanical properties were also significantly improved. Concretely, the CF/PEKK composites functionalized with MXene at 1 mg/mL exhibited an excellent EMI shielding effectiveness of 65.2 dB in the X-band, 103.1% above that of the virgin CF/PEKK composites. The elevated EMI performances might be attributed to the enhanced ohmic losses and multiple reflections of EMW by means of the MXene and CF layers. Furthermore, CF/PEKK composites achieved superior mechanical properties by optimizing the dispersion concentration of MXene to 0.1 mg/mL. The flexural strength, flexural modulus and interlaminar shear strength of CF/PEKK composites achieved 1127 MPa, 81 GPa and 89 MPa, which were 28.5%, 9.5% and 29.7% higher than that of the virgin CF/PEKK composites, respectively. Such promotion in mechanical properties could originate from the comprehensive effect of mechanical interlocking, hydrogen bonds and Van der Waals forces between the introduced MXene and CF, PEKK respectively. Briefly, this study puts forward an effective interfacial modification technique for developing CFRTP composites with integrated high EMI shielding performances and mechanical properties.

Key words CF/PEKK composites, Ti3C2Tx MXene, Interfacial modification, Electromagnetic interference shielding performances, Mechanical properties

Session: Polymer Matrix Composites

Presenting Type: Oral–Invited

Silicone polymer nanocomposite materials

Long-Cheng Tang*
Hangzhou Normal University

Silicone polymer materials with unique organic/inorganic structure and outstanding physical performance have been widely used in various fields from building, automotive to aerospace. Typically, nanomaterials at high contents (>30 wt%) are utilized to improve the mechanical properties and functionalities of silicone polymers for practical applications. However, the inert side groups (e.g., methyl, phenyl and trifluoropyl groups) of silicone polymers and high surface area of nano-fillers easily induce the poor filler/matrix compatibility/interaction, nanofiller agglomerate and difficult processing behavior (increase in viscosity), thus resulting into the low mechanical strength and mutual exclusiveness of mechanical property and functionality. To address the above issues, some new silicone polymers were designed and synthesized, and several novel processing methodologies were developed to fabricate advanced silicone polymer nanocomposites. Typically, a series of hierarchical nano-coatings of silicone resin and graphene oxide (GO) derivatives on various combustible materials showed extremely rapid flame detection response in <3 s, efficient fire warning signal (below the ignition temperature of most combustible materials) and excellent flame retardancy. On the other hand, a new and green in-situ surface-reactive assembly approach was created to onstruct ultrathin 2D-filler layer bonded onto the silicone foam surface, thus producing significant improvements in thermal stability and flame retardancy of the PDMS foam without affecting its density and elasticity at ultrathin filler loading (≤0.50 wt%). Moreover, an ultrafast and environmentally friendly flame scanning strategy to fabricate robust superhydrophobic silicone foam materials that show excellent water contact angles of > 155° and water sliding angles of < 5°), reliable mechanical robustness and excellent water repellency after hostile environmental conditions. The developed multifunctional silicone polymer nanocomposites are promising for some emerging applications.

Key words silicone polymer, nano-mateirals, composites, strucutre and property, surface and interface

Session: Polymer Matrix Composites

Presenting Type： Oral-Invited

Compression property of glass fiber/polyimide honeycomb at elevated temperature

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2. Nanjing Institute of Technology

Since the 1970s, glass fiber/polyimide(GF/PI) honeycomb cores have been used in high-temperature electromagnetic transmission structures, but their temperature-dependent mechanical properties and failure modes have not been comprehensively studied. Therefore, we prepared continuous glass fiber reinforced polyimide hexagonal honeycomb cores with double cell wall thickness along the ribbon direction, using the same kind of polyimide resin as the honeycomb wall matrix as the adhesive at the nodes. The thermo-mechanical coupled finite element model was established to study the quasi-static compression behaviors of GF/PI honeycomb with the temperature dependant properties of cell wall and node adhesive layer were obtained by experiments. To validate the finite element model, out-of-plane quasi-static compressive tests under elevated temperature were carried out, resonable agreement was observed between the model predictions and test results. With high termal stability, GF/PI honeycomb core exhibits stablized progressive failure behavior under the quasi-static crushing process, reflecting its good energy absorption ability.

Key words Glass fiber/polyimide honeycomb; Temperature dependant; Thermo-mechanical coupling; Quasi-static compression.

Session: Polymer Matrix Composites

Presenting Type: Oral–Invited

Design and preparation of composites with optical transformation under laser ablation

Chen Ma*
Huaqiao University

High-energy continuous-wave (CW) laser has been considered as a significant technology in recent decades. Such laser can destroy conventional materials in an extremely short time, necessitating their protection. Preparing a coating with high reflectivity is an effective method to consume laser energy. However, the high reflectivity required by anti-laser coating and the low reflectivity required by laser radar stealth function that also has great significance conflicts with each other. In order to solve this problem, we design and prepared a novel short fiber reinforced resin matrix composite with the characteristic of "laser ablation-induced reflectance mutation". Combining the excellent thermal stability of boron-modified phenolic resin and the characteristics of the increasing reflectivity in the oxidation process of carbide ceramic particles, the reflectivity shows a remarkable increase during laser ablation process. We introduce low-melting-point ceramics and short-fiber into the composite to build the adhesion and binding mechanism, which has been proved to be effective to realize the structural strengthening of the formed high-reflectivity coating. In addition, the contrast experiments indicate the advantages of SiC fiber compared with carbon fiber, and the melting of low-melting-point ceramics could fill the cracks and promote the compactness of the formed high-reflectivity coating. Eventually, the reflectivity of the composite could show a remarkable increase to around 70% after laser ablation, which has bene demonstrated to be the key factors improving the anti-laser performance. The microstructure, phase change, and element distribution were specifically detected to analyze the laser ablation mechanism of composites.

Key words Laser ablation behavior; Optical transformation; Resin matrix composites; Anti-laser performance

Session: Polymer Matrix Composites

Presenting Type: Oral-Invited

Viscoelastic behaviours of rubber vulcanizates

Yihu Song*
Zhejiang University

Nanoparticles significantly reinforce rubber materials while they also enhance the dissipation and strain softening behaviours of the nanocomposites, the latter being characterized by nonlinear Payne effect. For a long time, formation of filler networks mediated by rubber-filler interfacial interactions is assigned to the major reinforcement mechanism beyond the hydrodynamic effect and breakdown of filler network mediated by chains slippage and desorption from the filler nanoparticles is thought to account for the Payne effect. We show that the filler amplifies microscopic deformation and therefore reinforces the rubber phase depending on the dynamics of the rubber, which is well accounted for by the time-concentration superpositioning principle. We show that the neat rubber vulcanizates exhibit nonlinear dynamic rheology that determines the Payne effect of vulcanizates nanocomposites. The filler amplifies the microscopic deformation and promotes softening of the rubber phase, which is well accounted for by the concentration-concentration superpositioning principle. We realize that many studies ignoring the viscoelasticity of the rubber matrices and simplifying the matrices to “the carrier of the particle network” give deceptively misleading conclusions being far away from guiding the industry to manufacture high-performance nanocomposites. We develop several strategies to optimize the reinforcement, dissipation and strain softening behaviours of rubber nanocomposites based on regulation of the nonideally crosslinked network of the rubber matrices in addition to improvement of filler dispersion and interfacial interaction.

Key words Rubber nanocomposites; Payne effect; viscoelasticity

Session: Polymer Matrix Composites

Type：Oral−Invited

The Processing of Functional Polymer Composites Through a Dendritic Colloids Based Strategy

Hua DENG*
College of Polymer Science and Engineering, Sichuan University

Various functions of polymer composites, including electrical conductive, thermal conductive, dielectric, EMI shielding, strain sensing, etc, has been extensively investigated. These functions need to be provided by functional fillers or networks. Therefore, the morphological control of these functional filler should play crucial role on the final properties of these functional polymer composites. In recent years, we have carried out a series of studies focusing on "The relationship between different morphological control methods--filler network morphology & property—functionality". Efforts have been made on investigating various morphology control methods including: construction and destruction of filler network during processing, multi-layered structure through high speed thin-wall injection molding and macroscopic segregated network structure. The basic issues regarding these morphological control methods are thought to be the confinement, assembly and relaxation of inorganic functional filler in organic polymer matrix. Herein, inspired by the hierarchically dendritic structure of plant root and its extraordinary ability of grabbing soil, various polymer dendritic colloids with such bio-mimic structure were fabricated by non-solvent induced precipitation under turbulent force. These polymer dendritic colloids have strong adhesion with various substrate, strong network building ability and excellent ability to "grab" large amount of filler onto their surface. Thus, various functional composites films could be prepared with high filler content and mechanical flexibility. Furthermore, such method could also be used to incorporate large amount of filler onto porous substrate (such as foam), thus, direct contact between active/functional fillers and fluid (water) could be achieved. Such novel strategy provides an interesting guideline for a range of applications.

Key words Functional polymer composites, confinement, assembly, relaxation, polymer processing, dendritic colloids

Session: Polymer Matrix Composites

Presenting Type: Oral-Invited

Enhanced thermal conductivity and heat resistance in polylactide-based composites via constructing stereocomplex crystallites

Yong Wang*、Ting Gu
Southwest Jiaotong University

As one of the biodegradable polymers that can be produced from natural resources, polylactide (PLA) exhibits great potential application in many fields. However, the relatively low heat resistance greatly restricts its application, especially in the environmental conditions relating to high temperature. At optimum conditions, poly(L-lactide) (PLLA) and poly(D-lactide) (PDLA) can form the stereocomplex (SC) crystallites, which exhibit higher packing density and melting temperature than those of the homogenous crystallites obtained from PLLA or PDLA. Inspired by this phenomenon, different strategies have been developed in this work to in-situ construct SC crystallites in the PLA-based composites to synchronously enhance their heat resistance and thermal conductivity, including constructing SC crystallites to tailor the network structure of carbon nanofibers (CNFs) in the PLLA composites through common melt compounding processing, grafting PDLA molecular chains on the surface of graphene nanoplatelets (GNPs) to induce the formation of SC crystallites at the interface between PLLA and GNPs, and constructing the segregated and double-percolated structures with multiscale SCs in the PLLA/GNP@SC composites through the compression molding method. And finally, a novel concept of SC crystallites assisted crosslinking between adjacent GNPs has been proposed, and the composite films with high thermal conductivity, high electrical insulation and excellent fracture toughness have been successfully achieved, providing alternative choice for the next-generation thermal management materials.

Key words Stereocomplex crystallites; Interfacial structure; Thermal conductivity; Heat resistance; Mechanical properties.

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Static and dynamic mechanical properties of epoxy nanocomposites reinforced by hybridization with carbon nanofibers and block ionomers

Zhiipeng Zhou、Weifu Sun*
Beijing Institute of Technology

Epoxy (EP) is widely used in many engineering applications, however, its inherent brittleness limits their impact resistance. Conventional toughening agents usually lead to compromised compressive strength. In this study, a ternary composite with epoxy as matrix mixed with sulfonated polystyrene-block-poly (ethylene-co-butylene)-block-polystyrene (SSEBS) and functionalized carbon nanofibers (CNFs) was reported. The quasi-static and dynamic compression characteristics of EP/SSEBS/CNFs composites at different loading rates (0.003 s-1 to 3600 s−1) are studied by means of a universal testing machine and split Hopkinson pressure bar (SHPB), respectively. The results show that the synergistic effect of SSEBS and CNFs can simultaneously strengthen and toughen epoxy composites. The Young's modulus, yield strength, compressive strength and failure strain of EP/SSEBS/CNFs composites with 0.75wt% CNFs are all higher than those of EP at high strain rates. Among them, at a strain rate of 3600 s-1, the increase of Young's modulus and compressive strength reaches 57% and 195.5%, respectively. The lengths of EP/SSEBS and EP/SSEBS/0.75%CNFs after impact are greater than those of EP, which indicates that both EP/SSEBS and EP/SSEBS/0.75%CNFs have excellent ability to adapt to rapid inelastic deformation. The rough fractographic features suggests that the synergistic effect of SSEBS and CNFs further promoted the absorption of fracture energy. Compared with EP, EP/SSEBS/CNFs composites exhibits more significant strain rate effect and strain hardening effect. Moreover, the large deformation ability of SSEBS, the bridging effect of CNF and the excellent interfacial properties between the hybrids and the EP matrix are found to be the main reasons for realizing the reinforcement and toughening of EP composites.

Key words Epoxy resin; Sulfonated rubber; Carbon fiber; Ternary hybrids

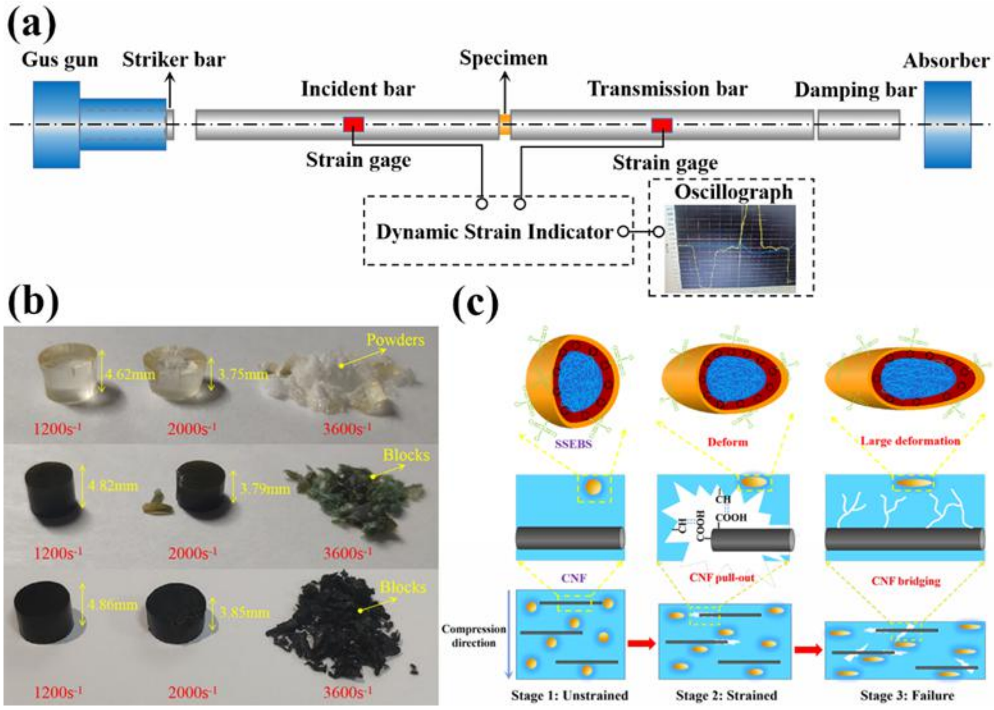

Fig. 1. (a) The schematic illustration of SHPB test system; (b) Optical images of EP, EP/SSEBS and EP/SSEBS/0.75%CNFs after impact loading at three strain rates ($1200s^{-1}$, $2000s^{-1}$, $3600s^{-1}$); (c) Toughening and strengthening mechanisms of EP nanocomposites by SSEBS block ionomer and CNFs.

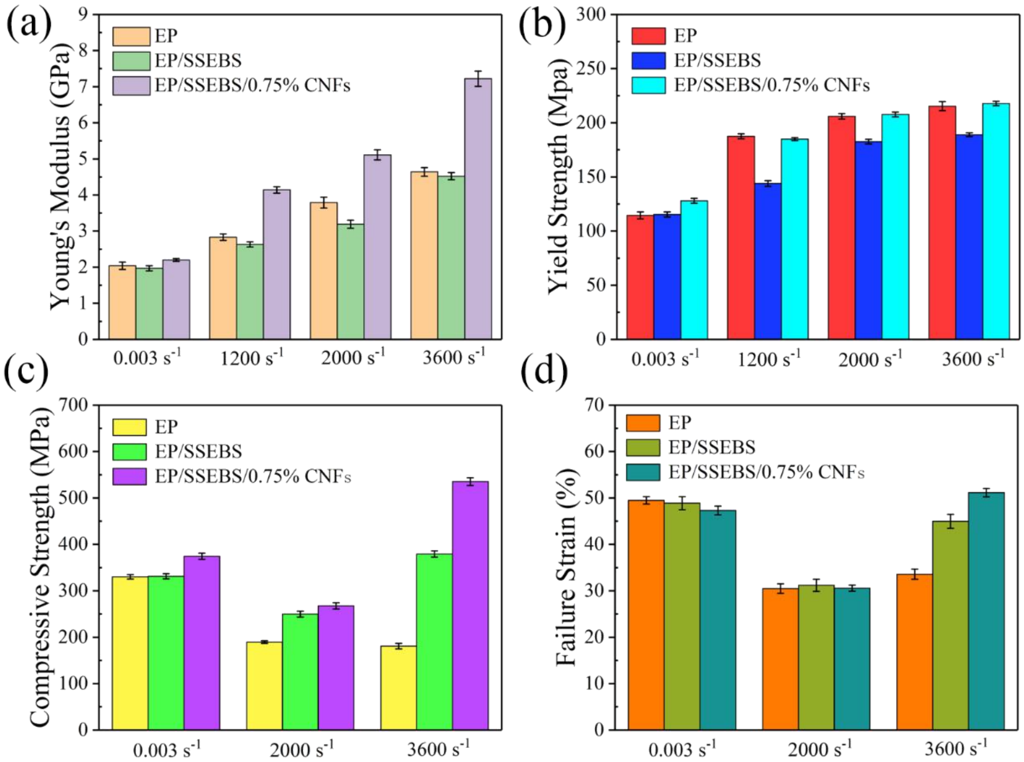

Fig. 2. Compressive mechanical properties of EP, EP/SSEBS and EP/SSEBS/0.75%CNFs at different strain rates: (a) Young's modulus; (b) Yield strength; (c) Compressive strength; (d) Failure strain.

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

CFRP interleaved by Short/Micro-length fibres: from laboratory to industrial pre-preg production

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1. University of Western Australia
2. Shaoxing Baojing Composite Materials Co., Ltd
3. Southwest University of Science and Technology

Laminar carbon fibre reinforced polymers (CFRP) made from pre-pregs are extensively used in aerospace and automobile industries. Due to the lack of interfacial toughening, delamination or cracking between carbon fibre plies is a critical concern for those laminar CFRP structures. This important issue has been studied extensively in laboratories utilising Z-directional toughening techniques such as Z-pins and stitching, and various interleaving methods including short/micro-length fibre interfacial toughening for quasi-Z-directional toughening.

We adopt the short/micro-length fibre interleaving method because of its effectiveness in interfacial toughening and minimum production cost increase, and readiness to be adopted in pre-greg manufacturing. The interfacial toughened pre-pregs even remove the extra step of interleaving, making their applications as simple as current normal pre-pregs. We examine the interfacial toughening effects of short/micro-length fibres including CNT and Aramid Pulp (AP) micro-/nano-fibres, and challenges for technological transfer from laboratory to potential pre-preg production.

Key words Carbon fibre reinforced polymer (CFRP); Interlaminar toughening; Ultra-thin interlayer

Session: Polymer Matrix Composites

Presenting Type：Oral-Onsite

Experimental and numerical investigations on the low-velocity impact response of short fiber reinforced composite laminates based on discontinuous slits

Yinyuan Huang*、Junfeng Hu、Xutong Zhang、Siqi Zhang、Rui Qian、Yifan Wang、Felix Thompson Eshun
Nanjing Tech University

The short fiber reinforced composites are widely used in manufacturing complicated structural component due to its excellent flowability. Damage resistance of composite materials under impact events and their residual strength is a key factor in the design of composite structures. In this study, short fiber reinforced polymer composite laminates based on unidirectionally arrayed chopped slits (UACS) and continuous fiber reinforced polymer composite laminates (CFRP) with thickness of 2mm and stacking sequences of [0/90]4s were prepared for low-speed impact tests under different impact energy levels (up to ~30J). Damage mechanisms of laminates during the impact events were observed by C-scan imaging system. The simulation model was based on the C3D8R element of ABAQUS/Explicit, and the VUMAT subroutine was used to simulate the damage evolution of fiber/matrix in the prepreg layer by importing the Hashin failure criterion and the equivalent displacement failure mode. The initiation and propagation of interlayer damage were predicted by using cohesive interfacial element combined with the traction separation law. The reliability of the simulation method was verified by comparing with the experimental data. Compared with CFPR, the impact process of UACS is longer due to its lower flexible stiffness. UACS laminates can absorb more impact energy, which means it has high damage tolerance. Numerical results show that the direction of damage propagation changed because of the silts for UACS laminates, but the main failure modes are dominated by the matrix cracking and delamination.

Key words Short fiber reinforced composite; Low velocity impact; Damage evolution; Numerical Simulation

Session: Polymer Matrix Composites

Presenting Type：Oral−Onsite

Novel and facile solution-based processing of polyetherketoneketone (PEKK) toward high performance composites

Xiaohua Zhang*
Donghua University

High-temperature engineering thermoplastics are gaining growing interests as they not only provide a lightweight solution but also affect the manufacturing processes and efficiencies. Polyetherketoneketone (PEKK) is a new evolving polymeric material, and is considered as another important member of the polyaryletherketone (PAEK) family in addition to polyetheretherketone (PEEK). Thus far, the impregnation of both PEKK and PEEK is mainly based on the powder strategy, which severely limited its composition with reinforcing fibers. Due to the high molecular polarity of PEKK, we have realized a breakthrough to dissolve PEKK into fluorine- and/or chlorine-containing solvents. Therefore, an ideal composition between PEKK and carbon fibers (CFs) is achieved, in which the tensile properties of CF can be utilized with a high efficiency up to 95%. Furthermore, in such ideal composition, a strong confinement effect is observed, which induces the suppressed crystallization for PEKK. As a result, the interfacial shear properties are remarkably improved, with a shear strength up to 100 MPa. Besides the application on the continuous CFs, we have also developed a new strategy to fabricate short-cut CF/PEKK, CNT/PEKK, and graphene/PEKK composite powders. Our investigations would greatly push a wide range of applications for PEKK.

Key words Polyetherketoneketone, solution-based processing, confinement effect, interfacial properties.

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Micro-structures Embeded Polymer Matrix Composites Manufactured by External Fields Assisted Methods and Its Dielectric Properties

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1. Qingdao University of Science and Technology

2. University of Gezira

External field assisted processing methods have been attracted lots of attention due to their advantage and convenience on rational design of the internal microstructures in polymer matrix. For shearing or compression force, fillers usually only align or assemble along the in-plane direction of composite films, which limits their practical application. By applying the electric or magnetic field, fillers can be easily aligned or assembled into unique microstructures along the out-plane direction. And this formed embedded microstructures can enhance the electric, thermal, optical properties of the polymer composite. In this study, we demonstrate a paradigm for fabrication of microstructure in silicone rubber Polydimethylsiloxane (PDMS) under electric fields. Polyaniline (PANI) modified by polyvinylpyrrolidone (PVP) to form a core-shell structure serve as functional particles and silicone rubber Polydimethylsiloxane (PDMS) is as matrix. Microstructures of PANI are assembled by electric field and then enhance the dielectric properties of the polymer matrix composites, which is promising materials in the area of electronics and electric industries. With addition of 2.5 wt% PVP@PANI, the dielectric constant can be significantly enhanced up to 23. This new processing technology provides important insights for assembling fillers in polymer matrix to form composite with enhanced dielectric property.

Key words Field assisted processing, dielectric, polymer matrix composites

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Enhanced interlaminar properties of unidirectional carbon fiber/epoxy composites by the synergistic effects of CNT powders and veils

Yunfu Ou*、Longqiang Wu、Dongsheng Mao
Ningbo Institute of Materials Technology and Engineering

While carbon fiber reinforced polymer (CFRP) composites are widely used in structural components because of their excellent mechanical properties, delamination between reinforcing plies remains a well-known Achilles heel, weakening the composite structure and limiting their more widespread applications. This work tried to improve the interlaminar properties of unidirectional CFRP laminates by the synergistic effects of CNT powders and veils. The short CNT powders (average length < 1 μm) were adopted for toughening the matrix, which effectively avoids the "self-filtration effect" commonly found in the VARTM process and allows the CNTs to penetrate between the tiny gap of the carbon fibers and be uniformly dispersed in the composites. In addition, an ultrathin CNT fiber veil (~100 nm in thickness) was used as the interleaf material, offering the opportunity to reinforce the interlaminar bonding with a minimal weight penalty and effectively avoid reductions in in-plane properties. The results showed that 0.5wt% is the optimum loading level of CNT powders for matrix toughening. The Mode I interlaminar fracture toughness (propagation value, GIC,prop) of the unidirectional CFRP composites increased as much as 32%, 62% and 123% when integrating CNT veil, CNT powder and CNT veil+powder, respectively. The figure of merit for interlaminar reinforcement, consisting of the change in interlaminar properties normalized by interleaf thickness and ply thickness, comes out as high as 2460, which far outweighs the state of the art.

Key words Polymer-matrix composites; Hybrid; Fracture toughness; Mechanical testing; interlaminar toughening

Hangzhou, PR China 25-28 April, 2023

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Investigation of potential green manufacturing of novel thermoplastic composites: curing process and mechanical performances

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Hong Kong University of Science and Technology

The current research aims to investigate the green manufacturing potential of the novel thermoplastic composites based on Elium® 188 resin. The exothermic behavior and mechanical performance of plain weave carbon fabric reinforced Elium® 188 composites under various curing temperatures (21°C, 40°C, 60°C, and 80°C) are studied. First, the exothermic behavior and curing cycle are determined by online monitoring of the temperature distribution and calculating the temperature difference between twice heating processes. On the other hand, the effect of curing profile on the mechanical performance is studied via tensile and flexural tests, followed by the C-scanning for evaluating the laminates forming quality and TGA for determining the void content. The results show that isothermal heating at 40°C for 2 hours is the best curing profile for the optimal mechanical performance and forming quality. Curing at room temperature for 6.9 hours is also recommended because of the excellent mechanical properties and nearly zero energy consumption during the curing process. In comparison with plain weave carbon fabric reinforced Epolam 5015 composites, Elium® matrix composites present a 9% higher specific strength and 6% higher specific stiffness, and consume less than 1/4 electric energy and curing time. This experimental investigation demonstrates the potential of green manufacturing of Elium® 188 matrix composites, promoting the broader application in the industry.

Key words Elium® 188 resin, thermoplastic composites, exothermic behavior, mechanical properties, green manufacturing

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

How does high temperature impact the physical and mechanical properties of engineered bamboo composites?

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2. Virginia Polytechnic Institute and State University

The objective of this study is to investigate the effect of high temperature on the physical and mechanical properties of the engineered bamboo composites (EBCs). The bamboo scrimber (BS) and glued-laminated bamboo (GLB) sheets were made from Phyllostachys pubescens (Moso) with phenol formaldehyde having a dimension of 2440 mm (longitudinal)×1220 mm (width)×25mm (thickness). The physical and mechanical properties of EBCs were conducted on testing samples prepared from BS and GLB sheets heated at the various temperatures constantly from 40 to 250 ^{0}C for 30 minutes. After treatment, the physical and mechanical properties were measure. The result showed that the heat had a significant effect on the physical and compressive behaviors of the EBCs. The mass losses of BS and GLB increased with the temperature, while the densities of BS and GLB exhibited an opposite. Total mass loss can reach 14.86% and 23.72% at 250°C for BS and GLB, respectively. The density reductions were measured to be 37.5% for BS, and 18.9% for GLB at 250°C. The color changes were not conspicuous when the heating temperature was less than 160°C, but the surface darkening was noticed at temperature above 190°C. Dimensions of BS and BLB were also affected by the higher temperature. The BS samples swelled 32.86% in thickness and 2.8% in width at the high temperature, while GLB samples shrank 3.24% in thickness and 2.48% in width at 250^{0}C. The compressive strength in parallel-to-grain increased with temperature reached a maximum when the samples heated at 160°C, which is considered to be a critical point for the compressive strength. The degradation of phenol formaldehyde resin and bamboo fibers at high temperatures, particular for the temperature from 190°C to 250°C, contributed to the decrease in the mechanical strengths. With the increase of temperature, the failure mode of the samples changed from ductile failure to brittle failure in parallel-to-grain.

Key words Engineered bamboo composites, Physcial property, Mechanical property, Glued laminated bamboo, Scrimber

Session: Polymer Matrix Composites

Presenting Type：Oral-Onsite

Design and Preparation of High Impact Polypropylene Composites with Balanced Toughness and Rigidity

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Changchun Institute of Applied Chemistry, Chinese Academy of Sciences,

Rigidity and toughness are two key parameters that determine whether a polymer can be used as an engineering material. Polypropylene (PP), used widely as a general polymeric material, its application is limited in engineering due to its poor impact resistance, especially at lower temperature. Introducing rubber/elastomer into matrix PP by blending or alloying in reactor can improve the impact resistance to prepare high impact polypropylene (HIPP). However, these methods will lead to a markedly decrease in rigidity, limiting the application of PP in engineering also. Therefore, by combining the brittle-ductile transition theory and the elasticity theory of multi-component polymer in this dissertation, we established a multiphase model to link the rigidity and toughness of polymers, and quantitatively investigated the factors that affected rigidity and toughness. Then, based on the theoretical research, the effects of the structure and properties of PP matrix and modifier on the balanced toughness and rigidity of the PP composites were investigated experimentally.

Key words high impact polypropylene, rigidity, toughness, brittle-ductile transition, balanced toughness and rigidity

Session: Polymer Matrix Composites

Presenting Type：Oral-Onsite

Hydrophobic cellulose nanocrystals-polyvinyl alcohol-methyltrimethoxysilane composite aerogels for effective oil and sound absorption

Xin Jia、Guijiang Tang、Xueliang Jiang*、Chu Yao
Wuhan Institute of Technology

Cellulose aerogel has great application potential in oil-water separation and noise pollution treatment, due to high porosity, high specific surface area, and easy modification. However, the fragile porous structure and the high hydroscopicity of cellulose aerogel greatly restrict its application at present. In this work, using cellulose nanocrystals (CNCs) as the matrix, polyvinyl alcohol (PVA) as the reinforcing agent, polyamide epichlorohydrin (PAE) as the cross-linking agent, methyltrimethoxysilane (MTMS) as the hydrophobic agent, the hydrophobic and ultralight CNCs-PVA-MTMS composite aerogels are prepared by internal chemical cross-linking, directional freezing pretreatment and freeze-drying technology. Benefitting by the enhancement of the PVA to the cellulose aerogels and the abundant chemical crosslinking between the MTMS and the hydroxyl on the CNCs and PVA, the mechanical properties and the hydrophobicity of the aerogels improve obviously. On the stable porous structure and effective hydrophobic modification basis, the composite aerogels show excellent oil absorption performance and sound absorption performance after the effective control of the microstructure. The composite aerogels can efficiently absorb dozens of common oil and organic solvents primarily through physical adsorption. And the maximal adsorption capacity can be up to 46.7 g/g and the adsorption capacities maintain stability after 12 cycles. The average sound absorption coefficient (ASAC) of the composite aerogels exceeds 0.85 over a wide frequency range from 500 to 6300 Hz. And the ASAC and the greater efficiency of the composite aerogels surpassed most of the reported sound-absorption materials, such as the conventional porous materials, composites and ultralight aerogels. The lightweight, high-porosity, and environmentally friendly aerogels proposed in this work are expected to achieve high-efficiency sound and oil absorption, which can stimulate broad interest in building competing candidates for noise pollution treatment and oil-water separation.

Key words Cellulose; Aerogels; Mechanical strength; Hydrophobic modification; Sound absorption properties

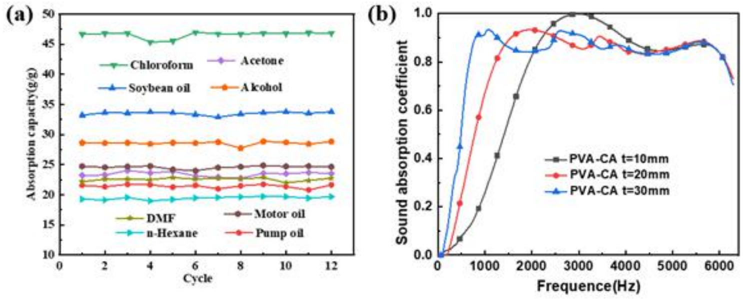

Fig. 1. (a) Composite aerogel adsorption rate curve different oil solvent/adsorption cycle curves. (b) Influence of thickness on sound absorption performance of composite aerogel

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Opening size effect of novel short fiber reinforced composite laminates: Experiment tests and numerical analysis

Xutong Zhang、Jufeng Hu*、Sudong Yu、Yifan Wang、Yinyuan Huang、Siqi Zhang、Rui Qian
Nanjing Tech. University

Defects are prone to occur in fabricating complex-shaped structures using carbon fiber reinforced plastic (CFRP) due to the poor flowability of continuous fiber. Unidirectionally Arrayed Chopped Strands (UACS) prepregs, which are prepared by introducing regular slits into the unidirectional CFRP prepregs, can maintain the fiber flowablity and show better strength than other short fiber reinforced plastics, are suitable for forming complex composite components. In addition, in practical engineering applications, it is usually unavoidable to drill holes or notches for connecting parts of composites. And these holes or notches are likely to cause severe stress concentration and reduce the strength of laminates.

In this research, the mechanical properties of UACS quasi-isotropic composite laminates with opening diameters of 0 mm, 4 mm, 6 mm, 8 mm and 10 mm under tensile load are investigated through numerical simulation and mechanical experiments. The simulation results show that UACS laminates have lower opening sensitivity than continuous fiber laminates. The strength retention rate of UACS laminates is larger than 80%, when the diameter to width ratio is less than 0.2. However, the slits aggravate the strain concentration around the hole, so that the strain concentration factor around the hole of UACS open-hole laminates is larger than that of continuous fiber open-hole laminates. Moreover, these slits effectively inhibit the initiation and propagation of delamination damage. With the increase of open-hole size, the progressive failure of UACS open-hole laminates eliminate gradually, and the brittle fracture phenomenon becomes more obvious.

Key words UACS composite laminates, open-hole tension, quasi-isotropic, finite element analysis, progressive damage

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Polymer composites-based flexible sensors for electronic skins and wearable electronics

Yutian Zhu*
Hangzhou Normal University

Electronic skins and wearable electronics have attracted considerable interest in recent years due to their versatile applications in human-machine interface, human health and motion monitoring, as well as smart robotics. Hence, the flexible sensors that convert external stimuli caused by the changes in mechanical forces, temperature, humidity, etc., to electrical signal, as the key components of electronic skins and wearable electronics, have been widely investigated. However, the basic sensing properties (detection limit, working range, detection precision, repeatability, etc.) and special properties (transparency, self-repairability, stretchability, breathability, etc.) of previously reported flexible sensors are not enough to meet their applications in electronic skins or wearable electronics. Over the past 5 years, a series of polymer-based sensors with the merits of flexibility, light weight, easy processability and resistance to corrosion have been designed and studied by our group to promote their applications in electronic skins and wearable electronics. More specifically, various high-performance transparent sensors, such as strain sensors, pressure sensors, temperature sensors, humidity sensors, etc., have been developed via material selection and structure design to satisfy demand for electronic skins. The polymer-based flexible sensors with a fibrous or porous structure, meanwhile, have also been prepared in our lab by multiple strategies, including large-scale wet spinning, electrostatic spinning and non-solvent induced phase separation to enhance their air permeability, stretchability and comfort in wearable electronics. We believe that our results can inspire future research to design full-featured flexible sensors for electronic skins and wearable electronics.

Key words Conductive Polymer Composites, Strain Sensor, Temperature Sensor, Humidity Sensor, Wearable Electronic

Session: Polymer Matrix Composites

Presenting Type：Oral–Onsite

High-content continuous carbon fibers reinforced PEEK matrix composite with ultra-high mechanical and wear performance at elevated temperature

Zhengbo XU*、Junnan Dai、Feng Qiu、Hongyu Yang
Jilin university

It remains challenging to incorporate high-content fibers in fiber-reinforced polymer matrix composites to significantly enhance their mechanical properties. This work prepared polyether ether ketone (PEEK) matrix composite reinforced with 66 wt.% carbon fibers with 0°/90° prepreg layer by compression molding, with aim to further increase the carbon fiber content in PEEK-based composites to improve the mechanical and wear properties at different temperatures, especially high temperature. The composite exhibits tensile and flexural strength, which is superior to many magnesium or aluminum alloys at 300 °C. Further, the composite has a lower wear rate at 200 °C by 1-2 orders of magnitude that of some materials with lubricating particles, and the wear surface is dominated by mild adhesive wear instead of abrasive wear at room temperature. The ultra-high mechanical and friction wear properties are attributed to the high content of staggered 90° carbon fibers, great interface bonding between the fiber and PEEK matrix, and self-lubricating effect of fibers and PEEK particles in the composite. This opens up a new performance level and provides a new idea for high-temperature applications of high-strength fiber-reinforced resin matrix composites.

Key words Carbon fiber; Polyether ether ketone; High temperature; Mechanical property; Wear; Mechanism

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Polymer based microwave shielding materials with multiple interfaces

Ming Wang*
Southwest University

Microwave shielding materials have become very important materials in modern society due to the increasing electromagnetic pollution. Polymer based microwave shielding materials (PMSM) gradually have come to the fore in recent years because of its lightweight, high mechanical flexibilities, good corrosion resistance, and low cost processing. However, the high-performance microwave shielding usually requires high content of conductive fillers in PMSM, which leads to new drawbacks, such as mechanical deterioration, cost increase, and processing difficulties. Therefore, the main challenge for microwave shielding PMSM is to achieve high microwave shielding effectiveness (SE) at low content of conductive fillers. In this presentation, we will introduce the PMSMs with multiple interfaces which exhibited high-performance microwave shielding at low filler loadings. The shielding enhancement mechanism of PMSMs with multiple interface will be discussed. The presentation will talk about some our recent researches on the PMSMs with multiple interfaces, which include the controllable fabrication strategies, ideas for the interfacial construction, and mechanism of interfacial microwave attenuation. Some perspectives for PMSM will be also given and discussed in this presentation.

Key words Conductive polymer composites, Microwave shielding, Multiple interface

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Predicting curing-induced deformation of unidirectional CFRP using long short-term memory units

Yuncong FENG、Zhibin HAN、Weizhao ZHANG*
The Chinese University of Hong Kong

Curing-induced deformation of carbon fiber reinforced polymer (CFRP) is one of the most common defects in composites manufacturing. To simulate the curing process of CFRP, various numerical methods, such as finite element modeling, have been developed. However, as curing simulation is nonlinear and multiphysics modeling involving chemical kinetics and thermomechanics, existing numerical methods usually have high requirements on computational resources. Inherent nonlinearity of Long short-term memory (LSTM) units has the potential to model complex curing behaviors with high efficiency. Therefore, an LSTM network was developed to identify the relationship among curing parameters, sample dimensions and stacking sequence, and maximum post-curing deformation. To generate datasets for training and validation of the established LSTM network, a thermo-viscoelastic modeling method completed by the authors was employed to simulate the curing response of unidirectional (UD) CFRP bi-lamina samples under fix-free boundary conditions. After development, the LSTM network method was compared with other neural network approaches in the aspect of curing-induced deformation prediction, and the results demonstrated the superior performance of the LSTM network in terms of computational speed and accuracy. Afterward, a case study to optimize curing parameters, stacking sequence, and dimensions of samples for minimal residual deformation was carried out using both the LSTM network and finite element analysis (FEA) based on the thermo-viscoelastic modeling method. It is illustrated that the LSTM algorithm leads to significantly higher computational efficiency with acceptable deviation compared to those of FEA.

Key words LSTM, Curing behavior

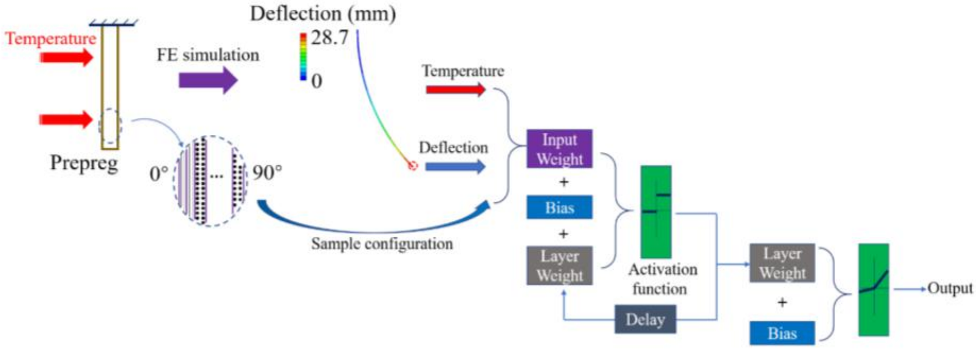

Fig. 1. Flowchart of LSTM network to predict curing-induced deformation of UD CFRP.

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

High Stiffness and Strength Polymer Nanocomposite with Hydroplastic Processability

Yunxiao Liu、Jianming Zhang*
Qingdao University of Science and Techology

Plastics have become increasingly indispensable in modern life due to the combination of characteristics, such as light weight, low cost and adaptability. The vast majority of their molding requires thermoplastic processing. This method usually involves harsh conditions, such as high temperature, or oxygen exclusion surroundings. Recently, Wang et al. synthesized a hydroplastic polymer cellulose cinnamate and achieved the facile hydrosetting method for shape-changing or shape-fixing at ambient temperature. However, this material can only change its geometry by bending and folding. Therefore, to be precise, this concept is hydroplastic deformation rather than processing.

Herein, we synthesis a sustainable plastic with high stiffness and strength as well as hydroplastic processability. This composite consisting of cellulose nanocrystals and polymers grafted on its surface, with Young's modulus up to 3.02 GPa and tensile strength 63.39 MPa, superior or comparable to most common plastics. In particular, water is the key factor affecting the processability, the as-prepared nanocomposites with a water content of 10 wt% can be processed by molding, extrusion, etc. at a lower temperature (<80 °C). This work provides an innovative method to fabricate strong mechanical performance nanocomposite with convenient processibility.

Key words Nanocomposite; Hydroplastic processing; Cellulose nanocrystal

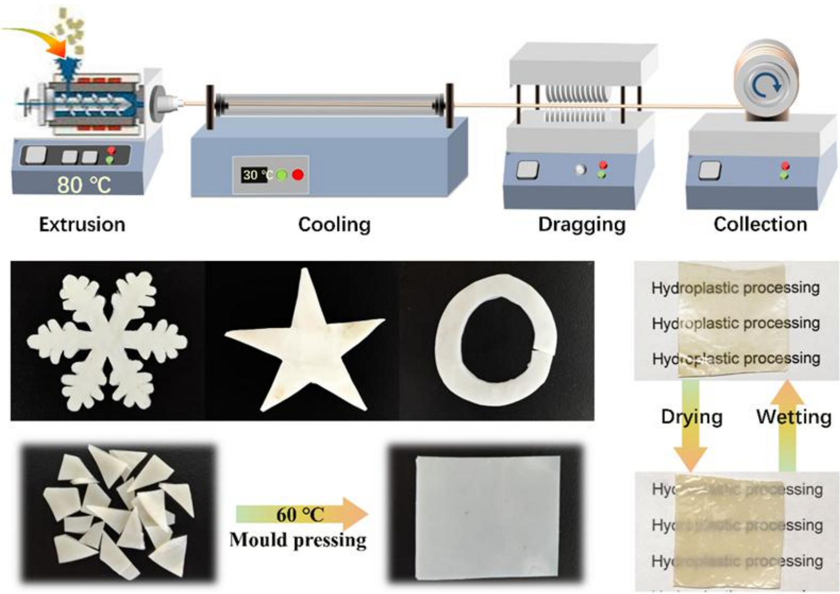

Fig. 1. Hydroplastic processing and sample display.

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

In-plane compression test and theoretical prediction of honeycomb cores and sandwiches with strip-type structure

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2. Dalian University of Technology

The mechanical properties of carbon-fiber aluminum-grid-core sandwich structures was limited by the difference of stiffness of interface and stress concentration at the interface between high-stiffness carbon-fiber sheet and low-stiffness aluminum grid. In this study, the honeycomb material is designed by flattening the hexagonal unit cells, which change the load-transfer path of the sandwich structure. The engineering elastic constants of the processed strip-type honeycomb core are derived, and the strip-type honeycomb cores are made into carbon fiber sandwiches. The in-plane compression tests of plain honeycomb sandwich and strip-type honeycomb sandwich are carried out. The experimental results showed that the average peak load and the average specific peak load for sandwich structures with strip-type honeycomb cores was 31.52% and 15.72% higher than the plain honeycomb core. The strip-type honeycomb core sandwich structure can mitigate the interface mismatch, as the bonding area between thesheet and the core is increased due to the dense strip structure of the strip-type honeycomb.

Key words Carbon fibers, Strip-type honeycomb, Sandwich structures

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Study on resin flowing behavior and impregnation of out-of- autoclave prepreg

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Out-of-autoclave (OOA) prepreg process technology was an effective way to achieve lower-cost manufacturing and processing of structural composites and favored by aerospace and industrial applications. The OOA prepreg resin system was designed by using intrinsic flexible epoxy resin (IFEP) and liquefied dicyandiamide (L-DICY). Resin system for rheology and rheological equation, and the time-temperature-transition-viscosity (TTT-η) graph of resin were established, the preparation conditions and forming conditions of OOA prepreg were determined. The resin system infiltration model was established by determining the parameters such as fiber volume fraction, fiber radius, fabric permeability, viscosity and boundary conditions. The porosity of the resin was investigated by studying the wetting behavior of the resin on the fiber during the warming and constant temperature curing of the OOA prepreg, showing that the experimental values were in good agreement with the model values. Compared to the hot press composites, the interlaminar shear strength (ILSS) and flexural strength (FL) retention rate of OOA composites were more than 80%, and the microscopic observations also supported the evidence of improved mechanical performance of OOA composites.

Key words Out-of-autoclave prepreg, carbon fiber, curing kinetics, rheology, impregnation

Session: Polymer Matrix Composites

Presenting Type：Oral–Onsite

Synergistic Effects of 3D-Woven Copper Wires with Graphene Foam on Enhanced Thermal Conductivity of Carbon Fiber Reinforced Composites

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Enhancing thermal conductivity of carbon fiber reinforced composites (CFRP) without deteriorating mechanical properties is still challenging for fabrication of multi-functional composites. In this work, novel 3D-laminated composites were prepared by weaving copper wires manually into carbon fiber fabrics, laminating graphene foams on surfaces, and infiltrating with epoxy resin. Synergistic effects of the 3D copper wires and graphene foams on thermal conductivity of composites were investigated in detail. The results indicated that the presence of continuous copper wires and graphene foams can form numerous conduction pathways for rapid heat and electron transport, greatly improving the thermal and electrical conductivity of composites. The out-of-plane electrical conductivity and thermal conductivity of the 3D-laminated composite increased to 25.8 S/m and 1.097 W/m·K, respectively. Related finite element analysis also confirms the synergistic effects. By virtues of the enhanced conductivity, the 3D-laminated composites can be considered as promising candidates for high-performance composites with structural and functional integration.

Key words Carbon fiber, 3D copper wire, Graphene foam, Thermal conductivity, Finite element analysis

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Tuning of microstructure and strain sensing performance of flexible conductive polymer composites

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Zhengzhou University

Strain sensor by flexible conductive polymer composites (CPCs) has shown great potential in artificial intelligence (AI), aerospace, healthcare and other fields. In our work, in order to improve the strain sensing performance of flexible CPCs, stretchable and fibrous thermoplastic polyurethane (TPU) mats are prepared by electrospinning. Conductive nanofillers, such as carbon nanotubes (CNTs), silver nanowires, reduced graphene oxide (rGO), etc., are decorated on the surface of the fibrous mat to pre-construct conductive pathways for building a series of high performance strain sensors. By fabricating electrospun fibrous networks with a designed aligned wavy-like structure, the strain sensing detection range of a CNTs/TPU fibrous composite mat has been enlarged to 900%, which is one of the highest strain detection ranges in the available reports to our knowledge. For improving the detection limit, we use pre-stretching method to construct microcrack structure on the surface of conductive fibrous composite mat and some flexible polymer fibers. Based on the crack propagation mechanism, the sensitivity (gauge factor, GF~3.9×10^7) and detection limit (0.001% strain) of CPCs have been greatly improved. The systems also show good sensing stability. Flexible porous conductive polymer composites are also prepared with pre-designed porous structure and conductive networks. Based on the aligned porous structure, the pressure sensing range of an aligned TPU foam is improved to 77%. By using a template method, this value of a carbon black/ polydimethylsiloxane (CB/PDMS) CPC is further enlarged to 91%, which is one of the highest pressure sensing ranges in the available literatures; the sensing stabilities are also improved. A novel porous fiber-shaped CNTs/TPU strain sensor is fabricated by using a dry-wet spinning method, and the tensile and pressure sensing capability are achieved and improved synchronously. Our studies provide new strategy for preparing high performance conductive polymer composites based strain sensors, which exhibit great potential in aerospace and healthcare fields.

Key words Conductive polymer composite, Electrically conductive properties, Strain sensor, Network, Sensing performance

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Enhancement of strength and toughness of bio-nanocomposites with good transparency and heat resistance by reactive processing

Yongjin Li*、Hengti Wang
Hangzhou Normal University

Growing concerns in addressing environmental challenges are driving the rapid advancement of both bio-based and environmental friendly materials. Biodegradable polymers have been compounded with various nanofillers to fulfill the multiple requirements in real applications. However, current technologies remain to be improved in terms of the intrinsic inferior performance and the lack of interfacial interactions. In this work, we employed a facile route to develop bio-nanocomposites integrating multiple functionalities by reactive processing of polylactide and reactive boehmite nanorods. The grafting of polymer chains onto the surface of the nanorods encourages fully homogeneous dispersion of nanofillers with even 30 wt% loadings. Such nanocomposites exhibit simultaneously enhanced tensile strength, modulus, ductility, and impact strength. Moreover, the bio-based nanocomposites present promising features such as high transparency, improved flame resistance, and heat resistance. This work demonstrates exciting opportunities to produce bio-plastics with diverse functionalities in versatile applications of sustainable packaging industry and engineering plastics.

Key words polymer nanocomposites, PLLA; properties; nanofillers

Session: Polymer Matrix Composites

Presenting Type: Oral–Onsite

MICRO-COMPUTED TOMOGRAPHY CHARACTERISATION OF LOW-VELOCITY IMPACT DAMAGE IN SANDWICH PANEL WITH UHMWPE FACINGS

Bin Yang、Qi Zhou、Kunkun Fu*、Yan Li、Bin Yang
Tongji University

This paper aims to investigate the low-velocity impact (LVI) responses of sandwich composites experimentally under three different impact energies (50 J, 80 J and 110 J). Polyethylene terephthalate (PET) and Polyvinyl chloride (PVC) foam cores were used as core materials, and adhesively bonded with two ultra-high molecular weight polyethylene (UHMWPE) fibres face sheets. The micro-computerized tomography (Micro-CT) was used as an inspection technique to compare and characterize internal failure status of sandwich composites, and the effect of areal densities of UHMWPE fibre fabrics and foam core materials on the impact response and failure pattern were addressed. The results show that the sandwich composite with PET foam core exhibits better impact strength and energy dissipation behaviour than that with PVC foam core.

Key words Low-velocity impact (LVI), UHMWPE fibre, Sandwich panel, Micro-CT, Failure pattern.

Session: Polymer Matrix Composites

Presenting Type：Oral-Onsite

Flexible Phase Change Materials for Overheating Protection of Electronics

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qingdao university of technology

With the increase of power density of electronics, adequate overheating protection of electronics is quite urgent, especially for wearable electronics integrated with biological tissues. It has been reported that advanced phase change materials （PCMs） can be used as the advanced overheating protection substrate on wearable devices to dissipate excessive heat and suppress skin temperature rise. Herein, flexible composite PCMs are rationally designed to drastically suppress the brittle problem of PCMs by using a novel static polymer swelling strategy, the method is more facile and versatile than reported polymer swelling strategy. The resultant flexible PCMs exhibited a stable latent heat of 136.5 J/g, pronounced shape stability even with a temperature resistance of 120 °C, and excellent mechanical properties (elongation at break~24%). The demonstration of wearable electronics with our fabricated flexible PCMs as the overheating protection substrate illustrated the flexible PCMs could effectively dissipate the excessive heat and suppress the temperature rise of the skin by storing the excessive heat of wearable electronics in the form of latent heat. Furthermore, the temperature rise of skin can be reduced to 31% compared with conventional overheating protection materials.

Key words thermal conductivity; phase change material

Session: Polymer Matrix Composites

Presenting Type: Oral-Onsite

Fabrication and compressive property enhancement of all-CFRTP composite honeycomb based on ultrasonic multi-spot welding method

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2. School of Materials Science and Engineering, Nanjing Institute of Technology

The ultrasonic multi-spot welding method was proposed to make an all carbon fiber reinforced PEEK thermoplastic(CFRTP) composite honeycomb core. Using this approach, a novel MWCNTs/PEEK energy director(ED) was molded on the surface of corrugated CF/PEEK laminates with a hot platen press to enhance the adhesive performance between honeycomb cell walls. The tensile-shear property, microstructure and fracture characteristics of the joints were analyzed. The effects of MWCNT content and ED distribution on the welding strength and interfacial stiffness were investigated . In addition, the out-of-plane compressive properties of honeycomb were measured and evaluated. The experimental results show that using the new ED could achieve better welding strength. However, ED tip effect and welding power were significantly susceptible to MWCNT content. In particular, excessive MWCNTs caused resin overflow and indirectly worsened welding quality. Compression process of the composite honeycomb consisted of elastic stage, debonding stage and failure stage. ED configuration optimization and interfacial performance enhancement were conducive to increase the out-of-plane compressive stiffness and strength of the honeycomb. Compared to the commercially available honeycomb, the CF/PEEK honeycomb fabricated in this study showed advantages in retrievability, lightweight high-performance and manufacturing efficiency. The ultrasonic welding method also provides new opportunities for manufacturing all-thermoplastic composite honeycomb as well as sandwich structures.

Key words Thermoplastic composite honeycomb; Ultrasonic multi-spot welding; Compressive property; Failure mechanism

Session: Polymer Matrix Composites

Presenting Type: Oral-Virtual Platform

Gradient-structured composite films of BT ceramics with different particle sizes for enhanced energy storage density

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Shaanxi University of Science and Technology

With the rapid development of science and technology, non-renewable fossil energy is rapidly consumed, and the negative impact on the environment is also increasing. Therefore, the development of new energy storage materials with superior performance and environmental friendliness is the key to solving energy problems. In recent years, polymer-based composite film materials with high energy storage density have become a research hotspot. However, the excellent energy storage density is jointly determined by the dielectric constant and the breakdown strength. Therefore, a four-layer gradient structure polyvinylidene fluoride (PVDF)-based composite film was fabricated by a solution casting method. The first three layers are barium titanate (BT)/PVDF composite layers, in which the particle sizes of the BT ceramic filler are 500 nm, 200 nm and 100 nm from top to bottom. The last layer is a pristine PVDF layer. This newly designed four-layer gradient structure composite film tactfully combines the merits of the high breakdown strength of the pristine PVDF polymer and the high dielectric constant of the BT ceramic filler. By designing a gradient structure to form a gradient electric field, the electric tree growth is hindered layer by layer during the breakdown process. Therefore, while introducing a large number of high-dielectric constant ceramic fillers to increase the dielectric constant, the breakdown field strength can be greatly increased to significantly increase the energy storage density. Eventually, a superior energy storage density of 19.91 J/cm3 is gained at 520 MV/m with the composite layer involving 7 vol% BT ceramic filler. Ultimately, this work proposes a valid strategy to develop energy storage composites with tremendous application prospects.

Key words PVDF, composite films, breakdown strength,energy storage

Session: Polymer Matrix Composites

Presenting Type: Oral–Virtual Platform

Design and construction of stretchable ionic conductive polymer composites

Chao Zhang*
Donghua University

Flexible pressure sensors are a class of electronic devices that can convert external mechanical stimuli into easily information-processed electrical signals. As a vital component of wearable electronic devices, they have broad application prospects in health monitoring, human-computer interaction, artificial intelligence and other fields. Stretchable conductors are the key to promoting the development of flexible pressure sensing, among which stretchable ionic conductors can achieve extremely difficult or even impossible functions of electronic conductors, such as high ductility, high transparency and biocompatibility. Aiming at the problems of insufficient mechanical properties, relatively weak conductivity and poor dynamic reversibility in the stretchable ionic conductive materials, we propose a graded response strategy to construct highly stretchable ionic conductive composite materials. There are two types of crosslinked networks in the composite system, including a room-temperature stable network and a highly reversible network. The stable crosslinking structure could endow the composites high mechanical strength and excellent resilience. The highly reversible network like high-density reversible bonds could make the composites have highly dynamic reversibility at room temperature, and its rapid fracture reconstruction during the deformation could significantly improve the mechanical toughness of the composites.

Key words Ionic conductive composites, High stretchability, Graded responsive network; Flexible pressure sensors

Session: Polymer Matrix Composites

Presenting Type: Oral-Virtual Platform

Rational assembly of liquid/solid composites for stretchable conductors

Zhenyu Wang*
Jiangnan University

Polymer-based composites with excellent stretchability and conductivity have gained significant research interests due to the imperative demands in next generation portable and soft robotics. However, it is still challenging to retain the original properties of the composites under large and complicated external loadings. In this report, two strategies are developed to rationally assemble liquid conductor and flexible elastomers based on 3D printing techniques. 3D core-shell lattice structure and solid-liquid bridged lattice structure are designed and successfully manufactured by coaxial and dual-material direct ink writing techniques, respectively. Both composites possess 3D interconnected and deformable liquid conductive network, which is supported by stretchable polydimethylsiloxane (PDMS) with robust and highly ordered architecture. The resultant liquid/solid composites deliver high electrical conductivity of over 7×103 S/m, excellent stretchability of ~180%, and excellent electromagnetic interference (EMI) shielding effectiveness of over 50 dB in X-band frequency range. Unlike those composites with dispersed solid fillers, the liquid conductor/elastomer composites exhibit negligible electromechanical coupling at tensile strain up to 100%, together with strain-invariant EMI shielding properties. The applications of the composites in flexible display circuits, microwave shielding layer, and EMI shields in wireless power transmission systems are demonstrated. The above findings suggest an effective strategy for fabricating liquid/solid composites with precisely controlled and unprecedented multifunctionality.

Key words 3D printing, direct ink writing, conductive polymer composites, lattice structures

Session: Polymer Matrix Composites

Presenting Type: Oral-Virtual Platform

Properties of poly(butylene adipate-co-terephthalate)/thermoplastic starch filled with treated and untreated sugarcane bagasse fiber

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2. Fakulti Teknologi Kejuruteraan Kimia, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia

Sugarcane bagasse which compose of fibrous rind and spongy pith components are often used as a reinforcement material in concrete and plastic container. For plastic film with thin thickness, sugarcane bagasse is commonly used in the form of small grinded particles in the composite film. Incorporation of this agricultural waste in the biodegradable plastic film may reduce in cost of production and facilitate the biodegradation of the film. This present work demonstrates the formulation of poly(butylene adipate-co-terephthalate) (PBAT)/thermoplastic starch (TPS) (90/10) with different sugarcane bagasse fiber loadings. The effect of alkaline and silane surface treatments on tensile strength, thermal and water barrier properties were discussed. With addition of sugarcane bagasse (5, 10, 15, and 20%), the tensile strength and elongation at break had reduced from 23.47 to 8.41 MPa, and 1135 to 55.83%., respectively. The Young's modulus also had increased from 47.12 to 188.50 MPa after addition of 20% sugarcane bagasse in PBAT/TPS matrix. There are slight improvement in tensile properties, thermal and water barrier properties was observed after the bagasse fiber had been treated with alkali and silane. SEM morphology also shows silane treated sugarcane bagasse exhibited higher surface roughness due to lignin and hemicellulose removal after the treatment. This facilitate the adhesion between the fibers and the PBAT/TPS matrix.

Key words Polymer composites, PBAT, tapioca starch, polymer blend

Session: Polymer Matrix Composites

Presenting Type: Oral-Virtual Platform

Co-assembly of nanoparticles and Semicrystalline Polymers

Christopher Li*、Christopher Li
Drexel University

Nanoparticles can be assembled into complex structures and architectures using a variety of methods for composite applications. In this work, we show that nanocomposites can be prepared by controlling the co-crystallization of nanoparticles and semicrystalline polymer chains. A library of functional nanocomposites with control nanoparticle location and orientation has been fabricated. A few cases will be discussed in this presentation. End-functionalized polymers can crystallize into 2D nanosheet PSCs, which are used to conjugate with complementary nanoparticles, leading to a nanosandwich structure. These nanosandwiches can find interesting applications for catalysis, surface-enhanced Raman spectroscopy, and nanomotors. Confined in-situ synthesis of nanoparticles in confined polymer nanostructures has also been used to synthesize biomimetic composites. Moreover, competition between nanoparticle assembly and polymer crystallization leads to unique crystalline morphologies with broken translational symmetry.

Key words crystallization, nanoparticles, semicrystalline polymers, nanocomposites

Session: Polymer Matrix Composites

Presenting Type: Oral-Virtual Platform

New materials for realizing mass production of thermoplastic composites via reactive molding

Dong Gi SEONG*、Jae Hyo LEE、Jung Jae YOO、Seung Mo SON
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Carbon fiber reinforced composite is one of the promising lightweight material with superior mechanical properties for the applications to various industries which often require the fast production system of composite parts with low costs. Liquid composite molding has been regarded as an efficient process for mass production of fiber reinforced composite parts, because it makes it possible to fabricate three dimensional structural parts by directly impregnating thermoset or thermoplastic resin into the dry fiber preform. Thermoplastic polymer based composites have been developed as a lightweight structural material due to the advantages over the thermoset based ones in recyclability, weldability, cost effectiveness as well as good mechanical properties including impact resistance. Reactive resin transfer molding using ε-caprolactam monomer, as a promising process for mass-production of carbon fiber reinforced polyamide 6 composites, has some difficulties in processability to be successfully applied to industries. In this study, several new functional materials introduced into the ε-caprolactam monomer are addressed to improve the critical problems in the thermoplastic resin transfer molding such as moisture induced termination of polymerization during the process, and property degradation by moisture absorption of the final composite, and so on. Porous particles with water absorption function are added into the monomer to prevent termination of polymerization during the reactive resin transfer molding process. Copolymer is introduced to improve mechanical properties of the thermoplastic composite at humid conditions by reducing the hydrophilicity of the polyamide 6. Some additional functional materials are presented to improve the processability as well as performance of the thermoplastic composites in this talk. It is expected to help the thermoplastic resin transfer molding process being successfully launched for mass production in various industries.

Key words Thermoplastic composite, reactive resin transfer molding, polyamide 6

Session: Polymer Matrix Composites

Presenting Type: Oral−Virtual Platform

Adjustment of Interfacial Interaction Force by Water Absorption and dehydration of Short Glass Fiber-Reinforced Polyamide

Quan JIANG、Tetsuo TAKAYAMA*、Akihiro NISHIOKA
Yamagata University

Short glass fiber-reinforced Polyamide (SGF-RPA) have excellent rigidity, mechanical strength, high dimensional stability and high melting point that can be used in high temperature environments and for long-term static high load applications. However, the water absorption characteristics of the material have a great influence on the mechanical properties of SGF-RPA, especially the interfacial interaction force, which is one of the factors that determine the mechanical strength. In recent years, studies on the water content and the mechanical strength of SGF-RPA have been reported, but the effects of water absorption and dehydration of articles on the interfacial interaction force have not been clarified. In this study, the interfacial interaction forces of different fiber content SGF-RPA (20, 25 and 30 wt%) in water absorption and dehydration were evaluated by interfacial strength (IFS) and interfacial shear strength (IFSS). The injection-molded products were immersed in 16°C water 48 hours for water absorption, and 80°C vacuum drying 48 hours after water absorption for water dehydration. Results shows that IFS, IFSS and interfacial interaction forces were decreased with water absorption and increased with water absorption dehydration obviously. Based on those results, Water absorption and dehydration of injection-molded products is an effective way to adjust the interfacial interaction force.

Key words Interfacial Interaction Force, Short fiber-reinforced polyamide, Injection molding, Welding strength, Short beam method

Session: Polymer Matrix Composites

Presenting Type: Poster

Investigation of temperature effect on interlaminar shear properties of carbon fiber reinforced polymer composites

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2. Nayang Technological University Singapore

Carbon fiber reinforced polymer (CFRP) composites are increasingly used in the aerospace industry, where the materials are exposed to the space temperature, especially the low Earth orbit environment. To better design CFRP structures for these extreme applications, it is necessary to understand the effect of low and high temperatures on properties of composite materials. In this study, short beam shear tests on the three different lay-ups of CFRP composites were conducted at different temperatures ranged from -183 °C to 80 °C. Here carbon fiber/epoxy-T700/SYE20005 composite laminates with the unidirectional ([0]16) and cross-ply ([0/90]4S and [45/-45]4S) manners were adopted. Results revealed that for unidirectional CFRP composites, the value of apparent interlaminar shear strength increased by 67% at -183 °C, and while had a 27% decrease at 80 °C compared to that at room temperature. It indicates that the low temperature has a positive effect on the interlaminar shear strength, but the high temperature plays a deteriorating role in the interlaminar shear strength of such composites. Meanwhile, the variations of interlaminar shear strength of cross-ply laminates at different low temperatures are not significant. The failure mechanisms such as delamination, intralaminar crack and delamination migration would be discussed based on the microscale observations through SEM images. The experimental findings of interlaminar shear properties could provide a preliminary assessment for the applications of CFRP composites in cryogenic environment.

Key words CFRP composites, cryogenic temperature, interlaminar shear strength, lay-ups, failure mode

Session: Polymer Matrix Composites

Presenting Type: Poster

The effect of reactive diluent on the properties of J-315 adhesive and the efficiency of glue injection repair

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Bismaleimide resin matrix composites are widely used in aerospace equipment due to their good temperature resistance and excellent mechanical properties. However, their properties are badly affected by the inevitable in-service damage, especially delamination. How to repair composites with delamination is a severe issue that demands to be tackled. Glue injection repair is one of the ideal repair methods for delamination damage of composite materials. Nevertheless, it is extremely difficult to put injection repair into practical application because of the high requirements on the viscosity of adhesive. Therefore, diluents are commonly used to reduce the viscosity of adhesive in resin injection repair. In this paper, J-315, an epoxy adhesive, was used to repair the delamination damage of bismaleimide resin matrix composites. Two active diluents, n-butyl glycidyl ether (BGE) and butanediol diglycidyl ether (BDGE), were selected to reduce the viscosity of J-315 adhesive, and the effect of diluents on the properties of J-315 as well as the repair efficiency were studied. The experimental results demonstrate that the addition of both diluents could effectively increase the thermal decomposition temperature and the initial curing temperature of J-315, which was beneficial to its storage at room temperature and its use at high temperature. The viscosity of J-315 adhesive significantly decreased by adding diluents. As a result, the process window (viscosity below 400mPa·s) time at 80°C was above 15 min. The bonding strength of J-315 with 30% BDGE content was 17% higher than that of the pristine one. Finally, J-315 adhesive modified with diluents was used to repair the delamination damage of bismaleimide resin matrix composite laminates, and the residual compressive strength of the laminates was restored to as high as 81% of the original intact samples.

Key words injection repair; active diluent; bismaleimide resin matrix composites; composite laminate; delamination; J-315 adhesive

Session: Polymer Matrix Composites

Presenting Type: Poster

Preparation and Properties of Copper Slag Modified Epoxy Cement Mortar

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Under the action of external loads or harsh service environments, the interior and surface of concrete materials are prone to defects and damages such as peeling, cracks, holes, etc, which lead to a serious shortening of the actual life of concrete.Therefore, the repair and reinforcement of concrete structures using repair materials will become one of the important research directions in the concrete industry.According to different application scenarios, different repair mortars are studied. Based on this, it is proposed to use epoxy resin as a reinforcing material for concrete repair, and by incorporating copper slag, the strength of the repair mortar can be enhanced, and the cost of the repair mortar can be reduced at the same time.

For the repair of concrete surface damage, we choose to use water-based epoxy resin to modify ordinary cement mortar. The incorporation of water-based epoxy resin will cause the mechanical strength of the mortar to decrease, but the fluidity, adhesion and durability of the mortar are improved.At the same time, the addition of copper slag will increase the density of the mortar, enhance the fluidity and reduce the cost.

For concrete structures that need to withstand large external loads or have a harsh service environment, E-51 epoxy resin is used to prepare epoxy mortar for repair. This kind of mortar uses epoxy resin as the Cementitious material, copper slag, cement and sand as the filler, and it has fast curing speed, high strength, good chemical stability, strong toughness and good bonding performance.

Through the research of this paper, it is expected to develop different repair materials for different concrete repair scenarios. By using copper slag to improve material performance, reduce costs, and achieve the purpose of solid waste utilization and resource recycling.

Key words Epoxy、Copper slag、Repair mortar

Session: Polymer Matrix Composites

Presenting Type: Poster

Bio-inspired strip-shaped composite with waste selvedge A. pernyi silk and glass fiber for lightweight and impact-critical application

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It is an advanced strategy to acquire bio-inspired composites with improved impact resistance by imitating the organic-inorganic structure in organisms. However, there are some problems limite its application, such as the expensive raw materials and complicated processing. In this work, a bio-inspired organic-inorganic composites were sucessfully manufactured with the waste selvedge A. pernyi silk facric and glass fabric by using simple hot-pressing process. A series of smaples with different hybridized structure were examined under quasi-static and dynamic loads. The sample with A. pernyi silk inside and glass fabric outside exhibited the highest impact strength ~224 kJ m −2, which is three times higher than glass fiber reinforced composite (67 kJ m− 2) and 245% higher than A. pernyi silk reinforced composite(90 kJ m− 2). A large number ofmultiple cracks could be observed from the fracture morphologies after impact testing, which could not be found after the quasi-static testing. Also, the density of the composite could reach ~1.5 g cm-3, which is much lower than that of glass fiber reinforced composite(1.92 gcm-3). Based on the strip shape of waste selvedge A. pernyi silk, such bio-inspired composites were expected to be applied as automobile bumpers with light-weight and high impact resistant.

Key words A. pernyi silk, bio-inspired composite, impact resistance.

Session: Polymer Matrix Composites

Presenting Type: Poster

Design, preparation and mechanical properties of composite conical shell with corrugated core

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Harbin Institute of Techonlogy

Composite sandwich structures with a corrugated core is employed extensively across a variety of industries as a result of its excellent bearing capacity and robust designability. In this study, the design, preparation, and mechanical mechanism of composite conical shell with corrugated core are studied. Firstly, the structure design of the conical shell with corrugated core is carried out, and an advanced forming method for the conical shell with corrugated core is proposed. According to this simple and easy-operating method, the composite conical shell with corrugated sandwich was successfully fabricated, and the typical failure modes of local buckling and face collapse of the conical shell with corrugated core were obtained through experiments. Advanced digital image correlation (DIC) method device was used to capture full-field displacement during the test. The theoretical models of typical failure load of conical shells with corrugated cores are derived. The theoretical and experimental results are in good agreement with the experimental results. it is anticipated that this work will serve as a guideline for the lightweight design and application of conical shells with corrugated core in the aerospace engineering.

Key words Corrugated core; Sandwich cone; Mechanical properties

Session: Polymer Matrix Composites

Presenting Type: Poster

Synergistically enhanced wave-transparent and interfacial properties by constructing self-assembly COF on PBO fiber

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PBO fiber composites with high specific strength & modulus, and ultra-low ε and tanδ are widely applied in the wave-transparent fields of missiles and microwave towers. However, PBO fibers present smooth surface and strong chemical inertness, resulting in poor interfacial compatibility and interfacial polarization, which severely limits their application in the new generation of wave-transparent composites. Usually, covalent surface functionalization including chemical etching and acid etching damage the surface and property of PBO fibers, thus non-covalent surface modification of PBO fibers such as carbon nanomaterials and aromatic ring molecules based π-π stacking has aroused wide attention. In this work, naphthalimide covalent organic framework with abundant π-conjugate and pores structure was synthesized by 1,4,5,8-Naphthalenetetracarboxylic dianhydride (NTCDA) and Tris(4-aminophenyl) amine (TAPA) and in suit self-assemblied on the PBO fibers surface through π-π stacking to obtain COF@PBO fibers. In comparison with pristine PBO fibers, an evidently rough surface with a dense inner COF layer and numerous nanocrystals were attached onto the outer surface of COF@PBO fibers. The TFBT and IFSS of COF@PBO fiber composites were 20.58 and 26.88 MPa, which were increased by 42.9% and 33.9% compared with those of pristine PBO fiber composites (14.40 and 20.08 MPa). The improved interfacial property was ascribed to the increase of the fiber surface roughness and specific surface area. Meanwhile, the complex permittivity (ε,r and ε,,r) and tanδ of COF@PBO fiber composites (2.54, 0.024, 0.009) were lower than those of pristine PBO fiber composites (2.85, 0.041, 0.014) at 16 GHz, attributing to the interfacial polarization reduction via improved interfacial compatibility. Moreover, the special pore structure of COF decreased the density of composites material, which resulted in the decline of polarized molecule per-unit volume. Therefore, the COF modified through non-covalent method on fiber surface provides a novel guidance for fabricating function and structure integrated wave-transparent composites.

Key words Self-assembly COF PBO fiber Interphase Wave-transparent

Session: Polymer Matrix Composites

Presenting Type: Poster

Enhanced interfacial adhesion and anti-hydrothermal aging properties of high-modulus carbon fiber composites by POSS/cyanate ester matrix

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High-modulus carbon fiber/cyanate ester (HMCF/CE) composites were currently used in components for satellite and space telescope fields due to the high rigidity and superior stability of dimension. However, the resin matrix tended to be plasticized and swelled at hydrothermal aging environment, and further contamination of surface and delamination of composites were caused. The stiffened and toughened POSS/cyanate ester (PCE) matrix was designed by introducing epoxy-functionalized polyhedral oligomeric silsesquioxane (POSS), and the effects on interfacial strength and anti-hydrothermal aging properties relative to cyanate ester (CE) matrix were investigated. The fracture toughness and tensile modulus of PCE matrix were improved 42.3% and 13.9%, respectively, which were verified by the increased cross-link density and reduced free volume of PCE matrix. In contrast to HMCF/CE composites, IFSS of HMCF/PCE composites were improved 26.6%, which was due to the modulus intermediate layer with a platform generated from modulus gap shrinkage and interphase extension between HMCF and PCE. Additionally, the saturated moisture uptake M_∞ (1.50%) and diffusion coefficient D (2.5×10-3 mm2/h) of PCE matrix were less than M_∞ (2.01%) and D (3.2×10-3 mm2/h) of CE matrix. Therefore, the hygroscopicity was reduced from HMCF/CE (2.31%) to HMCF/PCE (2.01%) composites and ILSS retention was enhanced from HMCF/CE (70.0%) to HMCF/PCE (74.1%) composites after immersed in distilled water at 95 °C for 30 days, which was ascribed to the combination of low moisture uptake matrix and ameliorated interfacial adhesion effectively, being consistent with the variation of fracture morphologies during aging progress. The anti-hydrothermal aging mechanism was proposed as that hydrophobic Si-O-Si cage structure and slow spread of water molecules in stiffened and toughened PCE matrix.

Key words Carbon fibers, Cyanate ester, Interfacial property, Modulus intermediate layer, Hydrothermal aging

Session: Polymer Matrix Composites

Presenting Type: Poster

Synergistically toughened epoxy resin based on Modified-POSS triggered interpenetrating network reinforcement

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The toughening of epoxy resin has always been one of the key topics in the researches about high-performance matrix used for advanced composites, and yet single-property enhancement is usually accompanied by some unexpected compromises of other properties. This work constructed a novel in-situ interpenetrating network structure composed of epoxy resin and vinyl ester resin, along with modified octavinyl polyhedral oligomeric silsesquioxanes (OVPOSS) as the toughening core. In the present resin system, the vinyl ester resin component was firstly introduced to form interpenetrating network structures without phase separation, for the improvement of overall strength and plastic deformation capacity. Moreover, the modified polyhedral oligomeric silsesquioxanes could realize nano-scale dispersion through the chemical reactions with resin matrix, which acted as the trigger of plastic shear deformation toughening under particle debonding and therefore absorbed a large amount of energy. With only 2wt% of the modified polyhedral oligomeric silsesquioxanes, the optimal increase in impact toughness reached 139.6%, in addition to the 17.92% improvement of tensile strength, 9.0% enhancement of Young's modulus and insignificant changes of the thermal decomposition temperature and glass transition temperature. In a word, the synthetic effect of the temporary physical entanglement of macromolecular chains, rigid effect and steric hindrance of modified polyhedral oligomeric silsesquioxanes contribute to the comprehensive enhancement of mechanical properties. The simple and economical scheme in this study not only realizes the toughening target at a high efficiency owing to the special structure of the toughening agents, but also makes it possible to prepare high-performance matrix for advanced composites with simultaneous enhanced strength and toughness.

Key words Epoxy resin; Polyhedral oligomeric silsesquioxane; In-situ interpenetrating network; Synergistic toughening; Non-phase-separated.

Session: Polymer Matrix Composites

Presenting Type: Poster

Flexible phase change hydrogels for mid-/low-temperature infrared stealth

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Infrared stealth technology has received widespread attention because of its important application potentials, such as defense industry and modern military. Phase change materials (PCMs) with thermal storage and management capabilities are capable of modulating temperature to hide infrared radiation, offering a plausible solution to the rational design of infrared stealth technologies. In this work, flexible phase change hydrogels with salient mechanical and thermophysical properties are prepared by compounding the hydrogel substrate with phase change microspheres. The resulting phase change hydrogel delivers a reduced thermal conductivity of 0.17 W/(mK) and an infrared transmittance of 0.3%, achieving an intriguing infrared stealth performance for the targets in the mid-/low-temperature range (-20-60 °C). The excellent flexibility and adaptability enable the phase change hydrogel to conform to arbitrary targets and to be facilely adhered to commercial fabrics for the development of wearable phase change devices, providing a constructive guidance to yield flexible PCMs for emerging infrared stealth applications.

Key words Flexible phase change materials; Phase change hydrogel; Infrared stealth; Wearable devices.

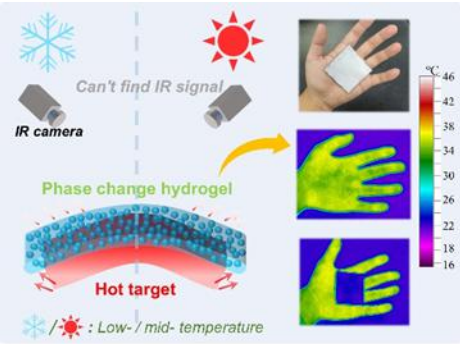

Fig. 1. Schematic diagram of the utilization of phase change hydrogels for mid-low temperature infrared stealth functions, and the combination with fabrics for human infrared stealth.

Session: Polymer Matrix Composites

Presenting Type: Poster

Balsa Wood-Based Photothermal Evaporator and Top-Down Evaporation Device for Seawater and Brine Desalination

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Solar-driven desalination of seawater has been considered as an effective method of attaining fresh water. However, accumulation of salt crystals often causes evaporators failure, and the evaporation rates of current salt-tolerant evaporators are generally low. Herein, a PVA and MXene coated balsa wood-based salt-resistant evaporator (EWPM) and a waterfall inspired Top-Down evaporation device are developed. By achieving multiple reflections of light through the special channel structure of wood and introducing MXene as a light absorber, based on the normalized spectral solar irradiance density, EWPM exhibits 97.9% light absorption. Utilizing the porous structure and inherent hydrophilicity of the wood and the ingenious design of the Top-Down evaporation device, coupled with the extraction of energy from the environment, the EWPM evaporator with 8 cm height achieves an evaporation rate of 4.3 kg m^{-2} h^{-1}. Furthermore, with the assistance of Top-Down evaporation device, the EWPM evaporator exhibits excellent long-term salt-rejecting performance with an average evaporation rate of 4.24 kg m^{-2} h^{-1} (100 h in 15 wt% NaCl solution). Moreover, the EWPM evaporators exhibits a metal ion rejection rate of over 99.9% for seawater, while the Top-Down evaporation device has proven to be applicable to other evaporator systems, demonstrating their potential for practical applications.

Key words Top-Down evaporation device; wood; MXene; desalination

Session: Polymer Matrix Composites

Presenting Type: Poster

Highly efficient thermal conductivity of polydimethylsiloxane composites via introducing "Line-Plane"-like hetero-structured fillers

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Polydimethylsiloxane (PDMS) is widely used as the matrix of thermal interface materials in electronics due to the excellent flexibility and processability, but intrinsically low thermal conductivity coefficient (λ) of PDMS matrix cannot meet the high thermal conduction requirements for electronics. In this paper, graphite oxide (GO) and modified multi-walled carbon nanotubes (*m*-MWCNTs) are utilized to fabricate "Line-Plane"-like hetero-structured thermally conductive GO@MWCNTs fillers by electrostatic self-assembly, which are then introduced into PDMS to fabricate thermally conductive GO@MWCNTs/PDMS composites. When the mass fraction of GO@MWCNTs is 20 wt%, the λ of GO@MWCNTs/PDMS composites reaches 2.10 W/(m·K), 950% higher than that of pure PDMS (0.20 W/(m·K)), which is also superior to the λ of MWCNTs/PDMS (0.68 W/(m·K)), GO/PDMS (1.59 W/(m·K)) and (GO/MWCNTs)/PDMS (1.28 W/(m·K)) composites with the same amount of single or hybrid thermally conductive fillers. Meantime, the GO@MWCNTs/PDMS composites also present good thermal conduction stability (average λ of 2.14 W/(m·K) after 15 heating-cooling cycles in the temperature from 21 to 100°C) and thermal stability (heat resistance index of 249.3°C).

Key words Polydimethylsiloxane, Thermally conductive composites, Hetero-structured thermally conductive fillers, Electrostatic self-assembly

Session: Polymer Matrix Composites

Presenting Type: Poster

Enhanced interfacial and hydrothermal properties of carbon fiber/cyanate ester composites with catalytic sizing agents

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A catalytic sizing agent of titanium epoxy resin was designed for enhanced interfacial, mechanical and hydrothermal properties of high modulus carbon fiber (HMCF)/cyanate ester composites, and the interface enhancement and low hygroscopic mechanism of HMCF composites were investigated. The crosslinking density and the content of functional groups of the interphase were tailored by the organic titanium in the epoxy resin sizing agents on HMCF surface, which determines the physicochemical properties and the wettability of the fiber surface. IFSS of HMCF composites with catalytic sizing agents are improved from 70.24 MPa to 95.52 MPa, which is attributed by the high crosslinked density interphase mainly consisting of triazine ring and oxazolidinone structure, stimulating the smooth transition of modulus. Further, the catalytic sizing agents changes the moisture diffusion path in the composites, resulting in the composites with a low water absorption of only 0.36% under hygro-thermal effect. This composites with high stiffness, high temperature resistance and low moisture absorption are expected to be applied to high-orbit space and aerospace structures.

Keywords Carbon fibers, Fiber/matrix bond, Surface treatments, Interfacial strength, Hygro-thermal effect

Session: Polymer Matrix Composites

Presenting Type: Poster

Synchronously improved wave-transparent performance and mechanical properties of cyanate ester resins via introducing fluorine-containing linear random copolymer

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Cyanate (CE) resins are recognized as the optimal candidate polymer matrix for radar radomes with the advantages of extremely low dielectric constant (ε, 2.8~3.2) and dielectric loss tangent (tanδ, 0.002~0.008). However, the toughness of cured CE resins is poor and their intrinsic wave-transparent performance needs to be further improved. Epoxy and fluorine-containing linear random copolymer of P(PFS-*co*-GMA) is synthesized from pentafluorostyrene (PFS) and glycidyl methacrylate (GMA) *via* RAFT polymerization, which is then performed to prepare modified bisphenol A dicyanate ester (*m*-BADCy) resin. The obtained *m*-BADCy resin with 15 wt% P(PFS-*co*-GMA) demonstrates excellent wave-transparent performance and mechanical properties. The obtained ε and tanδ values are 2.59 and 0.0053, respectively, lower than those of pure BADCy resin (2.97 and 0.0090), and the corresponding wave transmittance increases from 92.9% of pure BADCy resin to 94.5%. Meanwhile, the flexural and impact strength of *m*-BADCy resin increase to 122.4 MPa and 14.6 kJ/m^2, respectively, increased by 23.1% and 49.0% compared with those of pure BADCy resin (99.4 MPa and 9.8 kJ/m^2).

Key words Bisphenol A dicyanate ester; Epoxy and fluorine-containing linear random copolymer; Dielectric properties; Mechanical properties

Session: Polymer Matrix Composites

Presenting Type: Published only

A Multi-Point Perturbation Expansion Method for Generating Random Fiber Distributions for Composite

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In order to generate the representative volume element (RVE) of composite with the random distribution of fibers, a new method named multi-point perturbation expansion (MPE) algorithm is proposed based on the perturbation algorithm and the random sequential expansion (RSE) algorithm. The algorithm overcomes the jamming limitation when generating models with fiber volume fraction greater than 60%, and also ameliorate the issue of resin-rich zone which is easily caused by the RSE algorithm.A spatial fiber distribution considering different fibers' radius is established and four statistical characteristics are analyzed. The result shows that the method proposed in this paper can effectively generate a micro-model of fiber reinforced composite with random spatial distribution of fibers.

Key words Fiber Reinforced Composite, Random fiber distribution, Statistic Characterisation.

Hangzhou, PR China 25-28 April, 2023

Session: Polymer Matrix Composites

Presenting Type: Published only

Sound absorption properties of natural rubber-polysaccharide biomass composite aerogels

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With the continuous development and progress of modern society, noise pollution has become the third largest pollution after air pollution and water pollution. The use of sound-absorbing materials is the most widely used method to reduce noise hazards. However, most of the mainstream sound-absorbing materials such as open-cell polyurethane, urea-formaldehyde foam and other macromolecular materials that are widely used at present are derived from non-renewable petroleum fossil resources and are non-degradable materials. It also puts a lot of pressure on the environment. As the lightest material, aerogel has extremely high specific surface area, extremely low density and high porosity. Tailored surface composition and flexibly controllable aerogel shape and size make it a promising candidate in the sound absorption field. In addition, the material sources of aerogel are wide, and the natural biomass composite aerogel can reduce the production cost and the burden of the environment while achieving good sound absorption performance. Using biomass material natural latex as raw material to prepare biomass-based aerogel, after that, reinforcing materials such as sodium carboxymethyl cellulose, sodium alginate, and carboxymethyl chitosan are introduced to improve its structure and properties, and obtaining aerogels with complex pore structure are degradable, renewable and shows excellent sound absorption property、compressive and resilient properties. The introduction of other biomass reinforced materials with certain characteristics such as montmorillonite can give aerogel flame retardancy, heat resistance and other excellent characteristics on the basis of enhancing sound absorption performance. This provides new inspiration for the design of new environmentally friendly sound-absorbing materials.

Key words biomass；aerogel；sound absorbing material；natural rubber latex

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Session: Polymer Matrix Composites

Presenting Type: Published only

A novel approach based on stress-impedance effect to assess the interfacial properties in fiber-reinforced composites

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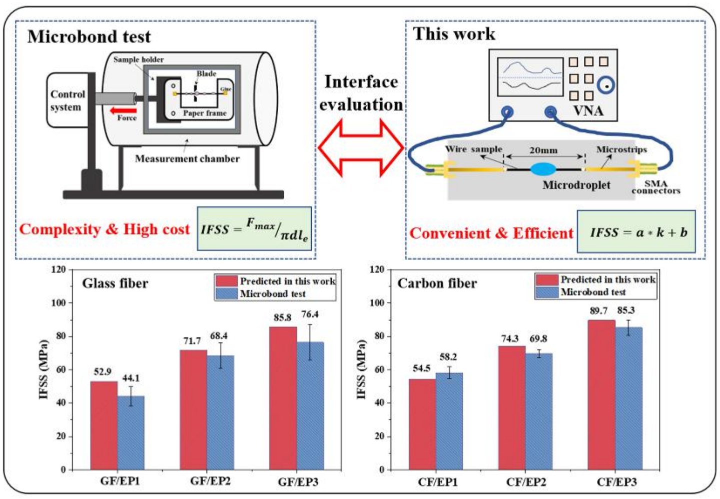
ABSTRACT: An effective assessing method for interfacial shear strength (IFSS) of fiber/epoxy composites based on stress-impedance effect of magnetic fiber (MF) has been proposed after experimental verification of engineering composites. The dependence of impedance of MF on interfacial stress and IFSS are investigated in succession. It is found that, with increasing resin embedding length on MF, the maximum interfacial stress increases while the impedance decreases due to the stress induced domain structure evolution. The correlation between impedance and IFSS has been successfully expressed by a prediction equation of IFSS, which is proposed herein for engineering fiber reinforced composite based on a stress coefficient from interfacial stress equivalent law. Indeed, applicability of the proposed approach is verified by the case studies of glass and carbon fiber reinforced composites in that the predicted IFSS show good agreement with the corresponding experimental values from widely used microbond test. Comparing with existing mechanical techniques, the proposed method proves to be convenient and efficient by shorter operation cycle, higher success rate and lower testing cost, which is instrumental to facilitate the advancement of high-performance fiber-reinforced polymer composites.

Keywords: Fiber-reinforced composites, Magnetic fiber, Impedance, Interfacial stress, Interfacial shear strength



Session: Polymer Matrix Composites

Presenting Type: Published only

Preparation and Performance Evaluation of Continuous Fiber-Reinforced Polypropylene Flame-Retardant Prepreg

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beihang

Thermoplastic resin matrix is difficult to impregnate with fibers because of the high melt viscosity. The addition of flame retardant will further increase the viscosity of the melt and increase the difficulty of impregnation. It is important to find a way to reduce the effect of flame retardant on melt viscosity. In this work, by adding high-flow polypropylene. the effect of flame retardant on the impregnation quality of prepreg was investigated. By adding high-flow polypropylene to improve the melt viscosity of flame-retardant modified polypropylene, continuous glass fiber reinforced polypropylene flame-retardant prepreg tape was successfully prepared. Intumescent flame retardant (IFR) was added at 20wt%, 25wt%, 30wt% of the polypropylene matrixes, which were prepared by melt impregnation. The composites were analyzed with thermogravimetric analysis, limiting oxygen index testing, UL-94 flame retardancy testing, cone calorimeter testing (CCT) and scanning electron microscopy. Tests involving the flame retardant showed that when the added amount of flame retardant reached 25%, the UL-94 flame retardancy grade reached V0. Compared with the CCT sample heating data, taking economic considerations into account, 25wt% IFR addition was the most suitable.

Key words polypropylene; continuous glass fiber; intumescent flame retardant; unidirectional prepreg; thermoplastic composites

Session: Polymer Matrix Composites

Presenting Type: Published only

Preparation and Properties of 3D Spongy Graphene Reinforced PDMS Composites with Vibration Isolation/Damping Function

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Polydimethylsiloxane (PDMS), as an elastomer, can rely on its viscoelasticity in the glass transition temperature domain to obtain good damping performance, but its damping performance at high temperatures is poor and cannot meet the damping requirements in certain complex temperature environments. In this study, a flexible composite material based on three-dimensional graphene oxide (GO) sponge and PDMS was synthesized, and its damping performance in different temperature environments was investigated. Firstly, GO suspensions with different concentrations were prepared and GO sponges were obtained by freeze-drying, filling the GO foam with PDMS, and forming three-dimensional sponge GO reinforced PDMS composites with different crosslinking densities by adjusting the ratio of prepolymer and crosslinker of PDMS. Through dynamic mechanical analysis tests, it was observed that the GO/PDMS composites prepared in this study have certain viscoelasticity at high temperature, and their dynamic mechanical properties first increase and then decrease with the increase of GO content; meanwhile, it can be seen that the damping attenuation properties of the composites show an increasing trend in a certain range as the cross-linking density of GO/PDMS composites decreases. In addition, GO/PDMS composite shims with different GO contents and different crosslinking densities were prepared and designed for random vibration tests at high and low temperatures, and the results showed that when the GO content was 0.75 wt% and the crosslinking ratio of PDMS material was 10:0.5, the composite had the best damping performance, and its dynamic amplification coefficient was improved by about The power amplification coefficient was improved by about 25% compared with that without shims and about 10% compared with that of pure PDMS.

Key words PDMS, GO, Composite Materials, Vibration damping

Session: Polymer Matrix Composites

Presenting Type: Published only

Multi-responsive EVA/Fe3O4 nanocomposites with self-healing and reprocessing capacity

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A facile strategy was put forward to prepare multi-responsive shape memory EVA/Fe3O4 nanocomposites with self-healing and reprocessing capacity via the dynamic transesterification between commercial ethylene vinyl acetate EVA with functionalized Fe3O4 nanoparticles in different proportions with the presence of proper catalyst. A series of composites were produced by blending first in a Torque rheometer for and then curing at 160 °C with a Vulcanizing machine. The swelling test showed that the gel fraction of the composites were between 60% and 70%, indicating the formation of cross-linking in composites. The thermal cycle curve tests by Dynamic Mechanical Analysis (DMA) show that the materials exhibited excellent one-way shape memory effect with high shape fixing ratio and recovery ratio. At the same time, the good two-way shape memory effect was also demonstrated in a wide temperature range. The intrinsic merits of dynamic feature of network, coupled with the photothermal effect of Fe3O4 nanoparticles endow the composites with satisfactory self-healing ability triggered by multiple stimuli including heat, light. Moreover, the composite can be reprocessed several times at 160 °C for 1h which was beneficial to reduce energy consumption.

Key words EVA，Fe3O4 nanoparticles，shape memory，self-healing

Hangzhou, PR China 25-28 April, 2023

Session: Polymer Matrix Composites

Presenting Type: Published only

Study on deformation of composite stiffened panels with variable cross section

houbing wang*、limin chen、jingchao wei、linan cheng
Aircraft strength research institute of china

In order to research deformation of composite stiffened panels with variable cross section under axial pressure, the part of composite adjustment panels with 3 stringers were experimentally investigated. The results show that axial strain difference of rows in the specimens coincide with variable cross section of stiffener, two speciments do not buckle at limit load under axial pressure.

Key words composite, deformatiion, compoist stiffened panel, limit load

Hangzhou, PR China 25-28 April, 2023

Session: Polymer Matrix Composites

Presenting Type: Published only

Properties of Toughened Prepreg Resin with Optimized Synthesis Process and Composite Materials

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Wuhan University of Technology

According to the rheological properties, gel time, etc., the basic formula of prepreg resin was obtained. The optimum synthesis process of prepreg resin was obtained, taking the surface quality of cured resin as the evaluation standard. It can reduce energy consumption and solve the problem of uneven dispersion of dicyandiamide. The experimental results show that the optimum amount of gas phase nano SiO2 is 1% as toughening agent, the tensile and impact strength of the cured resin are 74.41MPa and 20.23kJ/m2 respectively, which are increased by 72.64% and 58.79% compared with those before toughening. Finally, the prepreg resin formula is determined as E-51: E-20: NPCN704: dicyandiamide: dichlorophenyl dimethyl urea: gas phase nano SiO2: defoaming agent =50:30:20:7:2:1:0.2, and the curing process was determined as 100°C/1h+130°C/2h+150°C/2h according to the extrapolation of DSC non-isothermal curve. The mechanical properties of the casting and composites were compared with commercial prepreg resin, and the results showed that the self-made prepreg resin were excellent. Glass fiber and carbon fiber reinforced self-made prepreg resin composites were prepared by vacuum assisted molding process, and the resin content should be controlled at 40% and 35%, respectively.

Key words prepreg resin; synthesis process; toughening modification; composite materials

Session: Polymer Matrix Composites

Presenting Type: Published only

Synergistic effect of magnesium oxysulfate whisker on flame retardancy and mechanical properties of intumescent flame-retardant glass fibre reinforced polyethylene composites

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wuhan university of technology

The intumescent flame retardant (IFR) contained ammonium polyphosphate (APP) and poly(1,3-diaminopropane-1,3,5-triazine-o-bicyclic pentaerythritol phosphate) (PDTBP), and organic modified magnesium oxysulfate whisker (OMOSw) synergist formed synergistic flame-retardant system (IFR/OMOSw), which could improve the flame retardancy and mechanical properties of the continuous glass fibre reinforced polyethylene (GFPE) composites. The flame retardancy of GFPE/IFR/OMOSw composites increased first and then decreased with the increase of OMOSw synergist loading. The synergistic flame-retardant system (IFR/OMOSw) could produce intumescent char layer covered on glass fibre surface, which reduce the wicking actions of glass fibre. The mechanical properties (tensile strength and Mode I interlaminar fracture toughness) were improved after adding OMOSw synergist, except for the flexural strength with no obvious change. The GFPE/IFR/OMOSw composite had the best comprehensive performance when the matrix contains 24 wt% IFR/6 wt% OMOSw compared to GFPE composite containing 30 wt% IFR.

Key words Polymer-matrix composites, Fracture toughness, Intumescent flame retardant, Synergist, Flame retardancy

Session: Metal Matrix Composites

Presenting Type: Oral-Invited

Preferred Orientation and Mechanical Properties-Anisotropy of TiB Whiskers Reinforced Titanium Matrix Composites

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Thermo-mechanical processing (TMP) is essential to improve the microstructure and mechanical properties of whisker-reinforced titanium matrix composites (TMCs), but it also induces strong preferred orientations that lead to property anisotropy and affect their serviceability. In this study, the microstructure evolution during the hot-rolling process was investigated to reveal the formation mechanisms of matrix texture and whisker arrangement. It was found that TiB whiskers would weaken the texture intensity of the adjacent matrix by promoting the dynamic recrystallization of the primary α and selection for the secondary α variant. It was demonstrated for the first time by analyzing the misorientation distributions that TiB whiskers would induce α-variants selection during the β→α phase transformation, and there were three preferred misorientations between them: 0°/[010], 56°/[010], and 64.8°/[-953]. The selected α variants were significantly refined and equiaxed, and exhibited a strong 1⟨1-20⟩//RD fiber texture due to TiB whiskers aligned along the rolling direction. In addition, a universal shear-lag model was developed by introducing an off-axis critical aspect ratio of whiskers to predict the yield strength anisotropy caused by the whisker arrangement. Microscopic studies were conducted on the as-rolled IMI834 alloy, TiB/IMI834 composites to investigate the crystallographic textures of matrix alloy, and the aspect ratio and orientation distributions of TiB whiskers. And the tensile tests at room- and high-temperatures were carried out at different tensile angles relative to the rolling direction. It was confirmed that the anisotropy of strength and elongation of TMCs is the synergistic effect of matrix texture and TiB whisker arrangement.

Session: Metal Matrix Composites

Presenting Type: Oral-Invited

Structural Characterization of Metal Matrix Composites Reinforced by Negative Thermal Expansion materials

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Negative thermal expansion (NTE) compounds with abnormal thermal shrinkage properties can effectively regulate the thermal expansion of metal and even to form near zero expansion materials. Through chemical substitution and interstitial atom doping, the crystal structure and phonon structure of the compound can be tailored. Advanced structural analysis methods such as in-situ synchrotron radiation, neutron diffraction, and total scattering are used to clarify the mechanism of the intrinsic negative thermal expansion of the compound; By systematically studying the interfacial structure of NTE reinforced aluminum matrix composites, the evolution law of the interfacial structure of the composites was clarified; The effects of multistage and multiscale configurations on the thermal expansion properties of composite materials and their strengthening effects on mechanical properties were studied, and the low expansion mechanism of composite materials were clarified. The prepared large size zero expansion metal matrix composites have high thermal conductivity, low density, and high strength characteristics, and have great application value in the fields of electronic packaging, optical devices, and other fields.

Key words Negative thermal expansion; Metal matrix composite; Crystal Structure; Interface

Hangzhou, PR China 25-28 April, 2023

Session: Metal Matrix Composites

Presenting Type：Oral−Invited

Effect of Hot-Pressing Temperature on Microstructure and Mechanical Properties of In-situ Composites Fabricated from an Al-TiO2 Systemm

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In-situ Al matrix composites (AMCs) were prepared from 5wt% TiO2-Al by high energy ball milling (HEBM) and hot-pressing. In order to provide guidance for process optimization of this material, the effects of hot-pressing temperature (580-630°C) and holding time (1-2h) on the microstructure and mechanical properties of the composites at room temperature (RT) and elevated temperature were investigated using XRD, SEM, TEM, TKD and tensile methods. It was shown that the difference of ultimate tensile strength among different materials are larger at 350°C than at RT, due to the fact that the mechanical properties of the materials at high temperatures are more sensitive to the size of the reinforcements. In addition, the samples hot-pressed at 605°C and then held for 2h show good overall performance, with ultimate tensile strength and elongation reaching 367 MPa and 6.5% at RT, 170 MPa and 4.6% at 350°C, respectively.

Key words Aluminum matrix composites, High temperature strength, Particle reinforcement, In-situ reaction

Session: Metal Matrix Composites

Presenting Type: Oral-Invited

High Cycle Fatigue Properties and Damage Failure Mechanism of TiB2/7050 Composites

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During the service of TiB2/7050 aluminum matrix composites, high cycle fatigue is the main failure mode, so it is of crucial to study the high cycle fatigue fracture mechanism of the composites. The results indicate that, the tensile properties of TiB2/7050 composites at room temperature are significantly improved compared to 7050 aluminum alloy, with yield strength increased by about 153 MPa, tensile strength increased by about 146 MPa, elastic modulus increased by about 6.2 GPa, while the elongation only slightly decreased. When the stress ratio R=-1 and the specified fatigue fracture life is 3×107 cycles, the fatigue limit of the composite is 211.9 MPa, which is much higher than the matrix 7050 aluminum alloy. The reason why the addition of TiB2 improves the fatigue properties of the in-situ composites is attributed to two aspects: the refinement of the matrix grains, and the difference in the elastic modulus and thermal expansion coefficient between the reinforcement and the matrix, resulting in significant increase in the dislocation density of the matrix. By analyzing the microstructure parameters of the longitudinal section near the fracture surface of fatigue specimens, it is found that the grain orientation, dislocation density near the crack source, Schmid factor, and Taylor factor have the most significant correlations with the magnitude of stress levels.

Key words Aluminum matrix composite; TiB2 particle; fatigue property; fatigue damage

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Versatility of Trace Nano-TiC-TiB2 in Collaborative Control of Solidification-Sheet forming-Welding Microstructure Evolution in Al Alloys for Enhanced Properties

Tianshu Liu*、Hongyu Yang、Feng Qiu、Qichuan Jiang
Jilin University

It is challenging to concurrently control the microstructure evolutions after undergoing casting, sheet forming and welding. This work successfully addressed this challenge via trace TiC-TiB2 nanoparticles in whole microstructure evolution of Al-Mg-Si alloys and medium Zn-containing Al-Zn-Mg-Cu alloys. The microstructural response to the addition of nanoparticles and the enhancement mechanisms of strength-plasticity synergy were studied. It was suggested that trace nanoparticles can refine the solidified microstructures and improve the grain boundary segregation significantly. During sheet forming, the net driving force for recrystallization was increased significantly, and the optimized recrystallization configuration was established. Meanwhile, the precipitates were refined, distributing more uniformly, and the precipitation of nanoscale shearable precipitates were promoted. The coarsening of fusion zone and heat affected zone of Tig-welded joint, as well as the abnormal grain growth in the nugget zone of friction stir welded (FSW-ed) joint was also effectively suppressed. The strengthened yield strength (YS) and ultimate tensile strength (UTS) of rolled Al-Mg-Si plates were enhanced by 31.3% and 16.3%, respectively, without significantly sacrificing plastic strain (εp). Also, the YS and UTS of as-welded Al-Mg-Si Tig-welded joints were enhanced by 30.2% and 7.8%, respectively. The strengthened YS and UTS of medium Zn-containing Al-Zn-Mg-Cu extruded profiles were enhanced by 10.1% and 10.2%, respectively, and the εp was kept at 10.2%, surpassing the strength-plasticity synergy of high Zn-containing Al-Zn-Mg-Cu alloys. Also, the FSW-ed Al-Zn-Mg-Cu joint acquired ultra-high σY of 847 MPa and proper εp. This work detailedly explored the microstructure evolution mechanisms, providing a typical model for comprehensive amelioration of microstructural evolution in aluminum alloys under multiple processing conditions.

Key words Aluminum alloy, Microstructure control, Mechanical performance strengthening, Nanoparticle

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Achieving High Performance in Graphene Reinforced Ti-based Composite Through Interface and Microstructure Design

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Titanium matrix composites（TiMCs）display low density, outstanding specific strength, corrosion and wear resistance so that they are promising materials using in aerospace and automotive industry field. Graphene has 2D carbon nano-structure which exhibits large theoretical surface area has been regarded as 'star' nano-material applying in titanium. However, the difficulty of uniform dispersion, severe interfacial reaction and strength-ductility trade-off are simultaneously the most challenging and serious issues in graphene reinforced TiMCs. Our research focuses on the study of uniform graphene dispersion, interface reaction control and laminated architecture design. High pressure torsion, flake powder metallurgy and spray coating laminated consolidation techniques were applied in this research; studying the effects of fabrication parameters on graphene distribution, microstructure/interface evolution and mechanical property, uncovering the mechanical response, strengthening and toughening mechanism of the composite.

Key words Titanium matrix composite; Graphene; Interface; Microstructure; Mechanical performance

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Nano-Layered Flaky Ternary MAX Phases Reinforced Magnesium Composite: Interfacial Evolution and Fracture Mechanism

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Motivation:

In recent decades, the demand for lightweight and high-specific strength materials has brought about the development of magnesium matrix composites. Unlike traditional binary ceramic particles, such as SiC and Al_2O_3, the novel ternary nano-layered $M_{n+1}AX_n$ (MAX) phase ceramics exhibit metal-like properties and self-lubricate capacity. For giving one comprehensive understanding of the A-site element effect on the interface structure of Ti_2AlC-AZ91D composite, we introduced another representative Ti_3SiC_2 MAX phase to explain the interfacial evolution. Due to the high aspect ratio of the MAX particles, the mechanical performances of MAX/Mg composites could be anisotropically regulated by orientating the particles through plastic deformation. For illustrating the fracture mechanism and extending the accurate simulation, we developed one finite element (FE) model based on 2D and 3D microstructural observations.

Approach:

We combined 2D and 3D observations to accurately establish the FE model of actual nano-layered flaky MAX particle reinforced magnesium composite and to stimulate the mechanical properties and damage behavior in ABAQUS software.

Major findings:

(1) Al atoms in Ti_2AlC diffuse outwards into the Mg matrix, which favors the formation of nano-Mg grains at the interfacial zone. Ti_2AlC particles do not detach from the AZ91D matrix during the tensile deformation due to the strong Ti_2AlC-Mg interfacial bonding. Differently, no outward diffusion of Si atoms from Ti_3SiC_2 into the Mg matrix, and weaker interfacial bonding formed. Like SiC, Ti_3SiC_2 particles are easily detached from the Mg matrix. This discovery supports one new way to regulate Mg composites.

(2) Based on the nano-layered flaky structure of Ti_2AlC particles, a FE model suitable for MAX/Mg composites was established. The delamination initiated from the Ti_2AlC particle with its basal plane nearly perpendicular to the tensile direction. As the strain increases, the tensile fracture is initiated by the stress concentration area containing more particles. Then, the matrix crack propagated

and connected with the delaminated Ti_2AlC particles with the increasing strain, which finally resulted in the failure of the composite.

Conclusion:

The A-site atoms in MAX phases can affect the interfacial structure and create the idea of controlling interfacial structure by regulating A-site elements and their solid solution ratio in the MAX phase, such as $Ti_3(Si_{1-x}Al_x)C_2$. The established FE model can accurately simulate the mechanical properties and damage behavior of MAX/Mg composite.

Key words MAX phases; Mg composite; Interface evolution; Fracture mechanism; Finite element model; Mechanical properties

Session: Metal Matrix Composites

Presenting Type：Oral-Onsite

Microstructural Characteristics of Nano TiB Reinforced TC4 Composite Powder Fabricated by Plasma Rotating Electrode Process

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The traditional TiB reinforced titanium matrix composites (TMCs) have excellent mechanical properties at room and elevated temperature. However, since there is no TiB inside the network structure, the strength of the composites have not been further improved. The concentration of the reinforcement at the network boundary causes that the plasticity of the material is difficult to get fully exerted. In order to plant nano-TiB reinforcement into network structure TMCs, based on plasma rotating electrode process (PREP) has a large degree of supercooling which can inhibit TiB coarsening, it is selected to prepare spherical TC4-TiBnw composite powder with less satellite balls. For the reason that the concentration of B element in the composite powders was lower than the eutectic concentration, the proeutectic β phase precipitated first during the cooling process of the Ti droplets. In the meantime, the concentration of the B element in the liquid phase increased. When the B element concentration reached the eutectic reaction concentration, β-Ti and TiBnw precipitated around the proeutectic β phase and showed a network structure with a diameter of about 2-4 μm. TiBnw in the composite powders had quantities of stacking fault. The thickness of α lath in the composite powder was about 200 nm, and the orientation between the grains basically accorded with the Burgers orientation relationship. This experiment can provide guidance for the microstructure regulation of powder metallurgy TMCS.

Key words Titanium matrix composites；TiB；Plasma rotating electrode process

Session: Metal Matrix Composites

Presenting Type：Oral-Onsite

Construction of Analogy-Bicontinuous Structures Simultaneously Enhancing Mechanical Properties and Electrical Property of Cu-2 wt% Ag Alloy Matrix Composites

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Tianjin University

In order to realize the demand of high strength in practical applications, Cu alloys with precipitates offer a promising candidate for the matrix of Cu matrix composites. However, the mechanical properties and electrical conductivity (EC) of Cu alloy are not well coordinated. As a derivative of graphene, graphene nanoplatelets (GNPs) have similar excellent properties (high fracture strength, super Young's modulus, extreme charge carrier mobilities, high thermal conductivity) to graphene and are easier to obtain, all of which make it suitable as a reinforcement for composites. Meanwhile, GNPs has been associated with impeding the diffusion process of solute atoms, through which heterostructures could be constructed by combining appropriate process routes to sufficiently realize the unique properties of different composition and the synergy of strength and EC. Up to now, little work has yet been conducted to the study on modification of Cu alloy with graphene, with the intention of forming Cu alloy matrix composites with outstanding comprehensive properties. In this work, we present a novel strategy towards the fabrication of GNPs reinforced Cu-2 wt% Ag composites with analogy-bicontinuous structure (ABS), which mainly consists of GNPs@Cu and Cu-Ag alloy components, indeed leading to achieved the synergy of mechanical properties and EC. Concurrently, it can expand the preparation scale accompanied with forming the composite strip, and maintain the comprehensive properties well. Special attention was expended on underlying the contribution of intergranular and intragranular strengthening mechanisms, as well as the function of ABS on coordinating strength and toughness. Furthermore, the superior electronic transport path regulation effect originates from the as-formed ABS was probed in detail in order to interpret the exceptional EC of the composite. This study offers a new perspective to design future Cu matrix composites with high performance.

Key words Cu matrix composites, Graphene nanoplatelets, Comprehensive performance

Session: Metal Matrix Composites

Presenting Type: Oral–Onsite

Effect of Al4C3 on the Interface Properties and Performance Stability of Diamond/Aluminum Composites

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The diamond/aluminum composite possesses excellent properties such as high thermal conductivity, low coefficient of thermal expansion, and low density. As a fourth-generation thermal management material, it has broad development prospects in the field of electronic packaging. The interface bonding of diamond/aluminum is the focus of material preparation and design. Combined with first-principles calculations and experiments, the interfacial reaction of diamond/aluminum composites was systematically studied, and the selective bonding between aluminum and diamond (100) crystal plane was explained by simulation. The experiment is consistent with the theoretical calculation. The heat-moisture test further shows that inhibiting the formation of Al_4C_3 and improving the interface selectivity are of great significance for improving the properties and performance stability of diamond/aluminum composites.

Key words Diamond/aluminum composites; First-principles calculation; Interface reaction; Thermal conductivity

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Strength-Ductility Synergy of TiB/Ti6Al4V Composites with Tailored Hierarchical TiB Distributions

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Innovative titanium matrix composites with hierarchical structure distributed TiB have been designed and fabricated. In-situ generated TiB formed the first network architecture during the process of hot-pressing sintering. Inside the network cell homogeneously scattered TiB, which was synthesized in the powder atomization process. The designed composites possessed a remarkable strength-ductility synergy with the simultaneous improvement of tensile strength and elongation by 21% and 80%, respectively, compared with the matrix TC4 alloy. The hierarchically structured composites retained the good ductility by network structured TiB, and also improved the strengthening efficiency by the homogeneously distributed TiB inside the network cell. This study opened up a new way to circumvent the strength-ductility tradeoff of titanium matrix composites.

Key words titanium matrix composites; hierarchical structure; mechanical properties; strength-ductility synergy; reaction hot pressing

Session: Metal Matrix Composites

Presenting Type：Oral–Onsite

Enhancement in Strength-Plasticity Synergy of Cermet by Refractory Metal and Multiple Length-Scale Microstructure

Hongyu Yang*、Feng Qiu、Qichuan Jiang
Jilin University

Metal-ceramic composites have high strength and stiffness, low thermal expansion coefficient, and great application potential. However, due to the large difference in elastic and plastic deformation between the "soft phase" and the "hard phase" in cermets, their strong-plastic synergistic effects are limited, hindering their application. Therefore, we propose to use refractory metal particles and intermetallic compounds as a bridge between the "soft phase" and the "hard phase", and design an isotropic homogeneous multiscale microstructure containing micro-Al6MoTi, sub-micron TiC, nano-Mo particles separated by 30 vol% Al. This multi-scale microstructure can relieve stress concentration and enhance the work hardening effect and deformation compatibility of cermet, thereby greatly improving the strong plasticity of cermet at room temperature and high temperature. This study opens up new prospects for the design and application of high-strength-plastic synergistic metal-ceramic composites.

Key words Metal-ceramic composites; Strength-plasticity synergy; Multiple length-scale microstructure; Stress concentration delocalization; Deformation compatibility

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Damage Tolerant Graphene-Metal Nanocomposite Thin Films by Chemical Vapor Deposition Synthesis

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2. The Hong Kong University of Science and Technology
3. University of Illinois Urbana Champaign

Current flexible electronics are mainly based on stretchable conductive thin film or slender structures bonded on compliant elastomers. The ultrathin thickness and pre-designed wrinkled or serpentine-shaped film structures can effectively lower the flexural rigidity (~thickness^3) and minimize strains in metal materials, thus can easily accommodate deformations without excessive stress concentration. However, because ultrathin metal films exhibit much lower fracture toughness than their bulk counterparts, maintaining the good electrical conductivity of ultrathin metal film structures on elastomeric substrates upon large deformations and fatigue loading is still one of the grand challenges. In this study, we developed a novel route toward high strength and toughness metal nanocomposites by in situ synthesis of a graphene wrapper onto micro/nano-scale seed metals and demonstrated the enhanced electromechanical performance of ultrathin metal films under large strains and repeated deformations. Chemical vapor deposition synthesis of high-quality uniform graphene layers onto ultrathin metal films could introduce considerable work hardening ahead of the possible microscale crack tip and effectively torture the crack propagation directions, thus significantly enhancing the thin film's fracture toughness. Here, we used the ultrathin palladium films with pre-existing horseshoe shape patterns as a model system. The CVD-grown palladium-graphene film-based stretchable networks exhibit a much slower increase in electrical conductivity when uniaxially stretched beyond 60%, compared with an abrupt surge in conductivity of bare palladium films when strained to 30%. Moreover, as-grown palladium-graphene networks exhibit several times longer fatigue life under cyclic stretching with strain range up to 20%. Our experimental results are well described by the thin film electrofragmentation model and the Coffin-Manson relationship. The CVD-grown metal-graphene nanocomposite thin film materials show promise in improving the electromechanical robustness of flexible electronics.

Key words graphene metal nanocomposite, thin film, flexible electronic, fracture toughness, chemical vapor deposition

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Improvement of Mechanical Properties in Carbon Nanotube/Al-Cu-Mg Composites Through Introducing Laminate Structure and Grain Modification

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2009 aluminum alloy is one of the high-strength aluminum alloys widely used in the aerospace industry. By adding a small number of carbon nanotubes (CNTs) into the 2009Al alloy, the strength of the 2009Al alloy can be further improved, but elongation loss will be caused. In order to solve this problem, laminate CNT/2009Al composites were prepared by the powder metallurgy, which consisted of ductile layers (DLs, coarse or ultrafine grain Al) without CNTs and brittle layers (BLs, ultrafine grain Al) rich in CNTs alternately. DL and BL powders were alternately pressed into a cylinder mold and hot pressed at 813 K with a layer thickness ratio of 1:2. Then the composite billets were hot extruded at 723 K. Finally, the extrusion rods were hot rolled at 753K along the extrusion direction, and then the solid solution and natural aging treatment (T4) was carried out. The tensile test was carried out and the microstructure was observed by light microscope, scanning electron microscope, and transmission electron microscope. The yield strength (YS), ultimate tensile strength (UTS), and elongation (El) of composite with coarse-grained 2009Al as DLs (CG DL-BL) were 554 MPa, 660 MPa, and 4.8 %, respectively. While the YS, UTS, and El of composite with ultrafine 2009Al as DLs (UFG DL-BL) were 628 MPa, 720 MPa, and 4.8%, respectively. The microstructure examination illustrated that the mechanical incompatibilities between the layers during tensile deformation produce a large number of geometric necessary dislocations between the DLs and the BLs, which inhibited strain localization and enhanced the strength-ductility. Compared with the CG DL-BL, the YS of the UFG DL-BL was further increased by 14%, while the El was no loss. This is because the ultrafine grains of the DLs can obtain higher strength than the coarse grains and have better coordination with the BLs.

Key words Carbon nanotubes, Aluminum matrix composite, Mechanical properties, Laminate composite

Session: Metal Matrix Composites

Presenting Type：Oral-Onsite

Multi-Scale Study of Microstructure Evolution Al Matrix Composites with Graphene Encapsulated Cu Nanoparticles as Reinforcement

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It is well recognized that piling-up of dislocations enables increased strength, and the sustainable accumulation of dislocations under high stress can markedly improve the toughness. Herein, we propose a novel manufacturing of Cu nanoparticles coated with graphene (G) reinforced Al matrix (Al-Cu@G) composites via combining ball-milling, pressure sintering as well as heat treatment. Comprehensive characterizations show that in-situ generation of multi-interfaces nanostructures with distribution along Al grain boundary, composed of graphene and Al2Cu nanoparticles at the grain boundary (GB), was governed by a restricted diffusion process of Cu and Al, ascribing to the physical geometric confinement of graphene. The structure was emphasized to address its contribution to the improved GB strengthening effect and sustainable storge of dislocations. We demonstrate that the dislocation storage ability in Al grains can be considerably improved through this novel GB engineering approach, leading to a remarkably enhanced strain-hardening capacity and tensile ductility. As a consequence, the Al-Cu@G composite exhibits a tensile strength of ~ 570 MPa and fracture elongation of ~17.1%. The present study may provide a promising strategy to optimize the dislocation behavior in the vicinity of GB, which is critical to enable increasing strength ductility synergy in metal matrix composites.

Key words Metal matrix composites; Graphene; mechanical property; Strain-Hardening; Al alloys

Hangzhou, PR China 25-28 April, 2023

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Experimental and Modeling Study on Longitudinal Tensile Behaviors of SiCf/TC17 Composites

Wenqi Hao、Duoqi Shi、Changqi Liu*、Xiaoguang Yang
BeiHang University

Unidirectional SiC fiber-reinforced titanium alloy composites are attractive candidate materials for use in bladed rings at the compressor stage of aero-engine, due to their high specific strength, high specific stiffness, excellent creep, fatigue properties and ability to operate at high service temperatures (~450°C). The use of these materials could contribute to ~40% weight reduction over unreinforced components, providing significant benefits to aero-engine design. In the present work, longitudinal tensile tests were carried out on SiCf/TC17 composites at 25°C, 450°C and 650°C to investigate the tensile behaviors of the material. The damage evolution and failure mechanisms were revealed based on microscopic fracture morphology analysis. Afterewards, a phenomenological constitutive model was developed to describe the tensile behaviors of SiCf/TC17 composites. The results show that the longitudinal yield strength and ultimate tensile strength of SiCf/TC17 composites decrease with increasing temperature, while the nonlinear segment of the stress-strain curve increases. The major failure mechanisms at room temperature are multiple fractures of the interfacial reaction layer and random breakage of weak fibers, whereas large-scale interface debonding and fiber pullout, matrix cracking and fiber breakage are more common at high temperatures. The predicted results of different strength models demonstrate that the failure mode of SiCf/TC17 composites at room temperature is controlled by local loading sharing while the high-temperature ultimate tensile strength is more consistent with the global loading sharing model. The stress-strain curve of SiCf/TC17 composites was simulated by the proposed constitutive model with coupling fiber cumulative damage based on global loading sharing. The simulation results exhibit a trend similar to that of the experimental data at 25°C and 450°C.

Key words Titanium matrix composites; SiC fiber; Tensile properties; Fracture mechanism; Constitutive modeling

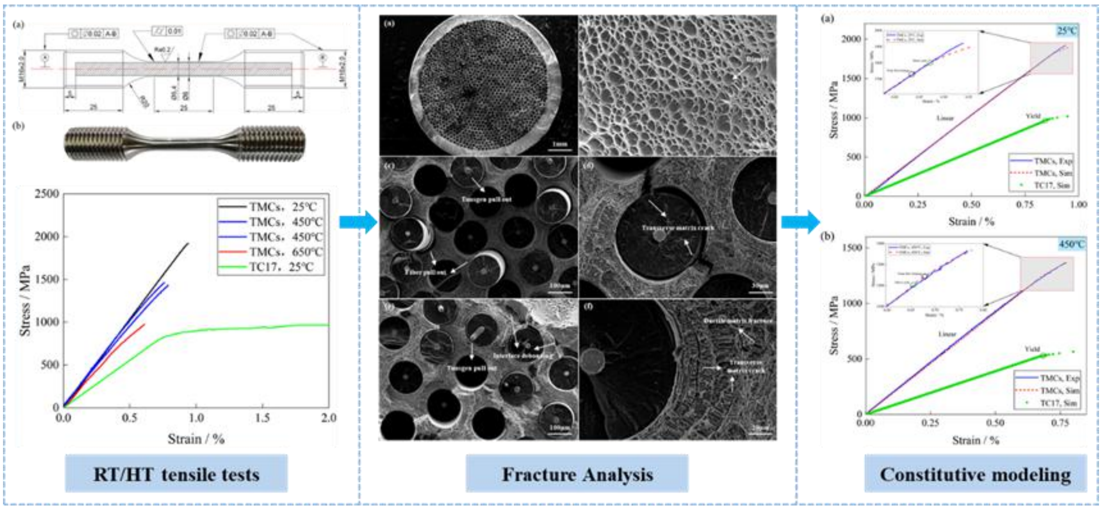

Fig. 1. The main research content and methods of this paper.

Session: Metal Matrix Composites

Presenting Type：Oral–Onsite

Simultaneously Enhanced Strength and Ductility in Graphene Nanosheet/Al-Cu-Mg Nanolaminated Composites through Incorporating Coarse Domains

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Heterogeneous structure through designing soft/hard domains with dramatically different strength is effective to maintain high ductility of metals, but always sacrifices the yield strength. Here we firstly demonstrate a simultaneous enhancement of yield strength and tensile elongation by ~20% in graphene nanosheet/Al-Cu-Mg nanolaminated composites through designing heterogeneous domains of little difference. The underlying mechanism was investigated, and the hetero-deformation induced hardening and nano-precipitation strengthening was mainly responsible for the strength-ductility synergy. This study broadens the in-depth understanding of the heterostructured materials in pursuit of extraordinary mechanical properties.

Key words Metal Matrix Composites (MMCs); Heterogeneous structure; Hetero-deformation induced (HDI) hardening; nanolaminated structure; precipitation strengthening

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Graphene/Copper Matrix Composites: From Bioinspired Strengthening and Toughening to Functional Properties

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Starting from the trade-off between strength-ductility/toughness and strength-conductivity in traditional metal matrix composites, by using the emerging two-dimensional material graphene with excellent intrinsic properties as the reinforcement, we foucs on preparation method, architecture and interface of copper matrix composites. This talk highlights the mechanism of strengthening and toughening in the graphene-copper composites with the nacre-inspired "brick-and-mortar" architecture, and also discuss its deformation behavior and characteristics of the composite under extreme strain rate. At the same time, by controlling the key parameters of the composite interface, we also discussed that the balance between strength-conductivity, ultra-high electrical conductivity, and the influence of the composite architecture on the properties of friction, corrosion and other functions.

Key words Metal matrix composites; Bioinspired architecture; Structural-functional intergration

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Anisotropy of the Wear Behavior for Carbon Nanotube Reinforced 6061Al Composites

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Carbon nanotube (CNT) reinforced 6061Al (CNT/6061Al) composites with directionally aligned CNT were fabricated and their wear behavior were investigated. The results indicate that the wear properties of CNT/6061Al composites exhibited a significant anisotropy. A certain CNT concentrations (1 wt.% and 2 wt.%) could effectively improve the wear resistance of CNT/6061Al composites along the CNT circumferential and CNT radial directions for the load transfer, grain refinement and self-lubrication effect of CNT. The Brass {011} <211> and {112} <110> textures inhibited the load transfer effect of CNT along the CNT radial direction, resulting in a better wear resistance along CNT circumferential direction than CNT radial direction. Along the CNT axial direction, the weak deformability of composites caused by the intensifying <111> fiber texture was the main reasons for the poor wear resistance of CNT/6061Al composites with increasing the CNT concentration.

Key words Carbon Nanotube, Metal matrix composite, Wear, Anisotropy

Session: Metal Matrix Composites

Presenting Type：Oral-Onsite

Fatigue Facture and Mechanisms of TiB/Ti-6Al-4V Titanium Matrix Composite under Different Stress States

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Due to reinforcements, the titanium matrix composites (TMCs) exhibit different fatigue properties compared with titanium alloys, and TMCs demonstrate more complex fatigue failure mechanism than titanium alloys. In order to systematically investigate the fatigue failure mechanism of TMCs, 8%TiB/Ti-6Al-4V was selected and the high-frequency cyclic fatigue tension-compression tests under different stresses were conducted. The fatigue life of specimens under different stresses were obtained and analyzed. The microstructure of fracture morphology and the cross-sections were characterized and discussed as well. The results showed that the fatigue life of 8%TiB/Ti-6Al-4V decreased with increasing the loading stress, but the volume fraction of TiB reinforcement was not linearly related to the fatigue life of TMCs. The fracture morphology of 8%TiB/Ti-6Al-4V indicated that the ''cleavage facets'' were obviously observed in the crack initiation region. In addition, the existence of ''small planes'' with different areas was shown in the crack propagation area while changing the loading stress. With the change of loading stress, the fracture mode of TiB also changed from interface separation to debonding, and finally completely pulled out, leaving a clear and visible trace on the fatigue section. By observing the propagation path of the main crack, it was found that the deflection angle of the main crack would also change greatly under different loading stresses. In addition, many microcracks and micropores sprouting at the tip of TiB were found. This work provides a theoretical and experimental reference for improving the fatigue properties of TMCs.

Key words Titanium matrix composites (TMCs); fatigue life; fracture morphology; crack propagation; loading stress.

Hangzhou, PR China 25-28 April, 2023

Session: Metal Matrix Composites

Presenting Type: Oral–Onsite

Finite-Volume Homogenization of Elastic-plastic Response of Boron/Aluminum Composites with Ductile Damage under Off-axis Loadings

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The parametric Finite-Volume Direct Averaging Micromechanics (FVDAM) method has been further extended to predict the combined nonlinear behaviors of unidirectional boron/aluminum (B/Al) composites, induced by plastic deformation and ductile damage for the first time. The latter is considered by gradual stiffness degradation via the continuum damage mechanics (CDM) model. The convergence of homogenized and local response generated by the new FVDAM damage framework has been demonstrated considering the hexagonal and square repeating unit cells (RUC) with different mesh discretizations under transverse tensile, transverse shear and axial shear loading paths. It is observed that increasing the mesh refinements only affect the smoothness of local field distributions while the predicted homogenized response is not significantly altered. Then, the reliability of the developed approach to predict the nonlinear response of B/Al composites has been verified extensively vis-a-vis the experimental response available in the literature, under monotonic loading path with various off-axis angles, where excellent agreements are obtained with the testing data. To accurately capture the experimental response, an RUC with actual microstructure characterized by a random fiber distribution is constructed and utilized in the numerical simulations. In addition, the developed model is also applied to predict the oligocyclic response of B/Al composites with different off-axis angles in further support of the theory's potential to capture the macroscopic behaviors of B/Al composites under more complex loading conditions. The new finite-volume based full-field analysis approach provides an independent means for the accurate multiscale analysis of actual unidirectional metal matrix composites with plasticity and ductile damage, and hence it is a good tool to understand macroscopic and underlying deformation mechanisms of such composites.

Key words Finite Volume Micromechanics; Metal Matrix Composites; Ductile Damage; Elastoplasticity; Cyclic Loading

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Novel Boron Nitride Structure Facilitates High Thermal Conductivity Copper Matrix Composites Foil

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tianjin Uinversity

Owing to the unique planar atomic layer structure, two-dimensional materials usually show excellent properties that are different from those of bulk materials. For example, graphene and hexagonal boron nitride (h-BN) have excellent mechanical properties and ultra-high in-plane thermal conductivity (Kr), which considered to be ideal reinforcements for copper matrix composites with excellent comprehensive properties. In this work, we prepared a new two-dimensional boron nitride by chemical vapor deposition (CVD), named layer-disarrangement boron nitride (l-BN), which has completely different properties from h-BN. Through the design of the composite material configuration, we prepared a laminated l-BN reinforced high thermal conductivity copper matrix composite foil, the thermal conductivity of which can reach 426 W·m-1·K-1, compared with 387 W·m-1 of pure copper · K-1 is increased by 10%, especially the thermal conductivity can be maintained at the same level as room temperature at 400 degrees. In addition, l-BN and copper have a very high interfacial thermal conductivity (ITC), and the cross-plane thermal conductivity of the composite material can also be maintained at 370 W·m-1·K-1, which is close to the thermal conductivity of pure copper. In this work, a copper matrix composite foil with high thermal conductivity is prepared through the synthesis of l-BN, which provides a new solution for the interfacial thermal resistance of metals and semiconductors.

Key words l-BN, chemical vapor deposition, copper matrix composites, thermal conductivity

Session: Metal Matrix Composites

Presenting Type：Oral–Onsite

Microstructure Manipulation and Strengthening Mechanism of TiAl Composites Reinforced by Cr Solid Solution and In-situ Nanometer-sized TiB2 Particles

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Jinlin university

The problems of poor plasticity at room temperature and insufficient strength at high temperature of TiAl have always plagued engineers and scientists. Therefore, this paper hopes to prepare TiAl composites reinforced with nanometer-sized TiB_2 particles and different contents of Cr by the method of fast hot pressing sintering (FHPS). It can simultaneously realize the generation of in-situ nanometer-sized TiB_2 particles, the solid solution of Cr element and the densification of the composite in one step. The results show that the nanometer-sized TiB_2 in the 4 vol.% TiB_2/TiAl-xCr composite has good interfacial bonding with the matrix. Compared with TiAl, the grain size of 4 vol.% TiB_2/TiAl-3Cr is reduced by 86.4%, its yield strength (1121 MPa), ultimate compressive strength (2188 MPa) and product of strength and strain (25.93 GPa•%) have increased by 58.3%, 24.7% and 23.1% at room temperature, respectively. At high temperature (600°C), the yield strength (912 MPa) and ultimate compressive strength (1496 MPa) of 4 vol.% TiB_2/TiAl-3Cr TiAl have increased by 80.2% and 3.3% relative to TiAl, respectively. It is expected that this study can offer some guidance to the simultaneous improvement of strength at high temperature and plasticity at room temperature, even more to other intermetallics and metals.

Key words TiAl composites; Nanometer-sized TiB2 particles; Interface; Microstructure; Strengthening and toughening mechanism

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Matrix Effect on Strengthening Behavior of Carbon Nanotubes in Aluminum Matrix Composites

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Many studies have shown that carbon nanotubes (CNTs) have excellent strengthening effect as a reinforcement in pure aluminum (Al). However, it is unknown that whether such merit can be also achieved in strong Al alloys for achieving higher-strength Al matrix composites. In this study, CNTs were incorporated into pure Al and a high-strength Al alloy (AA5083) via the same powder metallurgy route. Results showed that during the dispersion stage, the high energy ball milling process caused different amount of deformation to pure Al and AA5083, which led to a better dispersion state of CNTs in powders and composites of pure Al. Although the two composites had the same tensile strength coincidentally, the strengthening efficiency of CNTs in pure Al composite was more than five folds larger than that in AA5083, suggesting a strong matrix effect on strengthening behavior of CNTs in Al matrix composites. The present finding may show significant guidance for the optimization of fabrication processes and development of high-performance CNTs/Al composites.

Key words Metal matrix composites; Powder metallurgy; Mechanical alloying; Mechanical properties; Microstructure.

Session: Metal Matrix Composites

Presenting Type：Oral-Onsite

Fabrication and Strengthening-Toughening Mechanism of Micro-Nano Hierarchical Structured (TiBw+TixSiy)/TB8 Composites

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In the fields of aeronautics and astronautics, the development of titanium alloys with an impressively good combination of strength and ductility/toughness is critically important to meet the rapidly increasing demand for structural weight reduction and performance improvement. In this project, we innovatively propose to use high strength and high toughness TB8 (Ti-14.9Mo-2.8Nb-3.1Al-0.2Si) beta (β) titanium alloy powders, boron powders, and silicon powders as raw materials, and to build a primary micron-sized network structure composed of β grains with numerous TiB whiskers (labeled as TiBw) surrounded by a combination of low-energy ball milling, reaction hot-pressing sintering, and hot extrusion. In particular, for the additional 1.0 wt. % Si composite material, the heterogeneous structure composed of recrystallized area and recovery area, is formed due to the resistance of the silicide to dynamic recrystallization during hot extrusion deformation. Compared with the TB8 matrix, its strength is increased by 10% to 1040MPa from 940MPa, and the uniform elongation is increased from 2% to 12%, achieving the simultaneous improvement of strength and plasticity. Then, the in situ precipitation of the hierarchical nanostructure α phase induced by Si elements and silicide distribution was realized during the ageing. That is, the secondary nanocomposite structure was constructed in the β crystal, the micro-nano structure (TiBw+TixSiy)/TB8 composite was prepared, and the ultra-high strength (>1800MPa) and plastic (>5% elongation at fracture) composite was achieved. The synergistic strengthening mechanism among micro-sized TiB whiskers, TixSiy and nano-sized α precipitates can be elucidated with an in-situ transmission electron microscope. In addition, the in-situ X-ray tomography technique will quantitatively characterize the fracture characteristic, including the initiation, propagation and density distribution of three-dimensional cracks. Finally, the strengthening-toughening mechanism of micro-nano hierarchical structured (TiBw+TixSiy)/TB8 composites can be revealed. This project will provide a theoretic guide and experimental basis for overcoming the strength-ductility/toughness trade-off of titanium alloys and titanium matrix composites.

Key words Titanium alloys; Titanium matrix composites; Reinforcing phases; Hierarchical structure; Strengthening-toughening mechanism

Session: Metal Matrix Composites

Presenting Type：Oral-Onsite

Fracture Mechanisms of 3D Printed Titanium Matrix Composites with High Strength and Toughness

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Designing and developing composite materials with excellent high tensile strengths and ductility is an important pursuit of the materials research. In this work, a three-dimensional network structure made of TiB+TiC has been designed and achieved in the matrix of Ti6Al4V via Laser Metal Deposion Additive Manufacturing processing. The 3D printed (TiB+TiC)/Ti6Al4V composites demonstrated a good combination of tensile strength and ductility.

Key words Additive manufacturing, Titanium matrix composites, fracture mechanisms

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Microstructure and Mechanical Properties of Network Structure TiB/(TA15-Si) Composites Fabricated by Hot Isostatic Pressing

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Titanium matrix composites (TMCs) with network structure has the advantages of high specific strength, strong corrosion resistance, excellent mechanical properties at room temperature and high temperature. For purpose of further promote its application in the field of aerospace, it is necessary to explore a better preparation of forming process. Hot isostatic pressing (HIP) method can realize near net forming of materials and components, organization performance. Therefore, it is of great engineering significance to study the preparation of TMCs with network structure by HIP. In this paper, TA15 alloy powder was used as matrix raw material, TiB_2 and Si powder as reinforcement raw material. Combined with computation and simulation to explore the best HIP process. TiB/(TA15-Si) composites with network structure was successfully prepared by low energy ball milling and different HIP processes. The microstructure evolution mechanism, room temperature and high temperature mechanical properties, as well as deformation and fracture mechanism of composites were explained through SEM, TEM, EBSD, etc and mechanical properties test.

Composites fabricated by one-step HIP obtained the same level of mechanical properties as the composites fabricated by Vacuum Hot Pressing (VHP), the ultimate strength and fracture elongation at room temperature were 1067.6MPa and 4.2%. Nevertheless, composites prepared by two-step HIP achieved a higher strength and plasticity at room temperature, were 1161MPa and 6.6% respectively. The high temperature tensile strength has been significantly improved especially, the highest strength at 600°C, 650°C and 700°C are 680MPa, 619MPa and 514MPa, which is increased by more than 10% compared with other composites in paper. The factors that contribute to this situation include refinement of grain size, regulation of silicide precipitation and the interfacial pinning effect of TiB whiskers. In conclusion, it is an effective way to prepare TMCs with uniform microstructure and stable properties by HIP.

Key words titanium matrix composites, hot isostatic pressing, microstructure, mechanical properties

Session: Metal Matrix Composites

Presenting Type：Oral-Onsite

Texture Evolution of TiB/Ti-2Al-6Sn Titanium Matrix Composite after Electroshocking Treatment (EST)

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2. Shanghai Jiao Tong University

This work found that the electroshocking treatment (EST) with the external loading are beneficial to change the microstructure of titanium matrix composites (TMCs). In this study, the microstructural characterization of the in situ synthesized 8% TiB/Ti-2Al-6Sn was performed by scanning electron microscopy (SEM), electron back scatter diffraction (EBSD) and transmission electron microscopy (TEM). SEM indicated that the TiB was refined after EST and the large-size α appeared. When the 0.3 MPa external loading was applied during the EST process, the TiB refinement effect was more obvious, and the α size was refined. EBSD results showed that the percentage of high angle misorientation grain boundaries (HAGBs) in TiB decreased, mainly due to the introduction of abundant dislocations in the TiB/matrix after EST. The percentage of HAGBs in α increased first and then decreased. Mainly due to the α growth after EST, leading the low angle misorientation grain boundaries (LAGBs) transform to HAGBs. 0.3 MPa external loading was applied in EST, the α deformed and generated a lot of subgrains, resulting in the LAGs increased. After EST, the maximum texture strength of TiB decreased from 13.09 to 12.97. The maximum texture strength of α decreased from 3.11 to 1.58, and the TiB orientation changed. After EST with 0.3 MPa external loading, the maximum texture strength of TiB decreased from 12.97 to 8.10, and the orientation of TiB changed more. TEM results showed that plenty ofstacking faults are formed in TiB and α after EST with 0.3 MPa external loading. All the results show that the texture of TMCs can be changed by EST with 0.3 MPa external loading, which provides a new method for changing the microstructure of TMCs.

Key words Electroshocking treatment (EST); TiB / Ti-2Al-6Sn; microstructure; reinforcement; Phase content; Texture; EBSD

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Study on the Mechanical and Tribological Properties of Tiw-SiCw/5056Al Hybrid Composites

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In the present work, Tiw-SiCw/5056Al hybrid composites, with the Ti wire and SiC whisker added as reinforcements in the 5056Al, were fabricated by the pressure infiltration method. The mechanical properties and tribological behavior were investigated. The results showed that the flexural strength of the composites increased gradually from 478MPa to 616MPa with the incremental content of SiC whisker from 0 to 10 wt %. The tribological properties of the composites with 3wt% SiC whisker presented the lowest friction coefficient and wear rate among the composites, which are 0.375 and 7.5×10-4mm3/N m, respectively. The SiC whisker increased the hardness of the composite, and decreased the adhesive wear of the composites. Whereas, the SiC whisker could agglomerate when the content exceeded 3wt%, and fell off easily causing abrasive wear during the sliding process.

Key words Hybrid reinforced, Aluminum matrix composite, Mechanical property, Dry sliding friction

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Deformation and Fracture Behavior of Aluminum Matrix Composite with Network Architecture

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The network architecture design is a feasible way to strengthen metal matrix composites (MMCs). A thorough investigation on effect of network architecture on the deformation and fracture behavior of MMCs is reqiured. Here, a new modeling technology is used to establish the geometric model of network SiC/Al composite. The deformation and fracture behavior of SiC/Al composites is predicted by element finite method (FEM). The results show that the elastic modulus of SiCp/Al composites increases with the rising local volume fraction (fv) of particles in the network layer. However, this strengthening effect sacrifices elongation. This phenomenon is consistent with the experimental results. It is noted that, in SiCw/Al composites, the elongation is improved with increasing aspect ratio. Further rising aspect ratio, SiCw/Al composites presents higher strength and elongation, comparing with SiCp/Al network/homogeneous composites.

Key words Metal matrix composites(MMCs); Network architecture; Finite element method(FEM); Strenthening; Fracture

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Rolling Behavior and Superior Extensibility of Graphene/Copper Nano-Laminated Composites

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Copper matrix composites play an irreplaceable role in daily life, industrial production, aerospace and other fields. Graphene has excellent intrinsic properties. In recent years, the application of graphene as reinforcement in copper matrix composites has gradually attracted researchers' attention. However, the traditional strengthening method still cannot solve the trade-off between the strength and plasticity. The non-solid solution of copper and carbon and the good conductivity of graphene are expected to improve the conductivity of copper matrix composites, and graphene/copper composites with strength-plastic matching can be prepared. Based on the heterogeneous structure characteristics of biological materials in nature, this study aims to optimize the structural design of copper-based composites. In this study, the large-size, high-strength and high conductivity graphene/copper composite foil with "brick-and-motar" structure was prepared by hot-pressing sintering and cold rolling. The results illustrate that the graphene/copper composite foil with superior extensibility can be prepared by optimizing the raw materials and preparation process. After 98% deformation, the tensile strength of graphene/copper composite foil reaches 632 MPa, which is 42% and 49% higher than that of ultrafine grained copper and pure copper under the same deformation conditions. In addition, during cold rolling, fibrous grains are gradually formed, and the layer thickness becomes thinner. Stacking faults and deformation twins are gradually formed at the vicinity of the graphene/copper interface, and the number of deformation twins increases with the increase of deformation. The lamellar configuration, interlaminar graphene, stacking fault and deformation twin endow graphene/copper composites good processability, and synergistically improve the strength and plasticity of the composite foil. In this paper, the strength plastic matching mechanism of graphene/copper composite with ultra-high deformation ability is revealed, which provides a reference for the preparation of high strength and high conductivity graphene/copper composite foil.

Key words graphene/copper composite, rolling behavior, superior extensibility, deformation twins, strength and plasticity

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Microstructures and Mechanical Properties of In-situ TiBw/TA15 Composites Fabricated by Selective Laser Melting

Qi An*、Lujun Huang、Shuai Wang、Changying Jia、Lin Geng
Harbin Institute of Technology

TA15 alloy (Ti-6.5Al-2.5Zr-1Mo-1V) is a near α titanium alloy, which has been widely used in aerospace and military fields due to its low density, high specific strength, good corrosion resistance and high-temperature durability. To further improve the strength and service temperature of TA15 alloy and to achieve the near-net-shape manufacturing of complex components, the spherical TA15 alloy powder with a particle size of 15~53μm and TiB2 powder with a particle size of 0.5~1μm were used to fabricate in-situ TiBw reinforced TA15 composites through low energy ball milling and selective laser melting (SLM). The microstructure and mechanical properties of the titanium matrix composites by SLM were studied. The results show that the TiB whiskers are uniformly distributed in the TiBw/TA15 composites, and the columnar grains with inner acicular α' martensite were formed along the building direction. In addition, the TiB reinforcement effectively refined the size of the matrix grain. The maximum room temperature tensile strength of 2vol.%TiBw/TA15 composite reaches up to 1293.2MPa, but the elongation is only 1%. The tensile strengths of 1vol.%TiBw/TA15 composite and TA15 alloy room temperature are 1268.3MPa and 1158.2MPa, respectively. Furthermore, the tensile strengths of 2vol.%TiBw/TA15, 1vol.%TiBw/TA15 and TA15 at 600oC are 651.1MPa, 635.4MPa, and 591.3MPa respectively. Consequently, the TiB whisker has significantly enhanced the strength of Ti alloys. The corresponding strengthening mechanisms include second phase strengthening, load transfer strengthening, and grain refinement strengthening. However, the plasticity of the composites is decreased. The fracture morphology of the composite at room temperature shows inside porous defects, as well as shallow dimples and tear edges. No traces of TiB whiskers being pulled out, indicating that the TiB is well bonded to the matrix. The high-temperature fracture contains deep dimples indicating a ductile fracture model.

Key words TiBw/TA15 composites; selective laser melting; microstructure; mechanical property; strengthening mechanism

Session: Metal Matrix Composites

Presenting Type：Oral–Onsite

Overcome the Room Temperature Strength-Ductility Rrade-off of Two-scale Structure (TiB+Y2O3)/TC25G Composites for Short-term Application at 700°C

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Harbin Institute of Technology

High-temperature titanium matrix composites have extensive application prospects in the aerospace field due to their low density and excellent high-temperature properties, attracting attention from researchers. However, the near-α high temperature titanium matrix composites, widely studied at present, possess excellent high temperature properties but with unsatisfactory room temperature plasticity. Based on the above consideration, in this study, $(TiB+Y_2O_3)$/TC25G (Ti-6.5Al-4Zr-2Sn-4Mo-1W-0.2Si) composites with basketweave microstructure were prepared by vacuum hot pressing sintering combined with hot extrusion. The composites possessed both excellent elevated temperature performance (566MPa, 28% elongation at fracture at 700°C) and optimized room temperature strength-ductility (>1277MPa, >10% elongation at fracture). After solution and aging treatment, the microstructure of the composite presented multiscale architecture, and the silicide precipitated at the phase boundary. Compared with the extruded composites, the tensile strength of the heat-treated composites increased significantly at room temperature (>1550MPa) and 600°C (>1000MPa), accompanied by a decrease in plasticity (4% elongation at fracture at room temperature and 10% elongation at fracture at 600°C).

Key words Titanium matrix composite, tensile strength, strength-ductility, microstructure，heat treament

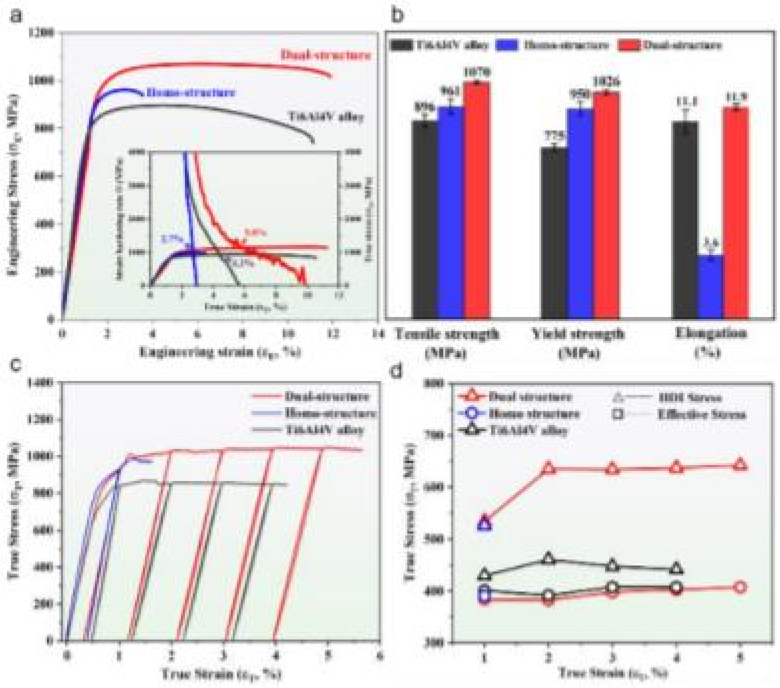

Fig.1. (a) Tensile stress-strain curves for dual-structure and homo-structure Ti6Al4V-TiBw composites, as well as Ti6Al4V alloy - the ductility limit for all these kinds of composites. Inset: The corresponding strain hardening curves for tensile results. (b) Mechanical properties of the dual-structure Ti6Al4V-TiBw, homo-structure Ti6Al4V-TiBw and Ti6Al4V alloy, (c) LUR stress-strain curves of dual-structure Ti6Al4V-TiBw, homo-structure Ti6Al4V-TiBw and Ti6Al4V alloy. (d) The strength contribution of HDI stress and effective stress for dualstructure Ti6Al4V-TiBw, homo-structure Ti6Al4V-TiBw and Ti6Al4V alloy.

Hangzhou, PR China 25-28 April, 2023

Session: Metal Matrix Composites

Presenting Type: Oral-Onsite

Enhancement of Strength and Ductility in Hetero-deformation Induced Strengthening Titanium Matrix Composites via Interdiffusion-selforganization Process by Powder Metallurgy

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A dual-structure Ti6Al4V-TiBw composites to achieve near-perfect ductility was developed in this study. The formation of the dual-structure separates the regions of different hardness in the composite, and the interaction between the regions is used to give the “reinforcement” deformation capacity, which increases the deformation coordination between the matrix and the “reinforcement”. Additionally, the heterogeneous grain structure generated by the non-uniform distribution of the reinforcement gives full play to the HDI hardening effect and further enhances the work-hardening ability of the composite. As a result, the prepared dual-structure Ti6Al4V-TiBw exhibits close to the ideal plasticity of the matrix with enhanced strength. This dual-structure material using the interaction between the regions will provide a new way to solve the strength-ductility inversion problem of traditional metal matrix composites and can also be applied to other high-performance metal matrix composite systems to meet needs such as weight reduction and functional design.

Key words Titanium matrix composites, Ti-TiBw composite powder, Heterostructure, Mechanical properties, Fracture mechanism

Session: Metal Matrix Composites

Presenting Type：Oral−Virtual Platform

Study on Interface Regulation of Annealed Pyrolytic Graphite/6061Al Composite of High Thermal Conductivity

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With the rapid development of the semiconductor industry and the continuous improvement of the heat flux density of electronic devices, hot spots caused by heat accumulation will seriously affect the reliability and life of electronic devices. Aiming to achieve a good combination between annealed pyrolytic graphite (APG) and aluminum alloy to improve the effective heat transfer at the interface, the surface of annealed pyrolytic graphite was plated with Cr and Ti elements by vacuum evaporation plating technology in this study. A novel annealed pyrolytic graphite/aluminum composite material with layered structure was fabricated by vacuum hot pressing to meet this requirement. The nanometer size of the modified layer formed on the graphite surface was controlled. The bonding method between the modified layer on the graphite surface and graphite was discussed by X-ray photoelectron spectroscopy (XPS) characterization technology. The effect of different carbide modified layer structures on the microstructures interface bonding of composite was investigated by transmission electron microscope (TEM) and high resolution TEM (HR-TEM), and the intrinsic relationship between interfacial microstructure and the macroscopic thermal conductivity was revealed. As a result, the titanium/chromium modified layer formed on the surface of the directional annealed graphite exhibits a gradient distribution, and an interface structure of the APG-Cr_xC_y/TiC-matel layer is formed between the annealed pyrolytic graphite and the metal modified layer. The annealed pyrolytic graphite after Ti modification treatment is used as a thermal conductive component, which can further improve the interface bonding state of the composite material, which has high comprehensive performance, that is, the thermal diffusivity and the flexural strength are 901 $mm^2 \cdot s^{-1}$ and 141 MPa.

Key words thermal management materials; graphite/aluminum composites; interface; thermal diffusivity

Session: Metal Matrix Composites

Presenting Type: Poster

Micro-anisotropic properties induced by crystallographic orientation and microstructure modulation of TiAl intermetallic

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Harbin Institute of Technology

TiAl intermetallic alloys have been used for aerospace applications over the last few decades owing to their superior mechanical properties at high operating temperatures. However, these alloys are also recognized as hard materials, involving complex deformation mechanisms that hinder precision manufacturing. Until now, few works are focused on the micro-anisotropic properties induced by crystallographic orientation and microstructure modulation. In this study, a systematic investigation on the micromechanical behavior of TiAl alloys via heat treatment modulation at different phase regions was conducted and three types of microstructures were achieved including near gamma (NG), duplex (DP) and fully lamellar (FL) microstructures. Among these, FL structures with higher contents of $\alpha 2/\gamma$ lamellar structures shows the lowest force during scratching test. Despite the noticeable reduction in scratching force, poorer surface quality was observed. While NG microstructure showed a higher degree of plasticity and distortion in the deformation subsurface during scratching, which was attributed to the coupled effects of dislocation slip and refined mechanical twins. On the other hand, the formation mechanism of the alloy with $\alpha 2/\gamma$ lamellar structure portrayed a ductile–brittle transition in fracture characteristics because of the weak bonding force between hexagonal $\alpha 2$ and tetragonal γ phases that led to preferential micro-cracking along each interface. The deformation behavior of different lamellar orientations can lead to the difference of crack propagation path based on the critical compressive stresses at the interface of $\alpha 2/\gamma$ lamellar structures. The differences observed in the micromechanical properties of the equiaxed γ grain structure and $\alpha 2/\gamma$ lamellar structure will advance the understanding of TiAl alloys.

Key words Titanium aluminides; Micro-anisotropic properties, Crystallographic orientation; Microstructure modulation;

Session: Metal Matrix Composites

Presenting Type: Poster

Ag / Nickel hydroxide heterojunction for Oxygen Reduction Reaction

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Zinc-air batteries (ZAB) is a hopeful energy storage and conversion device because of abundant zinc reserves and high energy density. However, oxygen reduction reaction (ORR) executed in the cathode of ZAB is really sluggish, which led to a substantial energy loss. The most active ORR catalysts are Pt and Pt-based alloys at present, but their high price and low reserves has undoubtedly increased the cost of ZAB. Ag is an environmentally friendly metal, its price is about 50 times cheaper than Pt and showing a better stability than Pt in alkaline condition, so Ag is a promising ORR catalyst. However, Ag has an excessively weak oxygen binding energy (OBE) because of its d^{10} electronic structure, making the area-specific activity of Ag is 10 times lower than Pt. In this work, we used a physical method, laser ablation in liquid, to prepare Ag clusters with negatively charged (-28.8 mV). And the positively charged (+17.9 mV) nickel hydroxide nanosheets (NSs) were prepared by a chemical method. So, the Ag/NSs heterogeneous structure is formed due to the electrostatic attraction, and forming Ag-O-Ni-OH new bonds to regulate the electronic structure of Ag and enhance the oxygen binding energy of Ag. Therefore, Ag/NSs exhibits an excellent ORR activity, even superior to commercial Pt/C. When applied in Zn-air batteries, Ag/NSs shows an extremely high discharge peak power density of 477 mW cm^{-2} and excellent discharge/charge cycling stability (> 500 h), which are far better than the Pt/C+Ir/C noble-metal couple.

Key words Zinc-air batteries, oxygen reduction reaction, heterojunction, silver

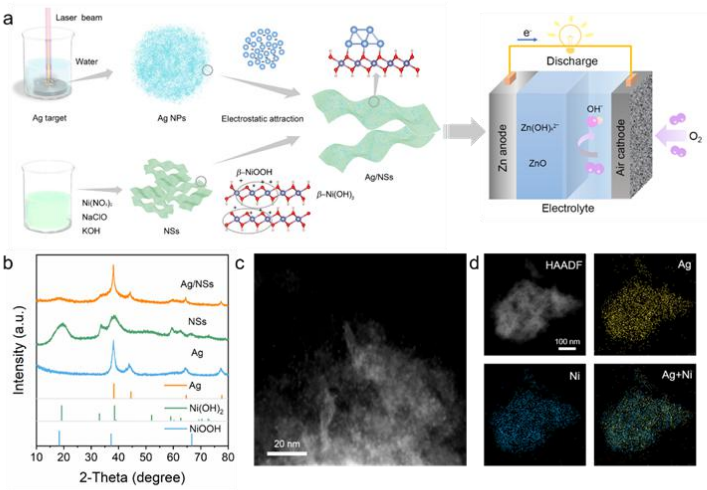

Fig. 1. Schematic illustration of Ag/NSs synthesis and micromorphology characterizations of Ag/NSs.

Session: Metal Matrix Composites

Presenting Type: Poster

Ultrahigh strength-elongation product in NiTiNb alloy via nanodomain-modulation

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A wide variety of industrial applications require materials with high strength and ductility. Unfortunately, most mechanisms for increasing strength led to ductility loss, an effect referred to as the strength ductility trade-off. Here, we report a NiTiNb alloy with highly dispersed and high-density nano-martensite domains, which exhibits a superb yield strength of ~1 GPa with an ultrahigh elongation of 83% and an ultra-high strength-elongation product of ~85 GPa%, above those of other state-of-the-art engineering alloys. The TEM results reveal the presence of 'sinusoidal' screw dislocations in the initial non-uniform deformation phase of the alloy ($\varepsilon<40\%$), with fluctuation periods close to the size of the nano-martensite domains, which are trapped by the nano-martensite domains and are the main reason for the increase in yield strength. Current work yields two surprising and novel findings for NiTiNb alloy with nano-martensite domains. First, NiTiNb alloy exhibits over 40% non-uniform deformation (no work-hardening). TEM results show that there were a large number of B2 (114) twins in the grains with a small amount of granular martensitic phases. Second, later nearly 40% homogeneous work-hardening deformation is a surprising result for the high yield strength alloy. At this stage, the presence of a large number of zigzag dislocations in the matrix of the B2 parent phase are evidence of further enhancement of dislocation mobility, which promoted the alloy to exhibit additional work hardening ability, in addition, it can be seen secondary nanotwins with width of ~10 nm. This work sheds light on multi-type deformation mechanisms in NiTiNb alloys modulated by nano-martensite domains, and thereby provides a promising route for improving strength and ductility materials.

Key words Microstructure; Nanodomain; Dislocation configuration; Transformation behavior; Mechanical properties.

Session: Metal Matrix Composites

Presenting Type: Poster

Effect of particle size on nanostructured Ni-TaC composites by planetary ball milling and spark plasma sintering: Reinforcement, densification, oxidation, and mechanical property

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Korea Institute of Industrial Technology

The metal matrix-carbide composites (MMCs) are used widely in manufacturing structures, cutting tool materials, aerospace propulsion components, and wear resistance parts due to the superior properties of transition metal carbides with the high melting point, thermal and chemical stability, high strength, wear resistance, and oxidation. In this study, the nickel (Ni) and tantalum carbide (TaC) powders were synthesized by mechanical alloying using planetary ball milling to explore their structural characterization and microstructural evolution against reinforcement interactions. The nominal compositions of Ni-TaC composites were Ni-(5, 10, 15, and 20) vol. % TaC, respectively. The formation of ductile (Ni)-brittle (TaC) components was correlated with continued severe deformation between the inter-particles observed work-hardened and refined by lattice distortion and strain. The compacts of Ni-TaC composites were densely consolidated by spark plasma sintering at 900°C and 60 MPa. The effect of hard phase addition on sinter-ability and mechanical properties of Ni-TaC composites was scrutinized by shrinkage rate, densification strain, state of distribution between matrix and carbide phase, grain size, and morphology of crack propagation. The oxidation behavior of Ni-TaC composites was conducted in a heating furnace in a ZrO2 crucible at temperatures up to 1000°C (10°C/min) to investigate the formation of the oxide protective layer.

Key words Ni-based alloys, tantalum carbide, spark plasma sintering, oxidation, mechanical property

Session: Metal Matrix Composites

Presenting Type: Poster

Microstructure and mechanical properties of dual-phase composite CrCoNi medium-entropy alloy

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The equiatomic CrCoNi medium-entropy alloy exhibits excellent cryogenic mechanical properties. However, its yield strength at room temperature is relatively low and needs to be further improved. In this work， we use the composition of the equiatomic CrCoNi alloy as the basis for alloy composition design and increase the proportion of Cr element in the alloy composition in a gradient. As the Cr content in the alloy increases, Cr-rich precipitations are gradually produced in the alloy. Compared to the equiatomic CrCoNi alloy, the Cr-rich precipitations lead to a significant increase in alloy strength. In-depth microstructural characterization shows that the CrCoNi alloy is a single-phase FCC alloy when the Cr content in the alloy is less than 50%. However， when the Cr content in the alloy is more than 50%, precipitations appear in the alloy, which ranges in size from 0.1~10 μm. Therefore, the Cr50Co25Ni25 alloy is a dual-phase composite structure (precipitations and FCC solid solution). Subsequently, we further investigated the precipitations in the alloy by SEM and showed that the Cr content in the precipitations was 61%, which was much higher than the Cr content in the solid solution of FCC in the alloy. The TEM and XRD experimental results show that the structure of the precipitations is BCC. In addition, the precipitations of different sizes hamper the dislocation movement during the alloy deformation, which enhances the strength of the alloy. Uniaxial tensile tests show that the alloy has ultra-high strength and good ductility, with a yield strength of 1100 MPa at room temperature and an elongation of 26%. Compared with the equiatomic CrCoNi alloy, the dual-phase composite structure of CrCoNi has significantly higher strength.

Key words Medium-entropy alloyc, Two-phase composite structure, Microstructure, Mechanical property

Session: Metal Matrix Composites

Presenting Type：Poster

Microstructure and mechanical properties of TiB-modified graphene nanoplatelets reinforced Ti-6Al-4V alloy composites

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In this study, the TiB@GNPs/TC4 composites with different GNPs content (0, 0.1, 0.2, 0.3, and 0.4 wt.%) were fabricated via ball milling (BM), fast hot press sintering (FHPS), and hot rolling (HR). The microstructures of the ball-milled powders, the as-sintered and as-rolled composites were characterized by Raman spectroscopy, scanning electron microscopy, and transmission electron microscopy. The results indicated that the tensile strength of TiB@GNPs/TC4 composites was dramatically improved with the increasing GNPs content. The ultimate tensile strength (UTS) of 0.4 wt.% TiB@GNPs/TC4 composites reach 1426 MPa with 3% elongation. The failure mechanism of composites was further discussed by analyzing the fracture surface morphologies.

Key words Titanium matrix composites, Graphene nanoplatelets, Mechanical properties

Session: Metal Matrix Composites

Presenting Type: Poster

Microstructural evolution of Y2O3p/Mg-Zn-Gd-Zr composites during hot compression

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6%Y2O3p/Mg-Zn-Gd-Zr composites fabricated by stir casting were hot compressed and the microstructural evolution of the composites were systematically studied. With increasing temperatures or decreasing strain rates, the dynamic recrystallized (DRXed) grains increased while the twins decreased. At the same time, the basal textures were weakened due to the increase of dynamic recrystallized grains whose orientation was relatively random. In addition, the added micro-sized Y2O3 particles could promote dynamic recrystallization (DRX) due to particle stimulate nucleation (PSN) mechanism while the nano-sized precipitations in Mg-Zn-Gd alloy could retard the generation and growth of dynamic recrystallized grains due to Zener drag effect. Therefore, the DRX behavior was the synergistic effect of the micro-sized Y2O3 particles and nano-sized precipitations and the grain sizes of the composites could be refined efficiently. PSN mechanism and continuous DRX (CDRX) were the main DRX mechanism in the composites.

Key words Magnesium matrix composites; hot compression; microstructures; dynamic recrystallization

Session: Metal Matrix Composites

Presenting Type: Published only

Hybrid Material-Influence of non-adhesive process on the strength of aluminum-glass fiber bonding

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Production of heterogeneous composite hybrid material sheets through hot-pressing process, we study the bonding strength of glass fiber reinforced thermoplastic composites (PC-GFRTP) / AA5052-H32 aluminum alloy composites with micropores on the surface. As the thermocompression bonding temperature increases to 170°C the bonding strength has been significantly improved, however, the hot-pressing process time requires at least 3 minutes could enhance bond strength. Even though 150°C is slightly higher than the Tg of PC, there is not enough time to that the melted polymer seeps into the hole perfectly to achieve mechanical anchorage effect. Experimental results show that when the time of hot-pressing process is 5 minutes, in the temperature range between from 170 to 210°C, the tensile strength is between 25~27MPa, furthermore, control the hot-pressing with temperature 180°C to 190°C and pressure 45kgf/cm2 will reach maximum strength 27MPa, but if the working temperature exceeds 220°C, the bonding strength starts to decrease.

Key words Fiber Reinforced Thermoplastic (FRTP), Dissimilar Materials Bonding, Fiber Metal Laminates, Hybrid Materials

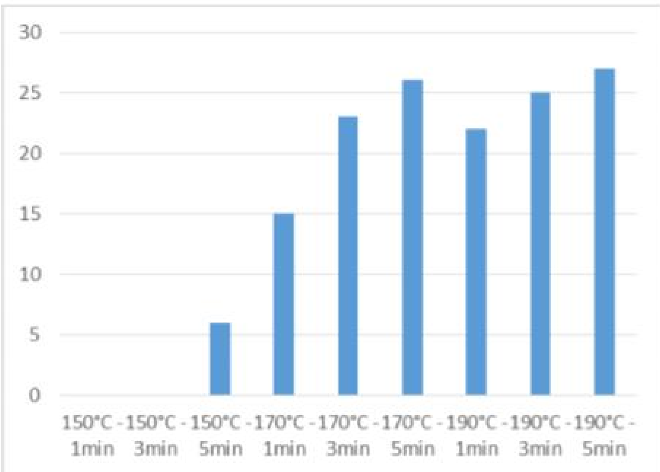

Fig. 1. Effect of different hot-pressing temperature and time on bond strength.

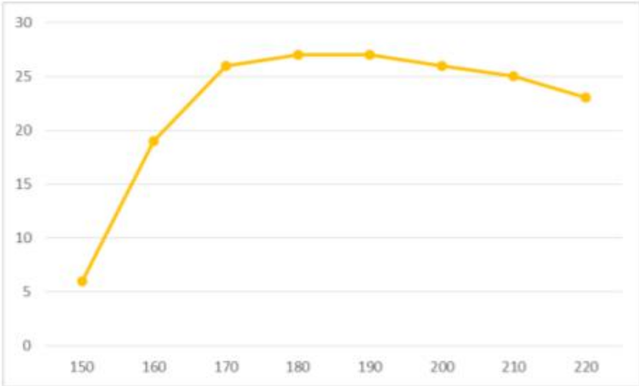

Fig. 2. The relationship between hot pressing temperature and bonding strength when keep 5 minutes process.

Session: Metal Matrix Composites

Presenting Type: Published only

Crack-free (TiB+TiC)/TiAl Composites Construction by Laser Melting Deposition

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Zhejiang University

TiAl intermetallic has gained extensive attention in scientific community as a promising structural material owing to its advantages such as low density, high creep resistance and good toughness. However, due to its intrinsic brittleness, cracks are more inclined to initiate concerning TiAl could not accommodate the high thermal stress generated by fast cooling during laser deposition manufacturing (LDM) process. Much research in recent years has focused on crack-free additive manufacturing TiAl. In the present work, crack-free (TiB+TiC)/TiAl composites were fabricated integrating with preheated and grain refinement technology. B4C nanoparticles were uniformly incorporated into the TiAl alloy utilizing high-energy ball milling in an argon atmosphere, and in situ self-generated TiB, TiC nanoparticles act as grain refiner and load transfer, effectively enhancing the compressive yield strength, ultimate strength and strain respectively. A preheated substrate up to 500°C substantially relieves high thermal stress due to rapid cooling, reversing massive cracking, and laying a solid foundation for surmounting the roadblocks of low processability.

Key words Laser Melting Deposition, Metal Matrix Composites, Titanium Aluminum

Session: Metal Matrix Composites

Presenting Type: Published only

Additive manufacturing of ultrafine-grained titanium aluminum intermetallic by LaB6

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TiAl-based composites have been considered an excellent candidate for demanding high-temperature structural components due to their attractive mechanical properties and low density. However, the intrinsic brittleness makes it difficult to process complex-shape components through conventional casting or powder metallurgy. Meanwhile, refined colonies in TiAl are beneficial to improving its mechanical properties. In this work, grain refiner LaB_6 nanoparticles were introduced to prepare in-situ ($TiB+La_2O_3$)/Ti-45Al-8Nb composites by additive manufacturing. The effect of LaB_6 addition on the grain size, phase transformation and microhardness of Ti-45Al-8Nb was identified. With 0.2 wt.% LaB_6, the lamellar colonies were refined and precipitates were distributed homogenously. The microstructure of TiAl-based composites showed a transition from coarse full-lamellar to refined near-lamellar colonies with equiaxed γ phases. Besides, the residual oxygen within the matrix was partly depleted by the formation of La_2O_3. This synergistic effect of refinement and purification by LaB_6 contributes to microstructure modulation from the perspective of alloy composition design.

Key words Laser Melting Deposition, Metal Matrix Composites, Titanium Aluminum

Session: Ceramic Matrix Composites

Presenting Type: Oral-Invited

Preparation and Ablation Properties of SiC/ZrB2–SiC/ZrB2/SiC Multilayer Coating on Graphite

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2. Harbin Institute of Technology

To improve ablation resistance of graphite, SiC/ZrB2-SiC/ZrB2/SiC coating was prepared by pack cementation and chemical vapor deposition (CVD). The microstructure, surface stress, ablation resistance and surface temperature response during ablation of the coating were systematically studied. SiC/ZrB2–SiC/ZrB2/SiC coating showed excellent ablation resistance, its mass and linear ablation rate were only 0.27 mg/s and 0.57 μm/s after ablation under oxyacetylene flame for 298 s. CVD ZrB2/SiC layer significantly improved the ablation resistance of SiC/ZrB2–SiC/ZrB2/SiC coating. The surface temperature response was affected by layered microstructure evolution and emissivity of different layers.

Key words ZrB2-SiC; Microstructure; Surface temperature response; Emissivity; Ablation resistance

Session: Ceramic Matrix Composites

Presenting Type: Oral-Invited

Continuous Carbon Fiber Reinforced ZrB2-SiC Composites Fabricated by Direct Ink Writing Combined with Low-Temperature Hot-Pressing

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ZrB2-SiC ultra-high temperature ceramics are a kind of non-ablation type thermal protection materials with great potential in extreme thermal oxidation environments, but the intrinsic brittleness severely limits their engineering applications. The application of continuous carbon fiber is one of the most effective technical means to overcome the brittleness of ceramic materials. Low-temperature hot-pressing and carbon fiber coating technology is a simple and effective process for preparing high-performance one-dimensional or two-dimensional continuous carbon fiber toughened ultra-high temperature ceramic composites. However, at present, the manual brushing and silk laying is still used to prepare continuous fiber toughened ceramic composites, which strictly limits their wide application and productivity improvement. So, in this work, Direct Ink Writing combined with low-temperature hot-pressing were used to fabricate continuous carbon fiber reinforced ZrB2-SiC ceramics. The thickness of carbon coatings and the angles of fiber lamination on the mechanical properties was investigated, and the toughening mechanism was analyzed. A new breakthrough was proposed in the construction technology of continuous fiber reinforced ceramic matrix composites with superior comprehensive performance.

Key words Direct Ink Writing; Low-Temperature Hot-Pressing; Carbon Fiber; ZrB2-SiC

Session: Ceramic Matrix Composites

Presenting Type: Oral−Invited

Mechanical Behavior and Failure Mechanism on Ceramic Matrix Composites

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The continuous improvement of aero-engines performance imposes higher requirements on the temperature resistance and weight reduction of the materials for its hot section components. Ceramic matrix composites (CMCs) with low density, high temperature resistance and oxidation resistance, etc have become the ideal candidate materials for the applications in hot section components of aero-engines. CMCs are composed of fiber, matrix and interface. Contrary to bulk ceramics, CMCs have a non-brittle mechanical behavior due to the high strength of continuous fibers, and due to the weak-bonding matrix/fiber interface after matrix cracking.

This paper mainly describes the failure mechanisms on CMCs. The formation and the propagation of damage, failure behavior of SiC/SiC CMCs were explored. Hysteresis measurements made upon the tensile testing have been demonstrated as a method for reflecting the failure mode of the composites. The influence of matrix/fiber interphases, prepreg layup and fabrication techniques (Si melt infiltration, chemical vapor infiltration/precursor infiltration and pyrolysis) on the failure mode in SiC/SiC CMCs also discussed. Meanwhile, the crack propagation behavior in SiC matrix modified CMCs was investigated and simulated *via* Extended Finite Element Method (XFEM). The simulation based on XFEM are shown to be good agreement with experimental results. At last, the failure mechanisms on oxide/oxide CMCs were also proposed. Because the oxide/oxide CMCs exhibit substantially different stress/strain behaviors which must be related to different properties of the constituents (fiber, matrix and interface). This paper is aimed at revealing the mechanical behavior and serving as references to the research of materials for aero-engines in China.

Key words Ceramic matrix composites; failure mechanism; SiC/SiC composites; oxide/oxide composites

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

Design, Fabrication and Performance of Ultra-High Temperature Ceramic Matrix Composites

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Continuous carbon fiber reinforced ultra-high temperature ceramic matrix composites (UHTCMCs) are endowed with excellent mechanical properties, ablation resistance at ultra-high temperatures, and furthermore, overcome the inherent brittleness and poor thermal shock resistance of bulk UHTCs. Therefore, these materials are considered as the most potential candidates for applications in thermal structures and anti-ablation components of hypersonic vehicles, such as sharp nose, leading edge, and combustor of solid rocket. For high temperature structural applications, mechanical and ablation resistant properties are the most critical performance indicators of UHTCMCs. How to realize the synergistical optimization of mechanical properties and ablation resistance is the main challenge for UHTCMCs. To address this issue, the UHTSMCs are synergistically designed and fabricated based on fibers/interphase protection and UHTC matrix optimization in this work. As a consequence, improved mechanical and ablation resistant performance are achieved for UHTCMCs. This presentation will report the progress we made recently in this field.

Key words Ultra-high temperature ceramic matrix composites, Ablation mechanisms, Interphase

Session: Ceramic Matrix Composites

Presenting Type：Oral−Onsite

Preparation and Properties of Lightweight High-Strength Carbon Foam Based on Sugar-Carbon Conversion

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Carbon foam materials have low density, adjustable thermal conductivity, high temperature stability, flame retardancy and high mechanical strength, and have good application prospects in the aerospace field, such as the sandwich of aerospace aircraft sandwich hybrid structures. At present, most of the carbon sources of carbon foam come from non-renewable resources such as asphalt, coal, resin, etc. The intermediate products in the preparation process seriously pollute the environment, and the material stability is poor, the cost of raw materials and preparation technology is high, and the production cycle is long. In response to this research status, a new template-free mechanical foaming gel route is proposed to fabricate robust and multifunctional sucrose-derived carbon foams with hierarchical porous structures, which can flexibly control the pores by adjusting the sucrose concentration during mechanical stirring. structure and porosity. The effects of process parameters on its microscopic morphology, physical properties and mechanical properties were studied, and the relationship between parameters, structure and properties was explored. The carbon foams after heat treatment at 1200°C exhibited low density (0.1-0.2 g/cm3) and high compressive strength (1-5 MPa), with thermal conductivity less than 0.1 W/m·K at room temperature. The work in this paper not only enables the preparation of energy-saving and environmentally friendly bio-carbon foams with reliable extreme environmental adaptability, but also exhibits good generality and flexibility in the fields of aerospace and practical carbon materials, realize component thermal insulation/lightweight integration.

Key words carbon foam, Sucrose-derivedm, echanical property, thermal insulation

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

Fabrication and Characterization of Polyanionic High-Entropy Carbonitride Ultra-High Temperature Ceramics with Excellent Mechanical Properties

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Abstract: As a new type of ultra-high temperature ceramic materials, high-entropy carbonitride ultra-high temperature ceramics have attracted tremendous attention due to their higher configurational entropy, wider performance regulation space, and stronger designability as compared with the traditional ultra-high temperature ceramics. However, the high-entropy carbonitride ultra-high temperature ceramics obtained by the current preparation methods still face the challenges of poor uniformity and high cost. Here, a green and low-cost controllable preparation process of high-entropy carbonitride ultra-high temperature ceramic powders, namely $(Ti_{0.2}Zr_{0.2}Hf_{0.2}Nb_{0.2}Ta_{0.2})C_xN_{1-x}$ powders, were successfully achieved by a sol-gel method combined with carbothermic reduction nitridation method using transition metal oxide mixed powders as the metal source, glucose is preferred as the carbon source and N_2 as the nitrogen source for the first time. The as-synthesized $(Ti_{0.2}Zr_{0.2}Hf_{0.2}Nb_{0.2}Ta_{0.2})C_xN_{1-x}$ powders possess high compositional uniformity and controllable particle size. In addition, bulk ceramics were prepared by hot pressed at 1800 °C displaying a high nanohardness value of 35.75±1.23 GPa, and high fracture toughness of 8.72±0.69 MPa·$m^{1/2}$ measured by Vickers indentation technique. This present work not only opens a novel perspective for the green and low-cost preparation of high-performance high-entropy ultra-high temperature ceramics, but also provides support for the preparation of ultra-high temperature thermal protection materials.

Key words High-entropy carbonitride; Sol-gel method combined with carbothermic reduction nitridation method; Nanohardness; Fracture toughness

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

Vibration characteristics investigation of a ceramic matrix composites beam under fatigue loading based on multiscale approach

Zhenyu Wang、Duoqi Shi*、Changqi Liu
Beihang University

On account of excellent properties of ceramic matrix composites (CMCs), such as high-temperature resistance and low density, nowadays the CMCs applications are potential in high-temperature components of advanced aero-engines. Vibration fatigue is typical failure mode of turbine vanes in service. In this work, vibration characteristics of a CMCs beam were calculated using multiscale mechanical analysis and finite element method. First, on microscale, matrix cracking, interface debonding and fiber fracture were quantitatively depicted by mean matrix crack spacing, interface sliding resistance and fractured fiber percentage under cyclic load with different stress amplitudes. Afterwards, considering influence of stress amplitudes and cycles for fiber bundle damage modes, the degradation law of elastic modulus was obtained based on equations between modulus and damage parameters. Then, on mesoscale, real geometric models were established in ABAQUS and elastic modulus of CMCs were obtained based on mean-field theory and finite element method. Finally, on macroscale, according to mesoscopic RVE size and stress amplitudes distributed in beam, reasonable areas were divided and corresponding degradation laws of elastic modulus were adopted in specific locations. On the basis of elastic modulus variation with spatial and temporal characteristics of composites, the vibration characteristics of beam, including natural frequency and mode, were analyzed under fatigue loading. The natural frequency variation of CMCs beam was verified by the vibration tests of a batch of CMCs specimens. Above results indicate that the multiscale approach proposed in this work is feasible and can be utilized in CMCs structure components to evaluate damage evolution and mechanical property degradation based on vibration characteristics variation.

Key words Ceramic matrix composites (CMCs); vibration fatigue; vibration characteristics; multiscale mechanical analysis

Session: Ceramic Matrix Composites

Presenting Type：Oral-Onsite

Sugar-Derived Anisotropically Oriented Carbon Films for Efficient Heat Dissipation and Excellent Electromagnetic Interference Shielding

Mingyi TAN、Wenbo Han、Xinghong Zhang*
Harbin Institute of Technology

The rapid development of next-generation portable electronic devices urgently requires dual-functional materials that possess both efficient heat dissipation and outstanding electromagnetic interference (EMI) shielding performances. In this study, anisotropically oriented carbon films with high thermal conductivity and excellent EMI shielding properties are prepared through an innovative glucose hydrogel-controllable carbonization method. The horizontal alignment of nanocrystalline graphite results in oriented structures with an extremely high in-plane thermal conductivity of 439.9 W m^{-1} K^{-1}, exhibiting a more effective heat-dissipating capacity on smartphones than their commercial graphite counterparts. Additionally, owing to multiple internal reflections arising from the oriented structures, the films exhibit an EMI shielding effectiveness (SE) of 21.72 dB at an ultrathin thickness of 480 nm in the X-band and an extraordinarily high absolute shielding effectiveness (SSE/*t*) of 275883 dB cm^2 g^{-1}, significantly outperforming most of the reported synthetic materials. Furthermore, the flexibility, high mechanical strength, and stability of the films have been demonstrated and therefore show promising application prospects. This study offers a facile yet feasible strategy for preparing dual-functional materials to address the heat emission and EMI problems of advanced electronic devices in a more economical and environmentally friendly manner.

Key words hydrogels, carbon films, oriented structures, heat dissipation, electromagnetic interference shielding

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

Preparation and Characterization of C/SiOC Composite Aerogels with Excellent Mechanical, Thermal Insulation and Antioxidant Properties

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Carbon aerogels are considered as one of the most promising candidates in thermal insulation applications owing to their lightweight, low thermal conductivity, and high-temperature resistance. However, it is frustrating that carbon aerogels exhibit inferior mechanical properties and oxidation resistance, which remains a significant challenge for their application. Herein, a novel C/SiOC composite aerogel was successfully synthesized by a simple copolymerization of dual sols, ambient pressure drying, and thermal treatment process. The C/SiOC composite aerogels exhibited excellent mechanical properties and oxidation resistance due to the formation of silicon-carbon and silicon-oxygen bonds and the construction of double interpenetrating nano-network structures. The C/SiOC composite aerogels displayed a low density (0.252-0.294 g/cm3), a high compression strength (3.30-5.12 MPa), and a low thermal conductivity (0.061-0.067 W·m-1·K-1). Furthermore, the oxidation resistance of the C/SiOC composite aerogels was improved compared to the carbon aerogel, with maximum mass retention of 44.6 wt.% under an air atmosphere at 1000 °C, while the carbon aerogel was exhausted. The results indicate that the as-prepared C/SiOC composite aerogels with lightweight, high strength, low thermal conductivity, and excellent oxidation resistance could be considered as a great potential candidate material for applications in harsh environments.

Key words C/SiOC composite aerogels; Ambient pressure drying; Mechanical properties; Oxidation resistance; Thermal insulation

Session: Ceramic Matrix Composites

Presenting Type：Oral–Onsite

Nano-Crystalline Graphite Carbon Matrix Composites Fabricated by Reactive Melt Infiltration

Jingsheng HU、Wenzheng Zhang、Boqian Sun、Yuan Cheng*、Jingsheng Hu
Harbin Institute of Technology

Increasing attention has been paid to SiC modified carbon matrix composites for their high specific strength and excellent high-temperature resistance. Reactive melt infiltration (RMI) is usually used to fabricate SiC modified carbon matrix composites, however, preventing fiber degradation from melt and controlling the reaction between carbon matrix and silicon melt are challenging. The slow reaction of large graphite prevents the melt from infiltrating the preform, while the reaction of amorphous carbon matrix is too fast. Here, a novel nano-crystalline graphite matrix is chosen as a carbon source that can protect fibers and react sufficiently to facilitate melt infiltration, so high-performance SiC modified carbon matrix composites are expected. This work is significant for the application of SiC modified carbon matrix composites in aerospace thermal structures.

Key words Nano-crystalline; Carbon matrix composites; Reactive melt infiltration; Reactivity

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

The Ablation Behavior of Multiphase Multicomponent Ultra-High Temperature Ceramics

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Novel multicomponent ultra-high temperature ceramics (UHTCs), including high-entropy ceramics (HECs), have revealed remarkably enhanced oxidation resistance than conventional ceramics. They are promising candidates for thermal protection materials used in extreme hot oxidizing environment. However, current researches are mainly focus on the oxidation mechanism of single-phase multicomponent system. While the oxidation behaviors of multiphase multicomponent UHTCs and underlying mechanisms are rarely studied, which limit their development and applications. Here, through studying the ablation behaviors of $Hf_{0.61}Zr_{0.26}Ti_{0.13}C$-$Hf_{0.30}Zr_{0.32}Ti_{0.38}Si_2$, the coupling effect of the preferential oxidation of ceramic phase and the preferential oxidation of components is revealed. We found that the preferential oxidation of silicide would lead to the earlier nucleation of Hf-related oxides in silicide phase. Meanwhile, the preferentially oxidized Hf element would migrate from the laggingly oxidized carbide phase to the earlier nucleate Hf-related oxides in silicide phase and subsequently lowering the Hf-content of the carbide. As a result, this coupling effect leads to the formation of “Hf/Zr-rich oxide skeleton infilled with the oxides rich in Ti”. More importantly, the Ti-content of the filling phase in higher than that of pure multicomponent carbide, which is more conducive to the formation of molten phase to seal the defects of oxide skeleton and finally form a denser oxide scale at high temperatures. The ablation results demonstrate that the mass ablation rate and linear ablation rate of the multiphase system are 64.7% and 60.2% lower than that of the corresponding single-phase multicomponent carbide, respectively. This work provides a preliminary basis for the selection of the second phase and the compositional design of the multiphase multi-component UHTCs.

Key words Multicomponent ultra-high temperature ceramics; Multiphase; Preferential oxidation; Coupling effect; Ablation resistance.

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

Fabrication of SiC Nanowires Reinforced SiC Ceramic Matrix Composites by NITE Process

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Layer by layer SiC nanowires paper reinforced SiC ceramic matrix composites were fabricated by nano impregnation and transient eutectic (NITE) process with SiC nanowires as reinforcement and Al2O3-Y2O3 as sintering aids. The effects of sintering pressure, Al2O3-Y2O3 content, the deposition time of PyC interface layer and SiC nanowires content on the properties of composites were investigated. The increase of the sintering pressure and Al2O3-Y2O3 content led to the density of the composites increase and the mechanical properties improvement. When the sintering pressure was 20 MPa and the sintering additive content was 12 wt%, the SiCnws/SiC composites had a maximum fracture toughness. The flexural strength–displacement curve of the composites showed a step shape. The composites with SiC nanowires content of 10 wt% exhibited the stepwise non-brittle fracture behavior due to the characteristic of layered structure, and the fracture toughness was 40.19% higher than that without PyC coating, with the flexure strength of 150.75 MPa. The SiC nws /SiC composites with SiC nanowires content of 15 wt% exhibited ductile fracture behavior and flexural strength of 60 MPa, because of the loose and porous structure.

Key words SiC ceramic matrix composites, SiC nanowires, SiCnws/SiC CMC, nano impregnation and transient eutectic (NITE) process

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

Novel Metamaterial for High Temperature Radar-Infrared Bi-Stealth

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With the development of aerospace technology, the multifunctional stealth technology compatible with infrared and radar is one of the most feasible ways to improve the survival of military equipment under high temperature conditions. However, it is difficult to effectively integrate multiple functions into one material owing to the contradictory stealth mechanism between infrared and radar. Herein, a multilaminate metamaterial for high temperature radar-infrared bi-stealth is prepared by the process of topological optimization design and nearly room temperature integrated synthesis. The metamaterial exhibited excellent electromagnetic wave absorption performance in S, C and X bands in a wide temperature range (25-1000°C). Particularly, the reflectivity less than -10 dB at a high-temperature of 1000°C is in the range of 3.1-6.2 GHz. Moreover, the porous structure and the micro scale of hierarchical skeleton make the metastructure exhibit excellent infrared stealth, which can reduce the radiation temperature (exceeding 800°C for object with temperatures above 1200°C). This study provides a new inspiration and insights for the preparation of multifunctional stealth structures.

Key words Metamaterial; Topological optimization; High temperature; Microwave absorption; Infrared stealth

Session: Ceramic Matrix Composites

Presenting Type：Oral-Onsite

Microstructure, Constituent Properties and Macro Mechanical Behavior of 3D Needle-Punched C/SiC Composites

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Carbon fiber-reinforced silicon carbide (C/SiC) composites have been rapidly developed and have been applied to aerospace hot-section components due to their low density, high specific modulus, and high thermal shock resistance. 3D needle-punched (3DNP) C/SiC composites consist of non-woven carbon fiber cloth, woven carbon fiber cloth, and short-chopped carbon fiber web, and possess better mechanical properties and lower cost than the 2D plain-woven or 3D braided C/SiC composites. The composite's microstructure and ply structure can be designed to improve the mechanical properties of 3DNP C/SiC composites. This paper focused on the investigation on the relationship between the composite's microstructure, constituent properties, and macro mechanical behavior. Four different ply structures and ply sequences were designed and adopted to fabricate the 3DNP C/SiC composites using the reactive infiltration method. Cycle tensile experiments were conducted to obtain the mechanical properties of the 3DNP C/SiC composites at room temperature. The composite's proportional limit stress and strain, composite's tensile strength and failure strain were affected by the microstructure and ply structures. Cyclic loading/unloading hysteresis loops evolve with increasing tensile peak stress and the hysteresis-based damage parameters were used to characterize the composite's internal damage evolution. Through the hysteresis analysis, the constituent properties of 3DNP C/SiC composites were obtained, and the relationship between the composite's microstructure, constituent properties and macro mechanical behavior was established. The research work can help the engineering designers improve the mechanical properties of the composites by optimizing the microstructures and ply structures.

Key words C/SiC; 3D needle-punched; Microstructure; Constituent Properties; Mechanical Properties; Ply Structures

Session: Ceramic Matrix Composites

Presenting Type：Oral-Onsite

Ceramic Matrix and Interface Modification of C/SiOC Ceramic Composites

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National University of Defense Technology

Carbon fiber-reinforced SiOC ceramics hold a very promising future because of their light weight, high temperature resistant and low cost. Whereas, the high temperature resistances of SiOC ceramic matrix and carbon fiber are mismatched, this significantly restricts the long-term application of C/SiOC composites at high temperatures. In this paper, the ceramic matrix and the interface are modified by introducing Y heterogeneous element to PSO and preparing interfacial C coating. Characteristics and high temperature evolution behaviors of SiYOC ceramic in different environments were investigated. The microstructure, mechanical properties and high-temperature evolution of C/SiYOC composites were analyzed. The density, flexural strength and fracture toughness of the as-fabricated C/SiYOC composites were 1.89 g/cm^3, 261.7 MPa and 13.54 MPa•m$^{1/2}$, respectively. The interfacial C coating played a positive role in the fracture toughness and thermal stability of C/SiOC composite by protecting carbon fiber and weakening interfacial bonding. By optimizing the concentration of phenolic solution and the pyrolysis cycles, a compact C coating with moderate thickness was obtained, and the flexural strength and fracture toughness of C/SiOC ceramics were improved from 214.2 MPa to 266.9 MPa and 11.5 MPa•m$^{1/2}$ to 13.7 MPa•m$^{1/2}$, respectively. In addition, it is found that properly increasing the thickness of C coating would prolong the high-temperature service of C/SiOC composites without significantly sacrificing its mechanical properties at room temperature.

Key words Carbon fiber reinforced SiOC composites; Precursor infiltration and pyrolysis (PIP); Herero-element modification; Interfacial C coating; High-temperature stability

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

Lightweight Surface Toughened Thermal Protection Composites

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The rapid development of new-generation reusable hypersonic aircraft put forward urgent demands on lightweight, reusable, non-ablative, and highly reliable thermal protection composites. As a kind of advanced lightweight and reusable thermal protection materials, TUFROC has been successfully served on the thermal protection system of X-37B aircraft, however, this material still faces problems such as insufficient mechanical properties and poor scouring resistance in service, which seriously affects the reliability of the material. On this background, we developed a new type of lightweight, non-ablative, and reusable thermal protection composites called lightweight surface toughened thermal protection composites. Needled carbon fiber braid was optimized as matrix to improve the mechanical strength, and a novel structure which called "Dense surface & Porous interior" was constructed through a innovative prepartion process to avoid thermal mismatch problem and enhance the anti-erosion performance of the composites. The mechanical, thermal, ablative resistance, and reusable properties of the composites were studied in detail. The overall density of the composite was lower than 0.5 g/cm^3, accompanied with the advantages of high compressive strength and low thermal conductivity. After being tested in an arc tunnel at 1700 °C, 940 s under a high dynamic pressure (>100 kPa) condition, the composite presented a low mass loss rate and linear ablative rate, showing an excellent anti-erosion and anti-oxidation performance. Meanwhile, the material passed an assessment of 1800 °C/1000 s combined with 2100 °C/120 s, realizing the reliable service in ultra-high temperature environments. Besides, the composite could also maintain the structure stability after 14 cycles of high-temperature oxidation environment test (1500 °C, 2000 s for one cycle), demonstrating outstanding reusable performance. This work could provide new sights into the design and preparation of thermal protection composites for reusable hypersonic aircraft.

Key words Reusable hypersonic aircraft; thermal protection composites; carbon fiber braid; high dynamic pressure

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

Understanding machinability improvements of ceramic matrix composites during laser-induced ablation assisted grinding

Kun Zhou*、Kun Zhou、Xin Li、Yun Huang
Chongqing University

Ceramic matrix composites (CMCs) are promising materials for some key components in aerospace and rail transit. A grinding procedure is necessary for a CMCs component to meet their shape and surface finish requirements. However, due to the hard-brittle, heterogeneous and anisotropic characteristics, CMCs can be easily subjected to various damages during grinding, including interface debonding and matrix cracking, which largely affects the service performance of a CMCs component. Aiming at solving the difficult-to-machine problem of CMCs, this study proposed laser-induced ablation assisted grinding (LIAAG) method, and performed an in-depth investigation on material removal mechanism, surface integrity and abrasive wear behavior during LIAAG of C_f/SiC composites. It is revealed that the C_f/SiC composites occurs a violent physicochemical transformation during picosecond laser ablating, resulting in the formation of SiO_2 and recrystallized SiC ablation products layer with loose structure. Compared with conventional grinding (CG), the grinding force, grinding temperature, surface roughness during LIAAG can be reduced by up to 87%, 64%, and 53%, respectively. Besides, carbon fiber macro-fracture and interface debonding are significantly decreased, the removal morphology of C_f/SiC composites is primarily shown as ductile removal, axial micro-fracture. Furthermore, the wear condition of diamond abrasive grains is greatly improved, and the wear form changes from crystal-face macro fracture to crystal-boundary micro fracture. More importantly, no residual ablation product is detected on the grinding surface. The observation results of grinding chips show that in addition to the loose ablation products, the carbon fibers in the ablated layer are cut flatly by laser, making it easier to remove during grinding. Consequently, the high-efficiency, low-damage, and low-abrasive wear machining of C_f/SiC composites is achieved through the proposed LIAAG. The work provides a theoretical and technical basis for the high-performance processing of CMCs components.

Key words C/SiC composites, Laser ablation, Grinding, Material removal

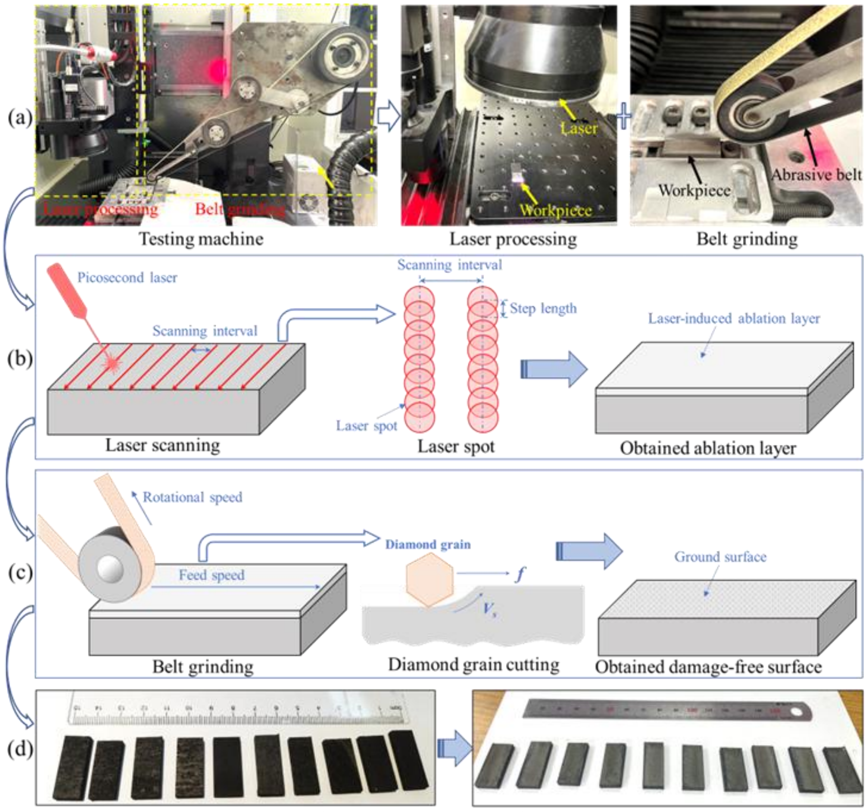

Fig. 1. LIAAG procedures: (a) LIAAG testing machine, (b) laser-induced ablation process, (c) belt grinding process, (d) C_f/SiC composites samples before and after LIAAG.

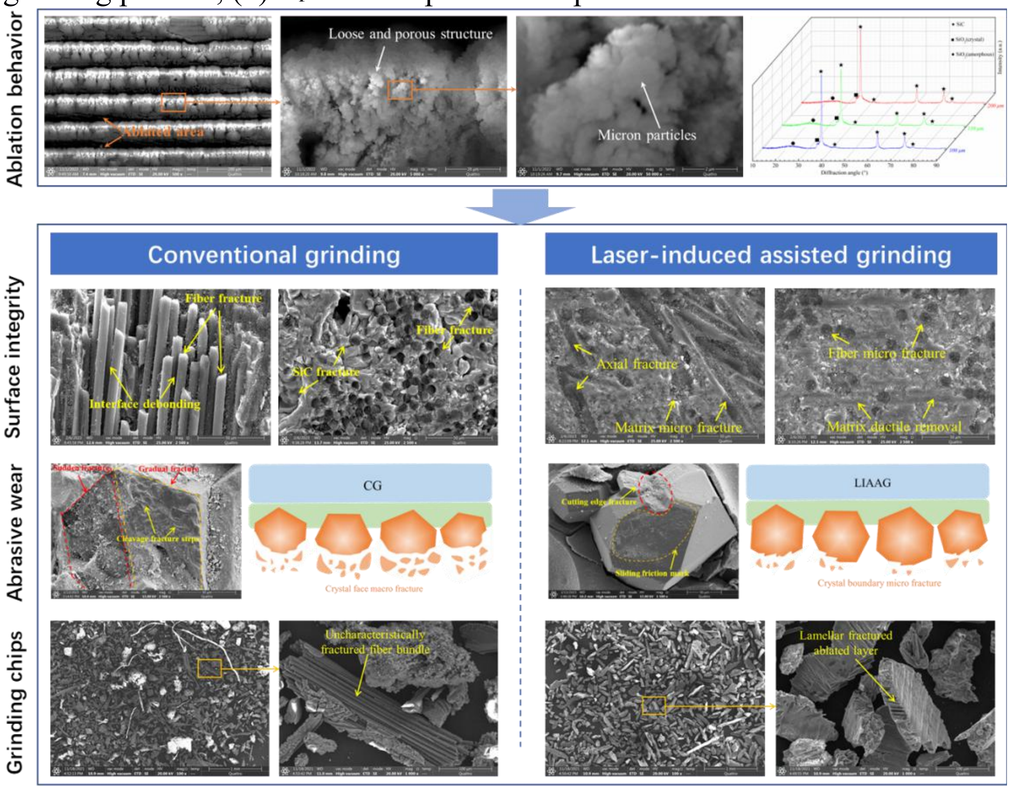

Fig. 2. Comparison of machining performance of CG and LIAAG.

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

Improved Thermal Conductivity of β-Si3N4 Ceramics Based on The "Nitrogen-Rich, Oxygen-Deficient" Liquid Phase Using YH2 as Sintering Additive

Weide WANG*
National University of Defense Technology

The combination of high thermal conductivity and excellent mechanical properties enables Si_3N_4 ceramics to be an ideal substrate material for high-power electronic devices. However, the thermal conductivities of Si_3N_4 ceramics were usually much lower than the theoretical value. The improvement of thermal conductivities relies on extended heat-treatment at high temperatures, which induced low mechanical reliability and high cost. Focusing on the thermal conductivity limiting factors of lattice oxygen content and thermal boundary resistance, we propose to regulate the grain growth kinetics and grain boundary film structure based on the "Nitrogen-rich, Oxygen-deficient" liquid phase using YH_2 as sintering additive.The effect of YH_2 on densification, microstructure, and thermal conductivity of Si_3N_4 ceramics were investigated by adjusting the amount of YH_2 in the range of 0 to 4wt% using a two-step sintering method. Native SiO_2 was eliminated, and Y_2O_3 was in situ formed by a metal hydride reduction reaction, resulting in a higher N/O ratio in liquid phase. Full densification of YH_2-doped samples could be achieved after sintering at 1900°C for 4h. The "Nitrogen-rich, Oxygen-deficient" liquid phase had a significant influence on the composition of crystalline secondary phases. Besides, the increased N/O ratio is conducive not only to the grain growth but also to the reduction of activity of SiO_2 in the liquid phase, resulting in enlarged purified grains, reduced volume fraction of intergranular phases and increased Si_3N_4-Si_3N_4 contiguity. Ultimately, the thermal conductivity increased by 29% from 95.3 to 123.0 $W\cdot m^{-1}\cdot K^{-1}$ after sintering at 1900 °C for 12h by the substitution of Y_2O_3 with YH_2.

Key words Silicon nitride; Liquid phase sintering; Thermal conductivity; Composition and structure regulation

Session: Ceramic Matrix Composites

Presenting Type：Oral-Onsite

A Study of Ultrasonic Vibration Assisted Drilling of Small Holes in Ceramic Matrix Composite

Jingfei YIN*、Jingyuan He、Honghua Su、Jiuhua Xu
Nanjing University of Aeronautics and Astronautics

Absract: Ceramic matrix composite(CMC) has been the most promising material to the hot components of the next generation aero-engines because of its excellent high-temperature resistance and high specific strength. For the next generation aeroengines, the working temperature of the hot components is the extremely high, which influences the performance of the CMC parts. Film holes are common structures for cooling. However, to make film holes in CMC is a big challenge. The hardness and brittleness of CMC are high, which generally leads to serious tool wear, undesired damage, and low machining efficiency during a machining process. This study represents the performance of ultrasonic vibration assisted drilling (UVAD) in machining small holes in CMC. It was found that tool wear was dramatically reduced by using UVAD. Compared with conventional drilling (CD), the tool life was extended three times. The variation of the diameters of the drilled holes was reduced by 60-86%, which is important to ensure the accuracy of the machined small holes. Therefore, UVAD is promising for machining the small holes in CMC. This study provides an effective solution for machining the film holes of the CMC parts in the future.

Key words Ceramic matrix composite, ultrasonic vibration assisted drilling, film hole, tool wear

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

Phase Prediction, Green Synthesis of High-Entropy Carbide Ultra-High Temperature Ceramic Powder and Preparation of Its Composite

Peitao HU*
Harbin Institute of Technology

Compared with traditional binary ultra-high temperature ceramics, high-entropy ultra-high temperature ceramics have a unique "high-entropy effect", which has been considered as a kind of thermal protection material with great application potential. However, due to the complex component structure of a high-entropy ceramic, the multi-component design strategy provides an almost infinite design space for the material, and how to quickly select the component system with a stable solid solution phase structure is of great significance to exert the "high entropy effect" of materials. To solve this problem, the criterion of enthalpy and entropy for high-entropy materials are established, and the first-principle calculation method is utilized to evaluate the synthesizability of the material and finds an easy-to-synthesize material component system. During the synthesis process of powder, utilizing glucose as a carbon source, and the problem of foaming of glucose under the high-temperature environment is overcome by combining with a gel structure, realizing the green synthesis of $Ti_{0.2}Zr_{0.2}Hf_{0.2}Nb_{0.2}Ta_{0.2}C$ powder via carbothermal reduction. Besides, this work also focuses on the inherent brittleness problem commonly faced by ultra-high temperature ceramic materials, through combining 3D continuous carbon fiber braid with high-entropy carbide ultra-high temperature ceramic with an efficient method, high-entropy ultra-high temperature ceramic composite has been fabricated. The mechanical, thermophysical, and ablation resistance properties of the composite are characterized, and the composite exhibits micro-ablation characteristics after being tested at 2500 °C/40 s. This work expands the compositional space of ultra-high temperature ceramics and provides a candidate material for next-generation ultra-high temperature thermal protection system.

Key words High-entropy carbide, ultra-high temperature ceramic, first-principle calculation, green synthesis, composite

Session: Ceramic Matrix Composites

Presenting Type：Oral-Onsite

A physics-informed machine learning approach for evaluating the rupture life of oxide/oxide ceramic matrix composites

Bo Zhang、Duoqi Shi、Changqi Liu*、Xiaoguang Yang
Beihang university

In the ultra-high temperature environment, the oxide/oxide ceramic matrix composites (CMCs) were penalized by high sensitivity to creep. Therefore, creep must be considered to avoid excessive strain or premature failure in the design of oxide/oxide CMCs components for high temperature applications during the anticipated lifetime of the structure. In this work, a unified physics-informed machine learning (PIML) model was proposed for creep rupture life prediction and key feature parameters identification of oxide/oxide CMCs. To ensure the integrity of the test information and the comparability of different magnitude indicators, the Light Gradient Boosting Machine algorithm and the Z-Score method were first used to fill the missing values and standardize the collected dataset, respectively. Afterwards, a high-explanatory data-based model coupling the microstructural characteristics and multi-mode damage was established by the machine learning (ML) method. The rupture life of oxide/oxide CMCs in a high temperature service environment was accurately predicted by the PIML model, which combined the physical information of creep damage with the ML method. The global sensitivity analysis method was finally used to accurately identify the key feature parameters affecting the rupture life. The results indicate that the predicted data of the PIML model lies in the ±3 error bands and can be applied to the creep rupture life prediction of a new material dataset due to its powerful generalization ability. The steady-state creep rate, loading stress, and test temperature are the key parameters of creep fracture life, which exhibits great consistency with physical experience and experimental results. This work demonstrates that the well-trained PIML model can be used for rapid evaluation and key feature parameters identification of the rupture life of CMCs, providing theoretical support and analysis methods for the design of CMCs components for high temperature applications.

Key words oxide/oxide ceramic matrix composites, creep rupture, physics-informed machine learning, life prediction

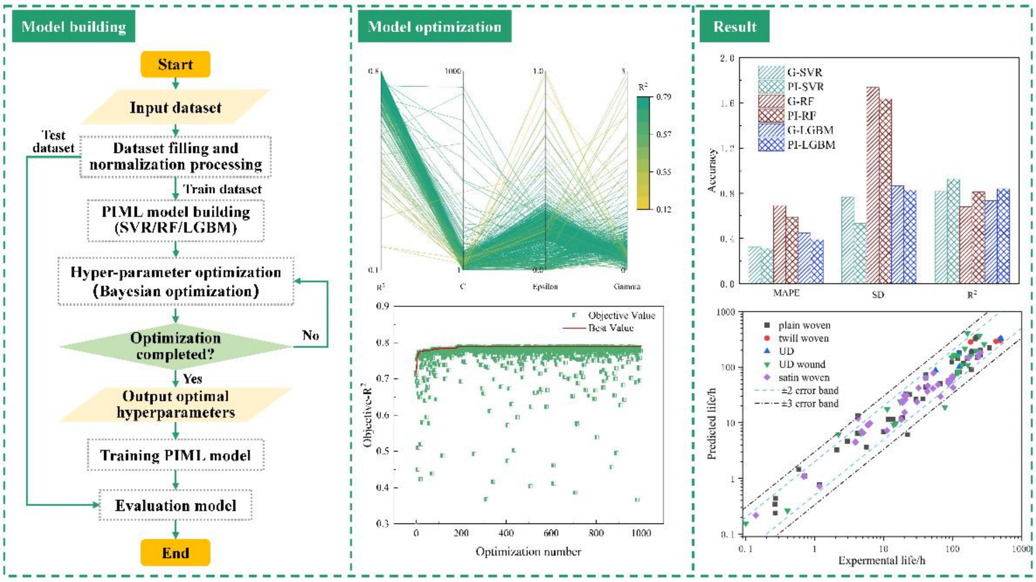

Fig. 1. The main research content and methods of this paper.

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

Preparation and Properties of Ultra High Temperature Ceramic Matrix Composites via Polymer-Infiltration-Pyrolysis process

Yuchen PEI*、Tongchen Sun、Wei Liu、Junpeng Liu
Research Institute of Aerospace Special Materials and Processing Technology

Ultra high temperature ceramic matrix composites are a kind of composite materials, with continuous carbon fiber as reinforcement and ultra high temperature ceramics as matrix. They have received great attention due to their application potentials in the thermal protection system of hypersonic vehicles. The development of the technology of preparing ultra high temperature ceramic matrix composites by polymer-infiltration-pyrolysis process is introduced, as well as the design and synthesis of ultra high temperature ceramic precursors, and the preparation and properties of C/ZrC-SiC and C/HfTaC-ZrC-SiC composites. Moreover， the future research trends of ultra high temperature ceramic matrix composites based on the recent research results are summarized and prospected.

Key words ultra high temperature ceramic matrix; composites; polymer-infiltration-pyrolysis process.

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Ceramic Matrix Composites

Presenting Type: Oral-Onsite

A Novel Method for Synthesizing High-quality SiC Nanoparticles

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Silicon carbide (SiC) ceramic matrix composites have attracted much attention due to their excellent performance and great application potential. To synthesize SiC ceramic matrix composites with high-quality and multi-performance, the quality of raw SiC nanoparticles is of great importance. While searching for a low-cost and environmentally friendly method for the preparation of high-quality SiC nanoparticles is still a challenge. In this work, high-quality SiC nanoparticles were synthesized through an innovative two-step method combining hydrothermal and carbothermal reduction processes by employing low-cost SiO_2 nanoparticles and glucose as raw materials. A core-shell structure of SiO_2@C was constructed via hydrothermal of SiO_2 nanoparticles and glucose solution to ensure sufficient contact of the reactants and it could also promote the dispersion of particles (SiO_2 nanoparticles would melt and sinter at high temperature) during the carbothermal reduction process. The results demonstrated that the processing parameters were critical for the as-prepared products. The optimized conditions for synthesis of high-quality SiC nanoparticles with a diameter of ~50 nm were selected as follows: the hydrothermal was carried out at 160 °C for 12 h and the carbothermal reduction at 1500 °C for 1h. This novel synthesis method was low-cost, environmentally friendly, and could obtain SiC nanoparticles with good dispersibility and great morphology, outperforming most of the reported traditional carbothermal reduction methods. This study offered a facile yet feasible strategy for synthesizing materials to address the agglomeration and uneven morphology problems of product SiC nanoparticles in a more low-cost and environmentally friendly manner which could lay the foundation for the synthesis of high-quality SiC ceramic matrix composites.

Key words SiC nanoparticles; Carbothermal reduction; Core-shell structure; Low-cost; Environmentally friendly; Nanoparticles dispersibility; Nanoparticles morphology

Session: Ceramic Matrix Composites

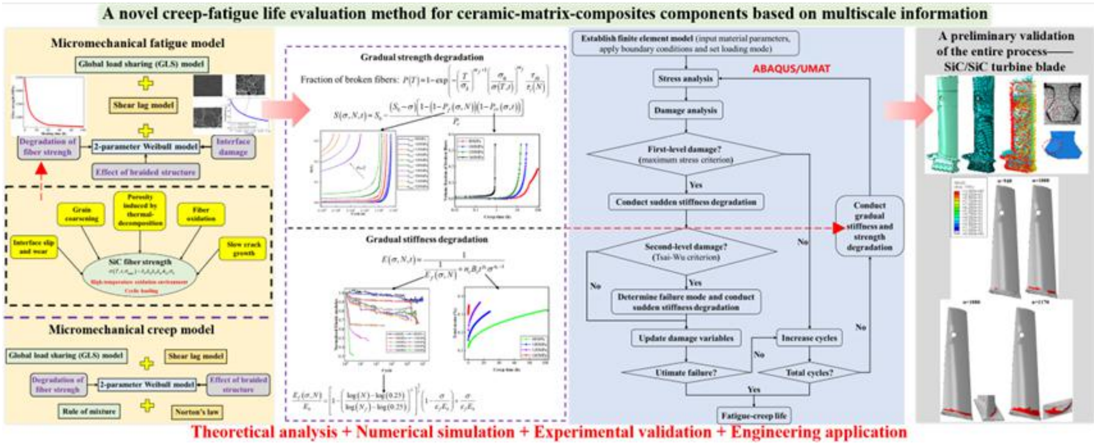
Presenting Type: Oral-Onsite

A novel creep-fatigue life evaluation method for ceramic-matrix-composites components based on multiscale information

Changqi Liu*、Duoqi Shi、Xiaoguang Yang
Beihang University

SiC/SiC composites, as representative ceramic matrix composite (CMC), are considered as ideal lightweight and reusable structural materials that can operate for long periods in extreme high-temperature environments. However, the damage to SiC/SiC composites is characterized by multi-mode, cross-scale, and strong interactions under complex mechanical loads and operating environments, resulting in significant challenges in predicting the service life of SiC/SiC composites and their structural components. A novel progressive creep-fatigue damage analysis method based on multiscale information was proposed to accurately predict the service life of SiC/SiC composites and their structural components under complex mechanical loads and external environments. First, the strength degradation of SiC fibers involving five damage mechanisms and degradation of the properties of the interface under high-temperature fatigue loading were described quantitatively based on experimental results. Subsequently, a micromechanical model incorporating the global load sharing model, two-parameter Weibull model, shear-lag model, property degradation models of various constituents, and the effect of the braiding angle was utilized to calculate the volume fraction of broken fibers. The fatigue life of 3D 4-directional SiC/SiC composites was predicted and exhibited a trend similar to that of the experimental data. The rupture life of the SiC/SiC composites was calculated considering the stress transfer among microscopic constituents and the influence of creep slow crack growth on the fiber strength. The volume fraction of broken fibers obtained in these micromechanical models was used to perform a gradual strength degradation in the novel progressive creep-fatigue damage analysis method. Microscopic constituents damage and macroscopic property degradation were quantitatively linked in this step. This infuses the micro information into the traditional phenomenological progressive damage method. The gradual stiffness degradation rules were derived from the fitting of the residual elastic modulus obtained from the fatigue and creep experiments. Finally, the damage evolution and service life of SiC/SiC turbine blades were simulated and evaluated as a preliminary validation of the entire process.

Key words ceramic matrix composites; high-temperature fatigue; creep; micromechanics; life prediction


A novel creep-fatigue life evaluation method for ceramic-matrix-composites components based on multiscale information
Micromechanical fatigue model
Global load sharing (GLS) model
Shear lag model
Degradation of fiber strength
2-parameter Weibull model
Interface damage
Effect of braided structure
Grain coarsening
Porosity induced by thermal-decomposition
Fiber oxidation
Interface slip and wear
Slow crack growth
SiC fiber strength
Micromechanical creep model
Global load sharing (GLS) model
Shear lag model
Degradation of fiber strength
2-parameter Weibull model
Effect of braided structure
Rule of mixture
Norton's law
Gradual strength degradation
Fraction of broken fibers:
Gradual stiffness degradation
Establish finite element model (input material parameters, apply boundary conditions and set loading mode)
ABAQUS/UMAT
Stress analysis
Damage analysis
First-level damage? (maximum stress criterion)
Yes
Conduct sudden stiffness degradation
Conduct gradual stiffness and strength degradation
Second-level damage? (Tsai-Wu criterion)
No
Yes
Determine failure mode and conduct sudden stiffness degradation
No
Update damage variables
Increase cycles
No
Utimate failure?
Total cycles?
No
Yes
Fatigue-creep life
A preliminary validation of the entire process—— SiC/SiC turbine blade
Theoretical analysis + Numerical simulation + Experimental validation + Engineering application

Session: Ceramic Matrix Composites

Presenting Type: Oral-Virtual Platform

A Method Considering Manufacturing Defects for Predicting The Equivalent Elastic Constants of Needled C/SiC Composites

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1. School of mechanical engineering, Dalian University of Technology
2. School of Aeronautics and Astronautics, Dalian University of Technology

Due to the composition and process, ceramic matrix composites are prone to manufacturing defects. As a result, the properties of composites are discrete and difficult to predict. A novel model for predicting the equivalent elastic constants of needled C/SiC composites is proposed. The manufacture defects caused by needling process were taken into account in the model. Based on the micro-CT scanning data of the composite, the microstructure characteristics of the fiber and matrix were analyzed by using the three-dimensional reconstruction software. Needled C/SiC composites were mainly divided into three parts: unidirectional fiber bundle layer, random short fiber layer and needled bundle. Two kinds of manufacturing defects, the pore and the fiber deflection, were simplified and characterized. The mesoscale pore was described as a tetrahedron. Two deflection angles were definite to describe the effects of fiber deflection. Three mesoscopic models were established by considering different quantity state of defects respectively. In these models, the elastic properties of each part were predicted theoretically. Then, the prediction model was homogenized by using periodic boundary conditions, and the equivalent elastic constants of the needled C/SiC composites were obtained. The comparison between the prediction results of the three models and the experimental data showed that the mesoscopic models considered the fiber deflection and pore defects were in good agreement with the experimental data. At last, the quantitative relationship between process parameters and manufacture defects was established to discuss the influences of different process parameters on the elastic constants of needled C/SiC composites. The results shows that needling density has significant influences on in-plane performance.

Key words Needled C/SiC composite; Manufacturing defect; Pore; Fiber deflection; Mesoscopic model

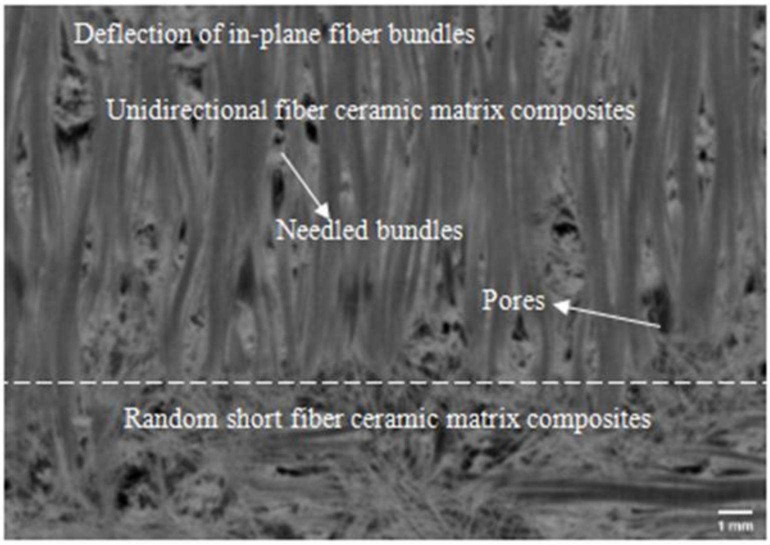

Fig. 1. Needled C/SiC composites microstructure of X-Y plane slice by micro-CT method.

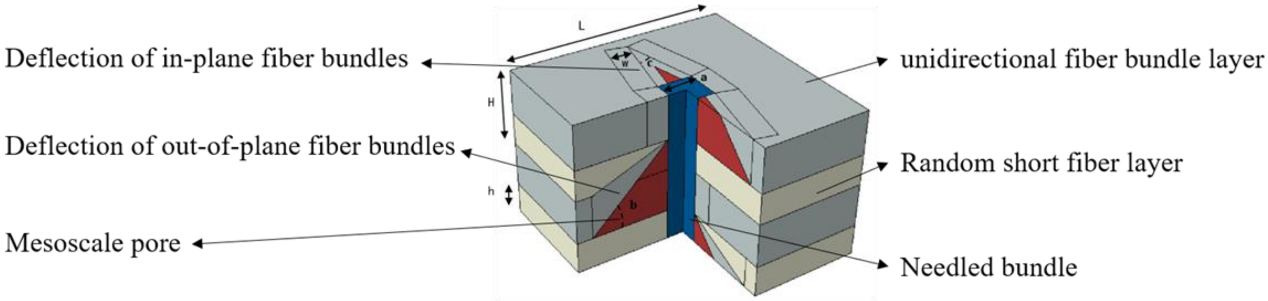

Fig. 2. Needled C/SiC composites mesoscopic model considering fiber deflection and pore.

Session: Ceramic Matrix Composites

Presenting Type: Oral-Virtual Platform

Enhanced Emissivity and Ablation Resistance of Multi-Layer Lightweight and Porous Carbon Fiber Composites

Lingyu YANG*
Harbin Institute of Technology

Severe aerodynamic heating of the vehicle surface occurs during hypersonic flight, with peak surface temperatures of components such as the nose cone and windward surfaces reaching 1700°C, posing a significant challenge to the anti-ablation resistance of thermal protection system materials. Ceramic coating approache has reported to be one of the most effective techinique in improving emissivity and ablation resistance. However, ensuring the lightweight of composites, improving the matching ability between the coating and matrix, and increasing emissivity remain a hot issue. This study used a modified porous carbon fiber braid as the substrate and optimized the manufacturing process to fabricate composites with a dense surface layer and porous inner layer to improve the thermal matching and ablation resistance. The overall density of the composite after the preparation of the dense layer is less than 0.5 g/cm^3, while the maximum emissivity is observed to occur with a value of 0.872 in the range of 2-14 μm at room temperature. The total emissivity rate decreased by 0.02 as the temperature rising to 1700 °C. Furthermore, the prepared dense layer exhibited excellent low mass and linear ablation rates under oxyacetylene ablation conditions with 1700 °C for 1000 s. This work presents a simple approach to achieve the synergy of high emissivity and superior ablation resistance of multi-layer lightweight and porous carbon fiber composites for thermal protection systems.

Key words Lightweight; Dense surface layer; Porous inner layer; Emissitity; Ablation resistance

Session: Ceramic Matrix Composites

Presenting Type：Poster

Thermal properties and thermal stability of (ZrxY1-x/4Ta1-x/4Al1-x/4Cr1-x/4)O

Yuhui Chen*、Pengyang Jiang、Jiaxiang Sun、Baiqiang Zhang、Jun Song
Zhengzhou University of Light Industry

The thermal conductivity of (ZrxY1-x/4Ta1-x/4Al1-x/4Cr1-x/4)O (x=0.2, 0.3, 0.4, 0.5, and 0.6) composite ceramic materials was investigated by molecular dynamics simulation. It is found that the thermal conductivity of the five groups of models has the same trend in the temperature range of 200 °C~1100 °C, which increases first and then decreases, reaching its maximum value at 900 °C. When x = 0.2, the thermal conductivity is the smallest compared with the other groups. Because the oxygen vacancies generated by doping are the most when x = 0.2, the phonon free path is reduced, which affects the heat transport inside the model. At the same time, high entropy ceramics (Zr0.2Y0.2Ta0.2Al0.2Cr0.2)O were prepared by the solid phase reaction method, and the thermal stability at high temperatures was studied. It was found that the volume of sintered samples at 1600 °C was significantly smaller than at 1500 °C. By means of XRD and SEM, it was found that the two groups of samples had a biphasic structure, and the second phase that existed at 1600 °C was significantly more than that at 1500 °C.

Key words Molecular dynamics; thermal conductivity; high entropy ceramic; thermal stability

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Ceramic Matrix Composites

Presenting Type: Published only

Multi-scale Analysis for 3D Braided Composites with Variable Geometrical Parameterized Fiber Bundle

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In 3D braided composites, the extrusion of the fiber bundle will inevitably alter the fiber bundle&39;s cross-sectional parameters. To predict the effects of fiber bundle cross-section parameters on mechanical properties 3D braided composites, a multi-scale prediction model is developed to predict the mechanical properties of 3D braided composites. In this model, fiber bundle properties are transferred to the mesoscale, and macroscopic mechanical properties are predicted using finite element and theoretical methods. The damage evolution was appraised based on continuous damage mechanics. A user-defined material subroutine (UMAT) in nonlinear finite element analysis is written to implement the proposed model and determine the response and damage evolution of 3D braided composites under quasi-static tension. The effects of fiber bundle cross-sectional shapes and area on tensile progressive damage and effective tensile modulus and strength of 3D braided composites are predicted. The modulus and strength of braided composites are positively correlated with the cross-sectional area of the fiber bundle. The modulus and strength of fiber bundle model with a large cross-sectional area are higher; The tensile modulus and strength are also related to the cross-sectional geometry of the fiber bundle. The more the number of fiber edges, the smaller the modulus and the more stable the prediction interval is. Under the same fiber bundle cross-sectional shape, the damage degree of fiber bundle X is intensified, the Z and Y damage element percentages decrease and tend to be similar, and the damage of matrix decreases, with the decrease of cross-sectional dimensions. Under the same cross-sectional area, the damage degree of fiber bundle X decreases, the damage degree of Z/Y tends to be similar gradually, and the damage of matrix decreases, with the increase of cross-sectional sides of the fiber bundle. This point can be well captured by the proposed multiscale damage model.

Key words 3D Braided composite; Multiscale analysis; Damage mechanics: Variable geometry

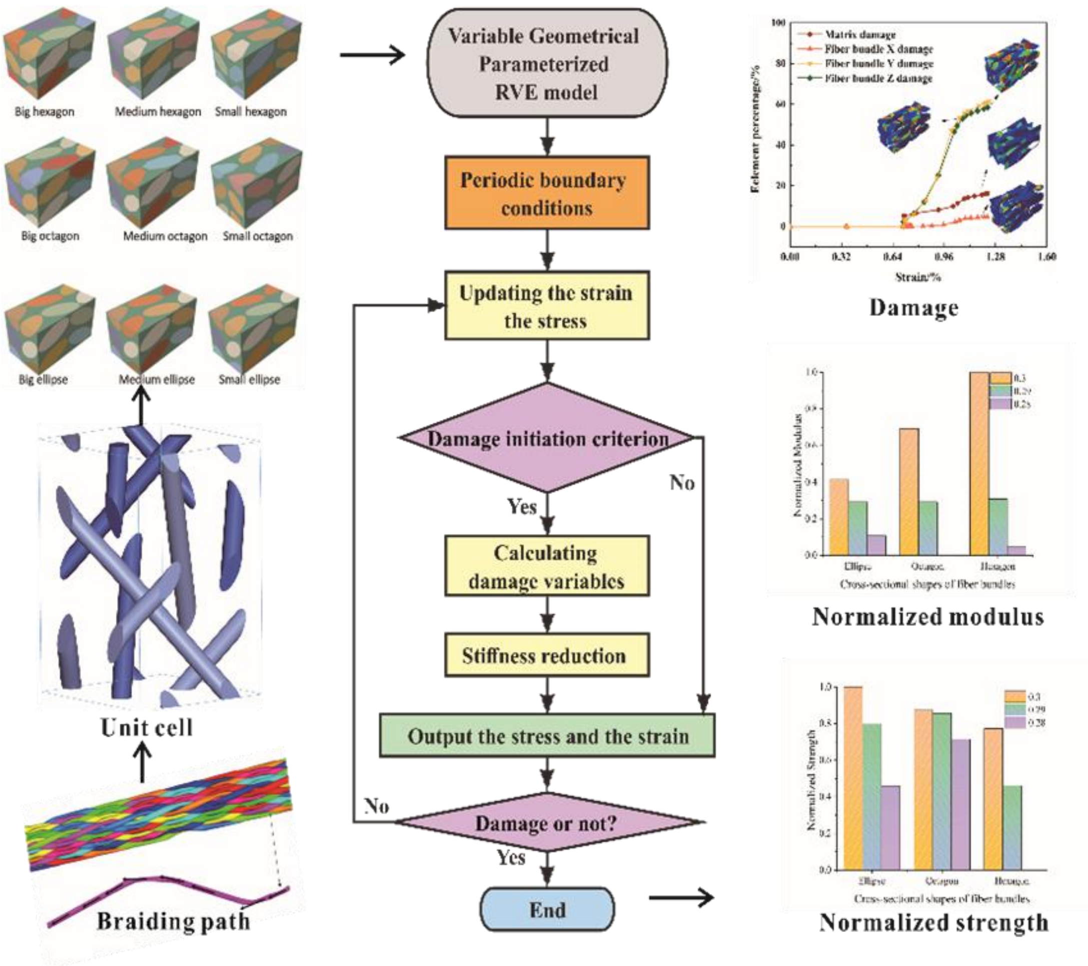

Fig.1. Analytical method

Session: Ceramic Matrix Composites

Presenting Type: Published only

Microstructure and mechanical properties of SiCf/SiC-Nb2AlC composites by Si melt infiltration

Yiran Zhou*、Jian Jiao、Jinhua Yang、Hu Liu、Yingjun Ai
National Key Laboratory of Advanced Composites, AECC Beijing Institute of Aeronautical Materials, Beijing

Continuous SiC fiber reinforced SiC matrix composites (SiCf/SiC) are the potential candidates for high temperature structural applications because of the excellent mechanical properties, low density, good thermal stability, oxidation resistance and corrosion resistance. For the purpose of the high toughness for the specific technological applications, the improvement of the toughness of the SiCf/SiC composites needed to be considered. Due to the high hardness and brittleness of the SiC, a second toughening phase is considered to introduce to the matrix. The ternary carbides and nitrides with the general formula Mn+1AXn (M: early transition metal, A: A group element, mostly III A or IV A, X: either C or N, n=1–3) have attracted much interest, which possess a unique combination of ceramic and metal properties due to its special structure.
In this study, we focus on Nb2AlC, which similar to other Mn+1AXn phases, relatively damage tolerant and resistant to thermal shock, and easily machinable. Nb2AlC has attracted considerable attention for the remarkable high-temperature oxidation resistance among the MAX phases. In this study, a novel SiCf/SiC-Nb2AlC composites were prepared by the Si melt infiltration, in which Nb2AlC phase is directly added to the SiC matrix. This method avoids the byproducts that the in situ synthesis would bring, and simplify the fabrication process. The lamellar Nb2AlC grains increase the strength and toughness of SiC matrix by the mechanisms such as crack deflection, grain's pull-out and fine-grain toughening. The lamellar Nb2AlC grains as the reinforcing agents in the SiC matrix exhibit significant strengthening and toughening effect to the SiC matrix and the composites show excellent mechanical properties. The bending strength and fracture toughness of SiCf/SiC-Nb2AlC composites can be greatly improved.

Key words Melt infiltration, SiC/SiC composites, MAX phase

Session: Ceramic Matrix Composites

Presenting Type: Published only

Preparation and Characterazation of Hot pressed SiCf/SiC Ceramic Matrix Composites

Qi Li[1]、Jian Jiao*[1,2]、Lamei Cao[1]、wei Wei[1]
1. AECC Beijing Institute of Aeronautical Materials
2. AECC Beijing Institute of Aeronautical Materials

In this paper, SiC_f/SiC ceramic matrix composites were prepared by hot pressing at 1700°Cwith the second-generation SiC fibers as reinforcements, and their basic physical and mechanical properties were characterized. The results show that the bulk density of SiC_f/SiC ceramic matrix composite is about 2.50g/cm^3, the open porosity is about 6.50 %. The typical values of tensile strength and tensile modulus are 261 MPa and 179 GPa respectively, and the typical values of bending strength and bending modulus are 621 MPa and 129 GPa respectively.

Key words Hot pressing, SiCf/SiC, ceramic matrix composites, mechanical properties

Session: Ceramic Matrix Composites

Presenting Type: Published only

Study on the Thermal Shock Performance of SiCf/SiC Composites

Z Y Jiang*、J jiao
AECC

In this paper, a study on the thermal shock performance of SiCf/SiC composites was carried out, and internal stresses during thermal shock of the composites were analyzed by finite element analysis. Results in the present study show that after 2000 cycles of thermal shock at 1200°C, the tensile property of the composites was improved with a strength retention of 107% and a slight reduction in bending strength with a retention of over 95%. Surface elemental analysis (SEM) of samples shows that during the thermal shock at 1200°C-2000°C, an oxide film was formed on the surface of the composite material with a thickness of about 7 μm. The oxide film above is considered to be a silica film, which can form a protective layer on the composite surface, preventing oxygen molecules from entering the samplethrough the pores on the surface of the composite. Therefore , the oxidation reaction of SiC fibers or interfacial phases during high temperature thermal shock cycling can be avoided, and both the oxidation resistance of the composite and the strength retention of the composite can be improved.

Key words Composites，thermal shock performance, SiCf/SiC

Session: Carbon Composites

Presenting Type: Oral

New carbon materials with novel properties from high pressure

Mingguang Yao*
State Key Laboratory of Superhard Materials, College of Physics, Jilin University

Design and synthesis of new carbon materials have been attracting intensive attention due to their application in various fields. The study of carbon nanostructures under high pressure provides us a very effective method to create new carbon material with novel structures and properties which are hardly observed at ambient conditions. In this presentation, I will introduce the latest progress on the new structures and properties of carbon materials under high pressure from our group. Firstly, I will introduce the synthesis of nearly all sp3 amorphous carbon bulk material from high temperature and high pressure (HPHT)-treated C60. We explored the reaction phase diagram of C60 up to 37GPa by using our developed large volume press technology for the first time. From different HPHT conditions, amorphous carbon materials with different sp3 contents were synthesized. These amorphous carbons exhibit a wide range of optical band gaps, depending on the sp3 concentrations. Particularly, an amorphous carbon bulk material with nearly pure sp3 bonds was synthesized for the first time, which shows an optical band gap of 2.7eV and extremely high Vickers hardness of 102 GPa, close to that of diamond. sp3 amorphous carbon is a multifunctional superhard amorphous carbon material with the highest thermal conductivity and hardness known in the amorphous materials up to now [Nature 599, 599 (2021)]. In addition, I will also talk about the disign of a eutectic Sc3N@C80 -cubane crystal with anomalous negative volume compressibility. The charge transfer from fullerene cage to cubane promotes the configuration change of cubane, which transforms into a “low density” configuration, resulting in an abnormal lattice expansion of the crystal [J. Am. Chem. Soc., 2020, 142, 7584]. This is the first experimentally discovered crystal which has negative volume compressibility.

Key words Fullerene, Superhard, Negative volume compressibility, High pressure

Hangzhou, PR China 25-28 April, 2023

Session: Carbon Composites

Presenting Type：Oral−Invited

Strategies for stable cycling of low-cost silicon microparticulates

Shichao Wu、Shichao Wu*、Quan-hong Yang
Tianjin University

Silicon micro-particle (SiMP) with low-cost, low specific surface area and high capacity is an alternative anode for next generation of lithium-ion batteries. The lithiation and delithiation of SiMPs features large volume expansion (~300%), leading to particle cracking and pulverization, solid electrolyte interface formation and fragmentation, particle debonding from current collector and electrode fracture. These issues critically hinder the application of Si anodes.

We focus on both mechanical control and adaptive electrical connection strategies for stable cycling of low-cost SiMP anodes. First of all, we design a strong yet ductile carbon cage from an easily processing capillary shrinkage of graphene hydrogel (Figure 1). Such a structure, analog to the stable structure of plant cells, presents "imperfection-tolerance" to volume variation of irregular SiMPs, maintaining the electrode integrity over 1000 cycles. Further, we propose liquid metal (LM) as an adaptive conducting continuum to cure electrical disconnection (Figure 2). LM encapsulated in a carbon layer constructs a local electrical "ocean" adaptively connecting pulverized Si "islands" upon cycling. With the increased tap densities (4.15 and 1.75 g cm−3 respectively for the composite and the electrode), these thick electrodes give highly stable and superior volumetric lithium storage.

Key words lithium-ion battery; silicon anode; graphene; liquid metal

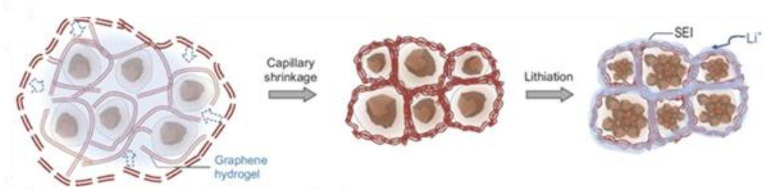

Fig. 1. Schematic of a stress control design for SiMP anodes.

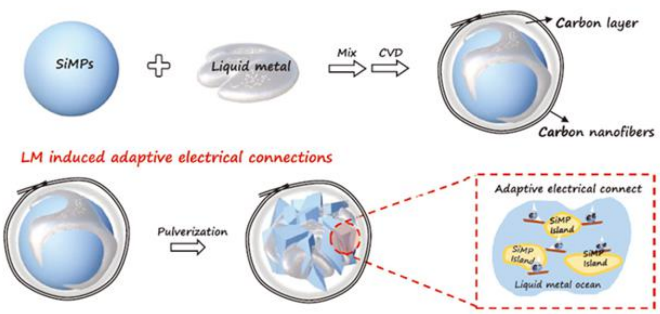

Fig. 2. Schematic of adaptive electrical connections for SiMP anodes.

Session: Carbon Composites

Presenting Type: Oral-Invited

Extreme Properties of Carbon Nanotubes and Their Applications

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2. University of Chinese Academy of Sciences
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4. Tsinghua University

Carbon nanotubes (CNTs) have excellent mechanical, electrical and thermal properties and have great potential to be used in many cutting-edge applications. In terms of extreme mechanical properties, we designed a non-contact acoustic resonance testing system to test the fatigue characteristics of a single defect-free ultra-long CNTs. The ultrahigh fatigue-resistance of CNTs and the fatigue failure mechanism dominated by single-bond-size defects were obtained. The controllable preparation of continuous cm-length CNT bundles with defect-free and well-aligned structure was realized by using the "gas flow focusing method". By further introducing "synchronous tightening and relaxing" strategy, the tensile strength of the bundles was increased to more than 80 GPa. The bright future of CNTs for flywheel energy storage was demonstrated. In terms of extreme electrical properties, the dynamic electrical failure behavior of CNTs and their application in lightning striking protection of large aircrafts were studied.

Session: Carbon Composites

Presenting Type: Oral-Invited

Research on the carbon/carbon composites reinforced by carbon nanotubes

qiang song*[1]、he jun li[1]、qian gang fu[1]、wei li[1]
1. Northwestern Polytechnical University

Carbon/carbon composites (C/Cs), as high-temperature materials, are widely used in aerospace industry. During the fabrication of C/Cs, microdefects, including matrix annular crack and fiber/matrix (F/M) interface relaxation, are unavoidable, which have a negative effect on their mechanical properties. To alleviate this limitation, it is efficient to apply in-situ growing carbon nanotubes (CNTs) in carbon fiber preform to strengthen carbon matrix and F/M interface as the secondary reinforcements. The introduction of CNTs in C/Cs will result in the formation of multiscale hybrid composites (CNT-C/Cs), which have attracted wide attention recently.

The present work is focused on how to fabricate CNT-doped carbon fiber preform by chemical vapor deposition (CVD), and how to control the dispersion morphologies of CNTs in carbon fiber preform, including CNT orientation, length, content and dispersion position. The effects of the doped CNTs on the microstructures, mechanical prosperities and mechanical strength retention before and after graphitization of C/Cs were discussed. Results show that the morphology of CNTs in carbon fiber preform could be controlled by adjusting the CVD parameters, mainly including the CVD temperature, gas system and deposition time. CNTs with different morphologies have different influences on the microstructures and mechanical prosperities of C/Cs. For example, randomly-oriented curved CNTs always induce the formation of isotropic carbon matrix and the porous F/M interface, which results in a moderate mechanical strength improvement and a great fracture ductility increase of C/Cs. Radially-aligned straight CNTs would induce the refined carbon matrix and the compact F/M interface, which results in over 200% mechanical strength improvements and sharp decrease of the fracture ductility. In addition, compared with the randomly-oriented curved CNTs, radially-aligned straight CNTs can not only decrease the anisotropy of compressive properties better, due to the smaller difference between out-of-plane and in-plane strength of the reinforced C/Cs, but also endow C/Cs with a higher retention of mechanical strength after high-temperature graphitization. The growth position of CNT has obvious effects on the out-of-plane compressive properties of C/Cs. As the CNTs are deposited on the surface of fibers, the mechanical strength of C/Cs will increase obviously since CNTs greatly reinforce the F/M interface of C/Cs, and C/Cs exhibit a brittle fracture characteristic. Adding CNTs in the space between carbon fibers can not only enhance the mechanical strength but also

drastically improve the fracture ductility of C/Cs, which is mainly attributed to the formation of the multilayer structured carbon matrix due to the existence of CNTs dispersed in the spaces between fibers.
The present results strongly indicate that it is important to design and control the morphology of CNTs in carbon fiber preform for regulating the service performance of CNT-C/Cs, which needs further research.

Key words carbon/carbon composite; carbon nanotube; multiscaled reinforcement

Session: Carbon Composites

Presenting Type: Oral-Invited

Research on High Performance Diamond Enhanced Thermally Conductive Composites

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Centre for Composite Materials and Structure

With the continuous and in-depth development of a large scale, high integration, and high power integrated circuit, its power density has enlarged rapidly, arising the issue of heat dissipation that severely impacts the efficiency and life span of electron devices. Therefore, the corresponding technologies of thermal conduction and heat dissipation are bound to be improved. Diamond is an isotropic thermally conductive material with high thermal conductivity of 2200 W·m-1·K-1 whilst relatively low thermal expansion coefficient and density, theoretically recognized as an ideal filler with high expectation for obtaining high thermal conductivity composites. Based on these, this report focuses on the main research of high thermal conduction diamond reinforced thermally conductive composites, and demonstrates our studies of diamond reinforced composites with three directions in recent years. Moreover, significant attentions are paid to scientific research hot issues such as diamond surface treatment, construction of external field-induced assisted thermal conduction paths, self-assembly of nanomaterials, additive manufacturing of diamond-metal composites. Additionally, the hot problems with common concerns of poor diamond wettability, limited enhancement of diamond thermal conductivity, and interfacial phonon heat transfer in diamond composites are attempted to be solved. Finally, relevant scientific research results with definite requirements and excellent properties show a powerful engineering application value in the fields of thermal interface materials, electronic packaging materials, and structural-functional integrated materials.

Key words diamond, high thermal conductivity composites, diamond enhanced thermal conduction, thermal interface materials

Session: Carbon Composites

Presenting Type: Oral−Invited

Vertically aligned graphene aerogel with high thermal conductivity obtained by a lyophilization-free approach

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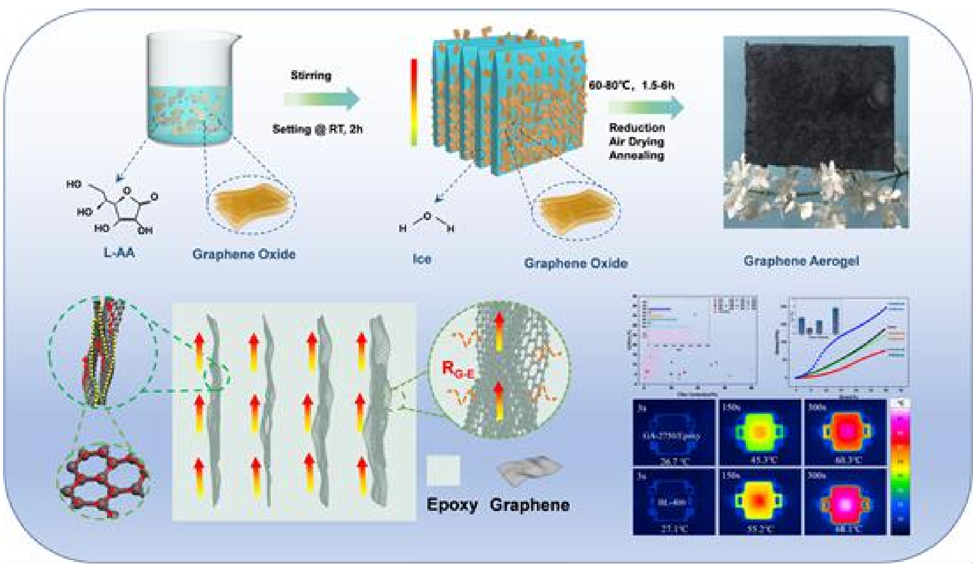
2. Harbin Institute of Technology

Compared with a disordered network, the aligned framework is more profitable for improving the thermal properties of composites. However, due to the long and complex lyophilization process, the current methods of building ordered structures are time-consuming and energy-intensive. Herein, low-density graphene aerogel (GA) with long-range oriented structure is obtained by a lyophilization-free approach followed by direct air-drying without severe contraction attributed to the strong π-π interaction. After annealing and compositing, the GA-2750/epoxy exhibits an ultrahigh thermal conductivity (~14 W m^{-1} K^{-1}) with a low graphene loading of 2.44 vol% (enhancement efficiency of 3330% per 1 vol%). According to the simulations, when the arrangement of graphene sheets is parallel to the heat flow, the thermal conductivity is optimal due to the lesser thermal boundary resistance. Moreover, the modulus of compression for composites is as low as elastic epoxy (0.1~0.4 MPa for composites and 0.25 MPa for epoxy). And for the composite with a thickness of 11mm, the total interfacial thermal resistance measured is just 0.002 K m^2 W^{-1}. Such outstanding performances mean that aligned-graphene/epoxy composites fabricated by this approach can be used as TIMs in advanced electronic packaging fields to heighten heat transfer.

Key words thermal interface materials, lyophilization-free, graphene aerogel, long-range oriented structure



Session: Carbon Composites

Presenting Type: Oral-Invited

Creating robust solid-state electrolyte and interface for advanced solid-state batteries

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Solid-state lithium batteries (ASSLBs) face the critical challenge of an extremely poor room temperature (RT) performance. The high-impedance electrode/solid-state electrolyte interface and low ionic conductivity of solid-state electrolyte restrict the improvement of the performance of the solid-state battery. An ultra-thin ZnO layer was constructed on the surface of Li1.4Al0.4Ti1.6(PO4)3 by magnetron sputtering, which effectively solve the problems of high interface impedance, interface instability and lithium dendrite growth. A stable interface chemistry and multiple ion transport of composite electrolyte was designed, which contributes to ultra-long cycling solid-state liNi0.8Co0.1Mn0.1O2/lithium metal batteries. A low-impedance integrated all-solid-state lithium battery was designed by using PEO-LiTFSI (PL) all-solid electrolyte with Li7La3Zr2O12 nanowires and PL-based cathode binder, which effectively reduces the ion transportation impedance at the cathode/electrolyte interface and in the cathode. In addition, we constructed a highly efficient ''solid–polymer–solid'' elastic ion transport network in cathodes, which can activate the room temperature performance of all-solid-state lithium batteries. Finally, we reveal lithium-ion spontaneous exchange and synergistic transport in ceramic liquid hybrid electrolytes for highly efficient lithium-ion transfer.

Key words Solid-state batteries, interface, ion transport, solid-state electrolyte

Session: Carbon Composites

Presenting Type: Oral-Invited

Structure designs and mechanics of highly strong carbon nanotube fibers

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Harbin Institute of Technology

In this topic, we designed a hierarchical helical carbon nanotube fibers (HCNFs), and investigated the tensile mechanical properties of HCNFs by molecular simulations and continuum theory. Especially, the roles of helical morphology on mechanical enhancement were revealed. Based on theoretical guidance, the shearing and peeling failure mechanism in HCNFs were studied by advanced in-situ SEM mechanical testing combining with theoretical modelling. Lastly, a highly strong HCNF, the tensile strength of which can reach ~ 7GPa, was successfully prepared.

Session: Carbon Composites

Presenting Type: Oral-Onsite

A predictive method for the mesoscopic ablation properties of carbonized composites

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2. Beijing Jiaotong University

As the thermal protection materials for ablation, carbonized composites possess significant advantages, such as the low density, the low thermal conductivity, the high pyrolysis rate, and the good thermal insulation performance, and are widely used in the thermal protection of space vehicles in extreme environments. The ablation of carbonized composites is a typical thermomechanical-chemistry coupling process composing of the surface thermal ablation, the volume thermal ablation, and the mechanical erosion. Based on volume-of-fluid and finite volume methods, the mesoscopic ablation model of carbonized composites for describing diffusion/reaction coupling problem is built. The effects of the braided angle, the pores in the matrix, and the reactivity distinction between matrix and yarns, on the surface thermal ablation behavior are investigated. Moreover, according to the energy conservation principle, the pyrolysis equation, and the ideal gas law, the volume thermal ablation model of carbonized composites is established on the mesoscale. The thermal response and internal pressure of carbonized composites are studied. Besides, the thermomechanical coupling response of carbonized composites is analyzed to predict the mechanical erosion behavior. The study can reveal the ablation and erosion mechanisms of carbonized composites in extreme environment, and provide theoretical basis and technical support for the application of carbonized composites in the thermal protection structures of space vehicles.

Key words Thermal protection; Carbonized composites; Mesoscopic ablation; Thermomechanical-chemistry coupling

Session: Carbon Composites

Presenting Type: Oral-Onsite

Interconnected Carbon Structures for Wearable Strain Sensors

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Chinese University of Hong Kong (Shenzhen)

Wearable piezoresistive physical sensors have attracted tremendous attention due to their broad applications in human-machine interfaces, robotics, health-monitoring, personalized medicine and therapeutics. Conventional metal- and semiconductor-based strain sensors are rigid, fragile, and opaque, restricting their applications in wearable electronics. Among various nanostructured materials that have been explored to construct stretchable piezoresistive sensors, carbon-based structures show the potential of achieving higher flexibility and transparency. We present several novel carbon-based interconnected structures including carbon nanofiber, graphene woven fabric, graphite nanoplatelet welded carbon nanotube networks, wrinkled and crack-bridging graphene film, unidirectional graphene aerogel, and graphene foam as highly sensitive, flexible, and stretchable strain sensors capable of detecting human motions. The synthesis strategies of carbon-based sensing structures, including 1D fibers, 2D planar networks and 3D interconnected nanoarchitectures are summarized. By bridging the technological gap between signal collection, processing and transmission and allowing data transmission to a smartphone via a custom-developed application consisting of a user-friendly interface, several wearable applications including wireless wearable musical instrument prototype, human motion detection and switch controls are demonstrated. The novel approaches reported here offer a wide range of practical applications, including medical diagnosis, health monitoring, early warning systems for structural failure, and wearable displays. With the development of new strategies and technologies as well as a deeper understanding of wearable sensor systems, we believe that carbon-based flexible electronics will play an increasingly more important role in driving the development of a wide range of emerging applications in biomedicine, healthcare, robotics, artificial intelligence and entertainment technologies.

Key words Interconnected Carbon Structures, Wearable Strain Sensors, Graphene, Carbon Nanotubes, Carbon Nanofibers

Session: Carbon Composites

Presenting Type: Oral-Onsite

Numerical evaluation of the effective thermal conductivity of needled C/C composites

Jian Ge、Wenlong Tian、Xujiang Chao、Wei Li、Lehua Qi*
Northwestern Polytechnical University

Needled carbon/carbon composites are composed of needled fiber bundles, weftless plies, and short-cut fiber plies, which generally causes the anisotropy of this composite. However, the isotropic thermal conductivity is required in special parts of aviation and aerospace. Thus, this paper proposes the hierarchical multiscale model to verify the potential of the isotropic heat transfer. Besides, the periodic boundary condition and volume-averaged homogenization method are applied to calculate the effective thermal conductivity of composites. The prediction values have a good agreement with experimental results. Based on this model, the microstructural parameters, including the diameter of needled fiber bundles, the ratio of the thickness of weftless plies and short-cut fiber plies, is investigated. The results show that the isotropic thermal conductivity can be complemented by adjusting these two parameters.

Key words Thermal conductivity, multiscale models, FEM, C/C composites

Session: Carbon Composites

Presenting Type: Oral-Onsite

Fabrication of Large Aerogel-Like Carbon/ Carbon Composites with Excellent LoadBearing Capacity and Thermal-Insulating Performance at 1800 °C

Sufang Tang*
Institute of metal research, Chinese Academy of Sciences

Carbon aerogels (CAs) are attractive candidates for the thermal protection of aerospace vehicles due to their excellent thermostability and thermal insulation. However, the brittleness and low mechanical strength severely limits their practical applications, and no signifificant breakthroughs in large CAs with a high strength have been made. We report a high pressure-assisted polymerization method combined with ambient pressure drying to fabricate large, strong, crack-free carbon/carbon (C/C) composites with an excellent loadbearing capacity, thermal stability, and thermal insulation. The composites are comprised of an aerogel-like carbon matrix and a low carbon crystallinity fifiber reinforcement, featuring overlapping nanoparticles, macro-mesopores, large particle contact necks, and strong fifiber/matrix interfacial bonding. The resulting C/C composites with a medium density of 0.6 g cm−3 have a very high compressive strength (80 MPa), in-plane shear strength (20 MPa), and specifific strength (133 MPa g−1 cm3). Moreover, the C/C composites of 7.5−12.0 mm in thickness exposed to an oxyacetylene flflame at 1800 °C for 900 s display very low back-side temperatures of 778−685 °C and even better mechanical properties after the heating. This performance makes the composites ideal for the ultrahigh temperature thermal protection of aerospace vehicles where both excellent thermal-insulating and load-bearing capacities are required.

Key words lightweight carbon/carbon composites, aerogel, fiber-reinforced, thermal insulation, mechanical properties

Session: Carbon Composites

Presenting Type: Oral-Onsite

Ablation behavior of C/C-ZrC-SiC composites prepared by Sol-Gel method

Mingyu Zhang*、Chen Zeng、Qizhong Huang
Central South University

Sol-Gel is a particularly efficient method to synthesize nano-sized ultra-high temperature ceramic powders. However, Sol-Gel method is immature in its application to the preparation of anti-ablation C/C-UHTCs composites. Herein, C/C-ZrC-SiC composites with different carbon fiber preform structure were successfully prepared by Sol-Gel method, and the microstructure, mechanical property and ablation resistance of the composites were investigated. The results demonstrate that dense ZrC-SiC ceramics, which had a homogeneous phase distribution, were formed in the composite matrix. The obtained 3D C/C-ZrC-SiC composites delivered a flexural strength of 148.926 MPa with a bulk density of 1.98 g/cm3, while the flexural strength of 2.5D C/C-ZrC-SiC composites is only 120.113 MPa. After being exposed to a stable oxyacetylene flame at 2800 ºC for 60 s, the mass and linear ablation rates of 3D C/C-ZrC-SiC are 0.2372 mg/(cm2×s) and 0.0110 mm/s, respectively, which are 25.94% and 25.73% lower than those of 2.5D C/C-ZrC-SiC composites. The excellent mechanical property and ablation resistance are attributed to the firm carbon fiber preform structure and the dense ZrC-SiC ceramic matrix.

Key words Sol-Gel method, C/C-ZrC-SiC composites, Mechanical property, Ablation resistance

Session: Carbon Composites

Presenting Type: Oral-Onsite

Molecular creep behavior of fiber/matrix interface under sustained load and moisture conditions

Marc Aurel NTJAM MINKENG、Chao Wu、Lik-ho Tam*
Beihang University

Carbon fiber-reinforced polymer (CFRP) composite is subjected to external load and moisture conditions throughout its expected service life, which lead to the degradation of fiber/matrix interface. In this work, recent molecular simulation investigations on creep responses of fiber/matrix interface under sustained load and moisture conditions are introduced. The constructed molecular interface model consists of epoxy matrix bonded to graphite sheets, which represent the fiber outer-layer. To simulate external loads, graphite sheets are subjected to different applied load levels, and certain water molecules are added inside interface to simulate the moisture absorption case. The threshold stress and energy barrier for the onset of interfacial creep failure are determined to quantify the interfacial creep resistance under sustained load and moisture conditions. Meanwhile, interfacial strain and stress evolution associated with configurational changes during creep are observed to understand the molecular behaviors and responses of fiber/matrix interface. The research findings provide fundamental understanding of interfacial creep behavior under sustained load and moisture conditions, which contributes to the prediction of interfacial degradation of CFRP composites during intended service life.

Key words Fiber/matrix interface; Sustained load; Moisture; Interfacial creep; Molecular dynamics simulations

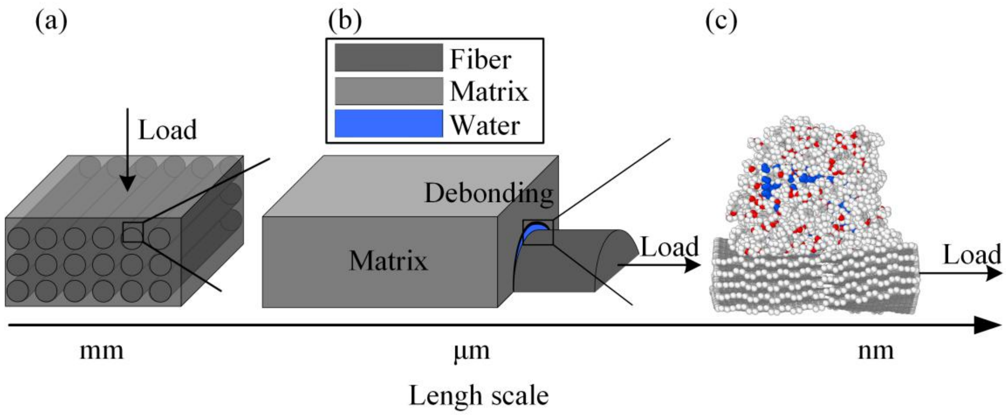

Fig. 1. Multiscale view of carbon fiber-reinforced polymer composite: (a) macroscale sample; (b) microscale fiber/matrix interface; and (c) nanoscale interface model consisting of epoxy molecule bonded to graphite sheets representing fiber outer-layer.

Session: Carbon Composites

Presenting Type: Oral-Onsite

Multiscale Construction of Graphene Fibers and films for High-Performance Flexible Sensors

Pingan Hu*
Harbin Institute of Technology

High performance nano-structured materials are of significance for flexible and wearable microelectronics. Core–sheath fibers were massively fabricated from ultralong chemical vapor deposition (CVD) grown graphene bundles. They exhibited superior conductivity and excellent mechanical properties which exceeded the reduced graphene oxide (rGO) fibers. Furthermore, safe strain sensors based on as–prepared core–sheath CVD graphene fibers have been demonstrated as a proof–of–concept application. The performance of strain sensors has been greatly improved by using CVD graphene fiber. Organic–inorganic nacre–like composites excited scientists for decades and have been investigated for use as coatings and thin films. Here we demonstrate that nacre–like fibers from nanoplatelets and polymers can be produced by shear–induced self–assembly. The combination of nanoscale brick–and–mortar and helical microscale structural organization gives rise to stretchability greater than 400% and a gravimetric toughness as high as 640 J g-1. The unique toughness of the fibers originates from the multiscale deformation regime involving energy dissipation at nanoplate–polymer interfaces and macroscale decoiling. Moreover, luminescent CdTe nanowires incorporated into the fibers conveys the unique property of mechanically tunable circularly polarized luminescence associated with the helical nano– and meso–scale deformations in the material. The nacre–like fibers create a novel technological work space for investigating the optomechanics of biomimetic composites while their continuous spinning methodology makes scalable production realistic; A skin-structure inspired strategy to prepare gradient pore microstructure (GPS) films which thus have gradient elastic modulus along film thickness direction, similar to the dermis of skin. The tactile sensors made of this GPS films show an improved sensitivity of 3.74 kPa-1 and an ultrahigh pressure resolution of 0.06% during large pressure range of 0-800 kPa because of high structural compressibility and stress adaptation characteristics of GPS film. GPS-based sensors provide a new avenue to realize high-performance tactile perception in the artificial intelligence equipment.

Key words Graphene fibers, sensors

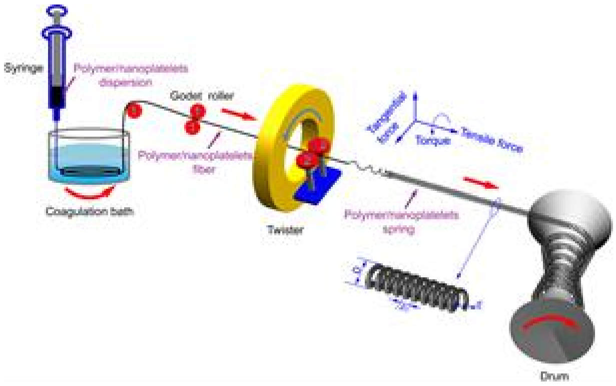

Fig. 1. Schematic diagram of the two-step formation of nacre-like composite fiber.

Session: Carbon Composites

Presenting Type：Oral–Onsite

Preparation and application of two-dimensional polystyrene-coated hollow multilayer graphene composites

Mingming Guo*、Yanke Li
Southwest University

Pickering emulsion system that spontaneously exfoliates graphite at the Oil (Styrene)/Water interface to produce unoxidized pristine graphene nanosheets (GN), which stabilizes the Pickering emulsion has been developed. The colloid chemistry effect of the graphene and graphite flakes significantly improves the interfacial compatibility and dispersibility of Oil (Styrene)/Water emulsion. The Polystyrene (PS)/Graphene nanocomposite materials with specific pore structure and graphene lining are polymerized by using this Pickering emulsion route. The PS/GNx has achieved the better glass transition temperature and thermal stability compare to the PS resin. These two properties of the PS/GNx nanocomposites are also better than tne graphite with prepared PS by solution mixing. The nanoblend materials by melt mixing the prepared nanocomposite PS/GNx(x=0.6,1.2) with the commercial PS resin have enhanced electrical and thermal conductivity, satisfactory thermal stability and processability. So that the nanocomposites PS/GNx(x=0.6,1.2) have broad and potential applications in energy storage, thermal conductivity and electronic sensing.

Key words Graphene; Polystyrene; Pickering Emulsion

Session: Carbon Composites

Presenting Type: Oral-Onsite

A Novel (Hf1/3Zr1/3Ti1/3)C Medium-entropy Carbide Coating with Excellent Long-life Ablation Resistance Applied above 2100 °C

Jiachen LI、Yulei ZHANG*、Junshuai LV
Northwestern Polytechnical University

Developing long-term ablation-resistant materials applied in ultra-high-temperature oxygen-containing environments (above 2100 °C) is a matter of prime importance for the new generation of hypersonic vehicles, but remains a huge challenge. Ultra-high temperature ceramics (UHTCs) have excellent ablation resistance but poor high-temperature mechanical properties, while carbon/carbon (C/C) composites express excellent high-temperature strength retention but are prone to oxidation/ablation. Combined with their merits, UHTC coatings are coated on the surface of C/C composites, allowing them to show excellent comprehensive properties and long service life in these extreme conditions. In recent years, compared to conventional monocarbides, solid solution or medium/high-entropy carbides (M/HECs) have aroused considerable interest because of their high hardness, high strength, and excellent corrosion resistance. Here, this work reported a novel (Hf1/3Zr1/3Ti1/3)C MEC coating firstly prepared on the surface of C/C composites. The formation of MEC and its element mutual diffusion processes were theoretically proved using first-principles calculations. (Hf0.5Zr0.5)C was first formed by the mutual diffusion of Hf/Zr in HfC/ZrC, and the MEC was then formed by the element diffusion in TiC and (Hf0.5Zr0.5)C. The fabricated MEC coating significantly prolonged the anti-ablation time (more than 210 s) above 2100 °C in an oxyacetylene flame ablation environment with a heat flux of 2.4 MW/m2, compared to the monocarbide coating (less than 90 s). The ablated surface of MEC coating was composed of amorphous Zr–Hf–Ti–C–O oxycarbide pinned by m-(Hf, Zr, Ti)O2 nanoparticles, forming a unique structure of oxide scale for the long-term ablation resistance. This work provides a new way to improve the ablation resistance of monocarbide coatings and develops a great promise for new generation structural materials in ultra-high temperature environments.

Key words Medium entropy carbide; First-principles calculations; Carbothermal reduction; Carbon/carbon composites; MEC coating; Ablation resistance

Session: Carbon Composites

Presenting Type：Oral-Onsite

"Two birds with one stone" strategy during the preparation process of C/C composites

Xuemin Yin*、Hejun Li
Northwestern Polytechnical University

In order to realize the efficient utilization of raw materials and the rapid preparation of composites, we found many interesting phenomena in the preparation of C/C composites and put forward a series of new strategies for the efficient preparation of composites. With precise control of the temperature gradient, CNTs and the pyrocarbon matrix could grow synchronously within a 2D needle-punched carbon fiber preform, achieving highly efficient preparation of CNTs reinforced C/C composites. In addition, during the growth of HfCNWs, CNTs were fabricated by using the waste gasses when thermal pyrolysis of Hf-containing precursor synchronously. In addition, we also achieved highly efficient preparation of core-shell structured ceramic nanowires @ vertical graphene nanosheets in one-step process.

Key words Carbon nanotubes; carbon/carbon composites；Highly efficient preparation

Session: Carbon Composites

Presenting Type: Oral-Onsite

Evolution of (Hf0.25Zr0.25Ta0.25Ti0.25)B2 high-entropy boride feedstock during supersonic atmospheric plasma spraying and following ablation behavior

Junshuai Lv、Yulei Zhang*、Jiachen Li
Northwestern Polytechnical University

High-entropy borides have the potential to be used in thermal protection systems due to their excellent oxidation resistance. In this work, $(Hf_{0.25}Zr_{0.25}Ta_{0.25}Ti_{0.25})B_2$ feedstock was synthesized by boro/carbothermal reduction and applied on C/C composites by supersonic atmospheric plasma spraying. In the as-spraying coating, $(Hf_{0.25}Zr_{0.25}Ta_{0.25}Ti_{0.25})B_2$ did not exhibit phase separation only slight oxidation occurred, and the oxidation exhibited a significant selectivity that Hf and Zr preferentially oxidized over Ta and Ti. As a consequence of the rapid melting and recrystallization of feedstock, refinement of the coating grains ensued after spraying. After ablation of the coating by an oxyacetylene flame, needle-like Ta-rich oxides were present in the oxide scale, which started with the separation of the Ta-oxide from the oxides composed of the remaining components at the oxidizing interface. The multiple oxidation products exhibited synergistic effects. The oxides with high melting points formed the skeleton to maintain the integrity of the oxide scale. The low-melting oxide facilitated densification of the oxide scale and exhibited the potential to heal defects. The results suggest that the composition requires optimization for the application of such new materials in thermal protection systems.

Key words High-entropy borides; C/C composites; Ablation-resistant coating; Cocktail effect; Atmospheric plasma spraying

Session: Carbon Composites

Presenting Type: Oral-Onsite

Strength prediction of a notched laminated plate

Qiang Ma、Zheng-Ming Huang*
Tongji University

A laminated structure is essentially bonded together from individual called primary layers through the matrix. In order to simulate the initiation and propagation of delamination, which already occurs in the laminate, a pure matrix secondary layer is inserted in between the primary layers (Fig 1). The thickness of a secondary layer is taken as 2% of that of a primary layer. However, the stresses in the weakest secondary layer element obtained from, e.g., a finite element approach (FEA) must be modified so as to satisfy a tensile or shear strength failure condition for the matrix before an ultimate failure of the laminate can occur. Then, the failed secondary layer element is deleted and the delamination initiation or propagation is attained. In this paper, it is found that the modification coefficient for the secondary layer stresses before the delamination initiation should be determined by the experimental data of a SBS (Short Beam Shear) on a UD (unidirectional) composite, whereas those after the initiation are obtained based on the measured parameters of DCB (Double Cantilever Beam) and ENF (End Notched Flexure) tests on the UD composite. The homogenized stresses of the fiber and matrix in the primary layers calculated through Bridging Model are converted to true values, on the basis of which detection of the fiber and matrix failures is made independently, and an ultimate failure of a primary layer element is then obtained. Due to the weak singularity or stress concentration at the free edge, hole edge or loading point, the stresses in its neighborhood are not realistic. The ultimate load carrying capacity of the structure can only be considered to achieve when the ultimate failure occurs in the primary layer element outside the neighborhood. It is shown that the neighborhood range for the weak singularity is 4 times of the primary layer thickness, while that for the singularity is 6 times of the former. The tensile strengths of four kinds of notched laminates with different lamination angles and different hole diameters are predicted. The predictions are in good agreement with the measured counterparts.

Key words secondary layer; notched laminate; delamination; neighborhood range; ultimate failure

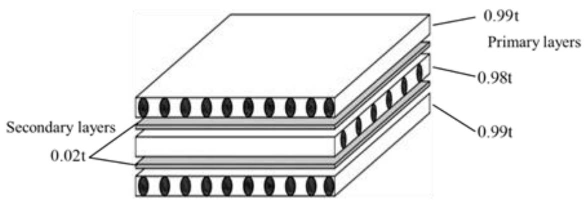

Fig. 1. Laminates containing matrix layers

Session: Carbon Composites

Presenting Type：Oral-Onsite

Nature-inspired energy dissipation of graphene reinforced sandwich composites with high damping

Jigang Feng、Zhaoye Qin*、Fulei Chu
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Although extensive studies have confirmed that graphene could reinforce the damping properties of polymer composites, to date, some critical issues including aggregation, mediocre damping enhancement capability remain unimproved. In this study, a nature-inspired sandwich composites are designed and prepared for suppressing and eliminating vibration, where the conventional blending composites and epoxy resin are also prepared as a reference. Dynamic mechanical analysis and vibration tests confirm that the damping properties of sandwich composites are superior compared to that of blending composites and epoxy resin, where the loss factor of sandwich composites with a mass fraction of 0.75wt‰ is increased to 0.0942 from 0.067 for conventional blending composites of the same mass fraction and 0.0426 for epoxy resin. The energy dissipation mechanism of competitive behavior is then proposed to interpret the bell-shaped variation of damping properties with the increasing thickness of core layer. Moreover, polydopamine (PDA) is used to modify rGO and realize the increase of surface friction, which improves the damping enhancing capability of rGO. To be specific, the damping ratio of PDA modified rGO (PDA-rGO) reinforced composites with a mass fraction of 0.5wt‰ is 42.5% higher than that of rGO reinforced composites of the same mass fraction. The modification of rGO and the validation of the sandwich composites provide a charming strategy for vibration energy dissipation and damping enhancement.

Key words Nanocomposites; Polydopamine; Reduced graphene oxide; Damping property

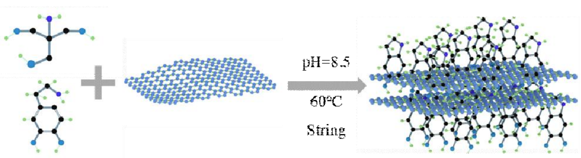

Fig. 1. Schematic of the fabrication process of PDA-rGO

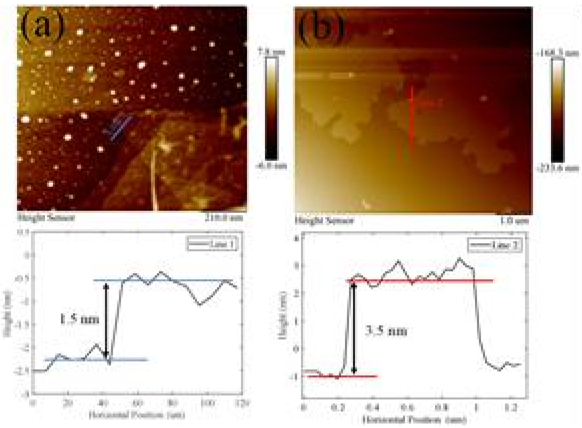

Fig. 2. Morphology of graphene: (a) PDA-rGO and (b) rGO

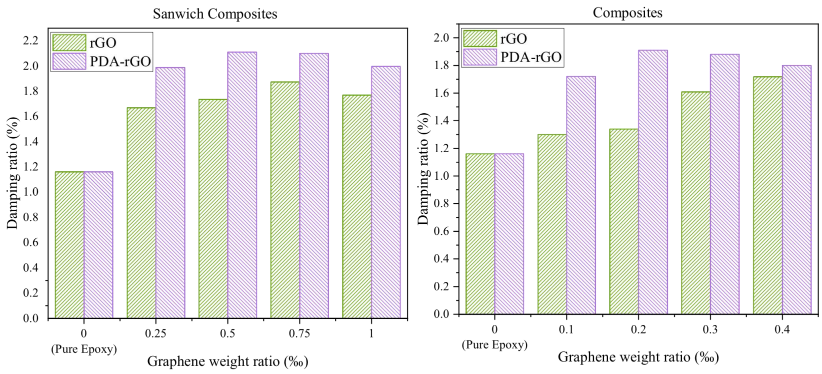

Fig. 3. The first order damping ratios of composites and sandwich composites

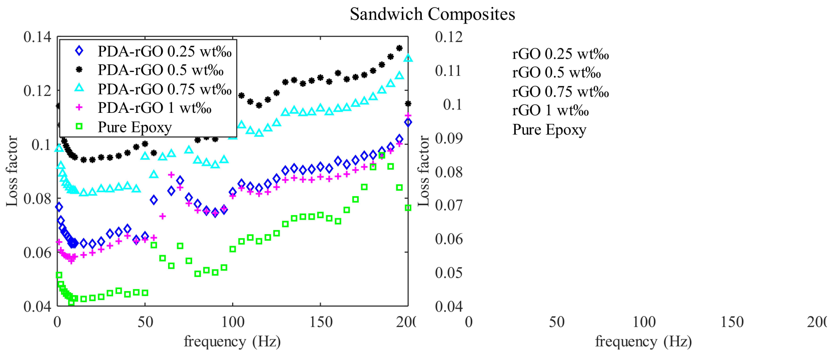

Fig. 4. The loss factors of sandwich composites

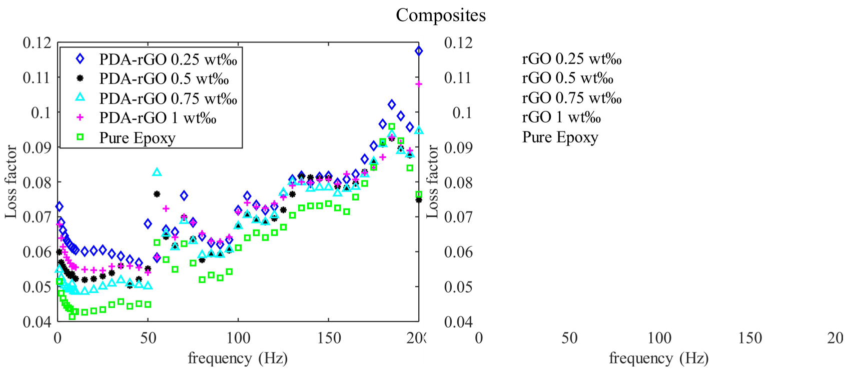

Fig. 5. The loss factors of composites

Session: Carbon Composites

Presenting Type: Oral-Onsite

MXene-Based Composites for Energy Storage Applications

Jun Yan*
Harbin Engineering University

MXenes are an emerging family of 2D transition metal carbides and nitrides with a general formula of Mn+1XnTx, where M is an early transition metal, X represents C and/or N, Tx denotes surface functional groups, and n = 1, 2, or 3. MXenes are generally produced by selective etching of the A-group (generally, group III A and IV A) element layers from MAX phase precursors (Mn+1AXn), which comprise a > 70-member family of layered, hexagonal early-transition-metal carbides and nitrides. Since their discovery in 2011, MXenes have attracted continuously growing attention from the scientific community for various applications including supercapacitors, Li-ion and Na-ion batteries, electromagnetic interference shielding, selective ion sieving as well as cellular imaging. Similar to graphene, aggregation and face-to-face self-restacking of MXene nanosheets are usually inevitable during drying and electrode fabrication processes owing to the strong van der Waals interaction between adjacent nanosheets. Self-restacking of MXene nanosheets has been demonstrated to significantly decrease the electrochemical utilization ratio, deteriorate the intrinsic performance and accessibility to electrolyte ions. In order to effectively prevent the self-restacking and improve the performance, various materials such as polypyrrole, nickel-aluminum layered double hydroxides, MnO2 and carbon nanotubes (CNTs) have been introduced to hybridize with MXenes for energy storage applications in recent years. In this presentation, our recent work on MXene based composites for energy storage applications will be briefly summarized.

Key words MXene; supercapacitors; lithium-ion batteries

Session: Carbon Composites

Presenting Type: Oral-Virtual Platform

Recent advances and future perspectives of space carbon-based composite materials and sandwich structures

Yufeng Liu*、Zhen Fan、Zhihai Feng
Science and Technology of Advanced Functional Composites Laboratory, Aerospace Research Institute of Materials and Processing Technology

Space materials science is an interdisciplinary research field developed through the interpenetration and combination of materials and space technology. Carbon-based composite materials has great advantages in the fabrication of space structures for its excellent characterized as lightweight, high mechanical strength, low thermal expansion and thermal shock resistance. With the rapid development of space materials science, many countries pay more attention to the research of carbon-based composite materials. This paper introduces the properties、development history and space-application status of carbon-based composite materials. And on this bases, the carbon-carbon honeycomb sandwich panels used for space ultra-stable structures developed by Aerospace Research Institute of Materials and Processing Technology was introduced. The future research tendency of carbon-based composite materials was also discussed.

Key words space, carbon-based composite materials, carbon-carbon sandwich structure

Session: Carbon Composites

Presenting Type: Poster

Implementing Omnidirectional Illumination in 3D Pine Cone-Derived Evaporator for both Water Evaporation and Photodegradation Decontamination

jing wu*
Beijing university of chemical technology

Extreme water shortage and serious water pollution are serious problems facing human development at present. Moreover, it remains a challenge to prepare a material with multi-functions to realize evaporation and light degradation at the same time. Here, we demonstrate a bio-derived three-dimensional structure generated from original pine cones decorated with MoS2 nanosheets (HCPM) with synergistic photothermal and photocatalysis effect, to be proposed for efficient solar driven water evaporation and decontamination. The treatment of hydrothermal carbonization (HTC) guarantees the material with satisfactory hydrophilic property which not only benefits for fast water transportation and exerts positive effect on the adsorption of pollutants in water while ensuring the light absorption capacity. Molybdenum disulfide (MoS2) nanosheets were in situ synthesized on the surface of pine cone by hydrothermal reaction, which further improved the solar-thermal performance of the evaporator due to the nonradiative relaxation effect of MoS2 nanosheets and endows the materials with photodegradation ability. Besides, the unique three-dimensional structure of pine cone accompanied with multi-angle scales allow it to absorb light from different angles for solar steam generation so that to display satisfactory evaporation rates in omnidirectional illumination. More important, experimental results show that the photothermal characteristic is vital to photocatalysis. Photothermal process can provide energy for photocatalytic process and accelerate its kinetic process. The combined characteristics of vapor-transportation-favorable morphology, enhanced broadband absorption, and heat-localization render the bio-derived structure a remarkable solar-driven water purification performance. (Evaporation rate of 1.85 kg m^{-2} h^{-1} with an efficiency of 96%.) and a methylene blue (MB) removal efficiency of 96% in 2 hours.

Key words Molybdenum disulfide, Pine cone, Water evaporation, Photocatalytic degradation.

Session: Carbon Composites

Presenting Type: Poster

Novel and facile solution-based processing of polyetherketoneketone (PEKK) toward high performance composite powder

Xin WANG、Yiting QU、Bolan LI、Feng ZHANG、Mengxiao JIAO、Yanbo LI、Junlei BAI、Xiaohua ZHANG*
DongHua University

High temperature resistant thermoplastic resin has attracted a lot of attention from researchers because of its excellent thermal and mechanical properties, which can not only ensure light weight, but also come true its application in many fields by applying different processing methods and compounding with other materials. Poly (aryl ether ketone) (PAEK) family has made great achievements in high-tech fields such as aerospace, automobile, electronic communication, medical treatment, industry and so on. In addition to polyether ether ketone (PEEK), which is now more studied, as another emerging and important polymer material, PEEK urgently needs to be developed for more applications. So far, the impregnation of PEKK and PEEK is mainly based on dry method, which seriously limits the interface bonding between PEKK and reinforced fiber, thus affecting the performance of their products. Due to the polymer polarity of PEKK, we have achieved a breakthrough in dissolving PEKK in fluorine-containing and / or chlorine containing solvents. Solution impregnation - a new strategy for preparing chopped carbon fiber /PEKK composite powder came into being. This method makes PEKK fully composite with chopped carbon fiber, effectively utilizes the reinforcement effect of carbon fiber in resin matrix, and improves the tensile properties of the material by nearly 20% compared with PEKK. Furthermore, the thermal stability of the composite powder was not affected, and the thermal degradation temperature was above 430 °C. This method is also suitable for the preparation of carbon nanotubes /PEKK and graphene /PEKK composite powders. Our research will greatly promote the wide application of PEKK.

Key words Polyetherketoneketone (PEKK)；chopped-carbon fiber；Solution impregnation

Hangzhou, PR China 25-28 April, 2023

Session: Carbon Composites

Presenting Type: Poster

Ablation behavior of sharp-shaped HfC-SiC-C/C composites under different heat flux

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Shaanxi Province Key Laboratory of Fiber Reinforced Light Composites Materials, Northwestern Polytechnical University

To improve the ablation resistance of sharp-shaped carbon/carbon (C/C) composites, HfC-SiC-C/C composites with a dense and homogeneous structure were prepared by precursor infiltration pyrolysis (PIP). The sample with a lower HfC to SiC ratio showed better ablation resistance under a heat flux of 2.4 MW/m^2, while the sample with a higher HfC to SiC ratio exhibited better anti-ablation performance under a higher heat flux of 4.2 MW/m^2. The results of ablation revealed that the excellent ablation resistance of the modified composite depends on the synergistic protection of HfC and SiC. During the ablation, HfC formed a stable HfO_2 skeleton that played a critical role in oxidation protection. The further incorporation of SiC generated SiO_2 which promoted the densification of the HfO_2 grains, in addition to providing effective protection of the edge region. However, when undergoing higher gas flux ablation, the oxide scales with excessive SiO_2 will be consumed. Therefore, the SiC content of the sample should be reduced in order to obtain excellent ablation performance at higher gas flux.

Key words Ablation behavior; Sharp-shaped; HfC-SiC-C/C composites; Precursor infiltration pyrolysis

Session: Carbon Composites

Presenting Type: Poster

Synthesis of Ribonucleoside-Derived Carbon Dots and the Topoisomerase-Like Catalytic Property

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School of Chemical Engineering and Technology, Tianjin University

In recent years, synthetic nanomaterials shown catalytic activities resembling enzymes in life systems were termed as nanozymes. Carbon dots have drawn a great of attention as a promising nanocatalytic platform by virtue of their metal-free, easy-to-prepare, and potentially recyclable properties. And the carbon dots-based nanozymes have drawn great attentions. Inspired by the catalytic activities of RNA molecules, we used ribonucleosides as precursors including adenosine, guanosine, cytidine and uridine, respectively, synthesizing four ribonucleosides carbon dots (A-CDs, G-CDs, C-CDs, and U-CDs) to mimic artificial enzyme. All four carbon dots show a planar graphene-like structure characterized by high-resolution transmission electron microscopy (HRTEM) and atom force microscopy (AFM). The unique structures of CDs can intercalatively bind with DNA double helix. Different from the other carbon dots, uridine derived U-CDs exhibit exciting Topoisomerase I-like catalytic property, which can mediate the topological transformation of supercoiled DNA to nicked open-circular conformation. Through the catalytic mechanism studying, we reveal that U-CDs can catalyze oxidation of O2 to generate singlet oxygen 1O2 via a Haber-Weiss reaction, and consequently mediate oxidative cleavage of phosphate backbone of DNA and release the torsional energy storied in supercoiled DNA. Explorations reveal that the unique highly active oxygenated species namely quinone groups that are on the edge of U-CDs, play a key role in the catalytic production of 1O2. Importantly, after the U-CDs treatment in proper time, protein expression of gene was greatly enhanced in a cell-free protein synthesis system. This work represents a new insight that using natural biomolecules in living systems as precursors can create new species beyond life.

Key words nanozyme, nanomaterials, carbon dots, ribonucleosides

Session: Carbon Composites

Presenting Type: Poster

Interlaminar toughening in carbon fiber/epoxy composites with carbon nanotube

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2. Ningbo Institute of Materials and Engineering

The susceptibility to delamination is one of the main concerns in carbon fiber reinforced polymer composites (CFRPs). Nano-scale reinforcement using nanofillers like carbon nanotubes (CNTs) in between the plies of a composite offers the opportunity to reinforce the interlaminar bonding with minimal weight penalty and effectively avoids reductions in in-plane properties, although their integration has been challenging. In this works, we proposed two different methods to integrate CNTs into CFRP system for interlaminar toughening. One is based on “interleaving” technique, in which CNTs was pre-assembled into a macro fiber veil. Another is spray coating method, in which CNTs was firstly dispersed in acetone via advanced dispersion technique, and then spray-coated on the surface of carbon fabric. Both designed methods showed a great interlaminar toughening efficiency and bears the feasibility of scale-up for real industrial production.

Key words CNT，carbon fiber，fracture toughness

Session: Carbon Composites

Presenting Type：Poster

MOF-derived ultrasmall Ru@RuO2 heterostructures as bifunctional and pH-universal electrocatalysts for 0.79 V asymmetric amphoteric overall water splitting

Zhe Li、tao Liang、chenyan hou、zhewen deng、hongliang wu*
Shenzhen University

Developing heterostructures in nano-electrocatalyst has been demonstrated as a feasible method to enhanceelectrocatalytic activities for water splitting, since it still remains a grand challenge to develop highly efficientand stable electrocatalysts for both oxygen evolution reaction (OER) and hydrogen evolution reaction (HER)within a wide pH range. Herein, we report a facile pyrolysis strategy of Ru-MOF for rationally constructingultrasmall Ru@RuO_2 heterostructures, which exhibit extremely remarkable electrocatalytic performance towardboth HER and OER in pH-universal electrolytes. Impressively, optimal Ru@RuO_2-250 achieves ultralow overpotentials for both OER (198 mV, 263 mV and 182 mV @ 10 mA cm^{-2} in acidic, neutral and alkaline media) andHER (31 mV, 43 mV and 32 mV @ 10 mA cm^{-2} in acidic, neutral and alkaline media) due to the full exposure ofhighly active sites, which are derived from the synergism of abundant heterointerfaces, ultrafine heterostructuresize and hierarchical porous structure with high surface area. Theoretical calculations reveal the charge rearrangement and electron conduction intensification near Ru-RuO_2 heterointerfaces, the electronic structurechanges of the active sites optimize the adsorption behavior toward various reaction intermediates, reducing theactivation barriers and speeding up the reaction kinetics. Deservedly, an asymmetric-electrolyte electrolyzeremployed with Ru@RuO_2-250 is assembled to acquire an ultralow applied voltage of 0.79 V at 10 mA cm^{-2}based on amphoteric water electrolysis (HER in acidic electrolyte while OER in alkaline electrolyte).

Key words Ru@RuO2，heterostructures，HER，OER，Water splitting，Asymmetric-electrolyte electrolyzer

Session: Carbon Composites

Presenting Type: Poster

A General Strategy to Fabricate Bending-Resilience Properties Inorganic Nanofibers

Xiao Wang、Jianhua Yan*
Donghua University

Inorganic nanofibers usually exhibit two extreme states of brittleness or flexibility randomly in fabrication, however how to accurately design specific mechanical property of inorganic nanofibers has always been a difficult problem to solve. Herein, we fabricate composite nanofibers with bending-resilience state in transition from freestanding carbon nanofibers to silk-like Titanium dioxide nanofibers. Through summarizing the rule of microstructure-macromechanics, we find that both softness of fiber membrane and bendability of single fiber were improved, however the bending-resilience ability was weakened with the increase of oxide components. The cause of this phenomenon is that oxides nanoparticles form heterogeneous interfaces inside nanofiber to alleviate stress concentration effect and reduce overall flexural modulus, meanwhile part of graphitized carbon assumes the function of storing and releasing deformation energy, thus realizing self-recovery rebound characteristics. Study of this unique mechanical property is the key for design and development of inorganic nanofibers to favor wider application.

Key words Electrospinning; Flexible oxide ceramic nanofibers；mechanical mechanism

Session: Carbon Composites

Presenting Type: Poster

Process and performance evaluation of induction welding of thermoplastic composites

Bo-Kyung Choi*、Chang-Soo Kang
Korea Carbon Industry Promotion Agency

Thermoplastic composites are replacing thermosetting matrix composites in various applications because they can be easily processed without cutting and ensure a long lifespan, low storage cost, high recyclability, and high impact resistance. In recent years, thermoplastic composite materials have been used in the aviation industry to develop parts for the Boeing 787 and Airbus A350, A380 mass-produced models through the application of automated fiber placement (AFP) and thermoforming techniques. Bonding is an important step in the process of manufacturing thermoplastic composites, which may weaken because bonding can cause irregularities in the structure. Mechanical fastening and adhesive bonding methods for metals and thermosets can be used, but they are not suitable for thermoplastics. Among the various fusion welding techniques (such as dielectric, microwave, resistance, and induction welding) that may be used to bond thermoplastic composites, induction welding can overcome the limitations related to adhesive bonding while avoiding an increase in welding time and weight. Induction welding is a non-contact, fast, and clean process. Also, the surface is less contaminated, thus enabling fast heating and constant temperature control, making it suitable for automated processes. In this study, induction welding was performed by manufacturing a thermoplastic composite using a carbon fiber/polyetheretherketone prepreg. The induction welded thermoplastic composites were characterized using optical microscopy, ultrasonic C-scan, single lap shear strength, and the temperature of the specimen surface was monitored using a thermal imaging camera.

Key words induction welding; thermoplastic composite; bonding

Session: Carbon Composites

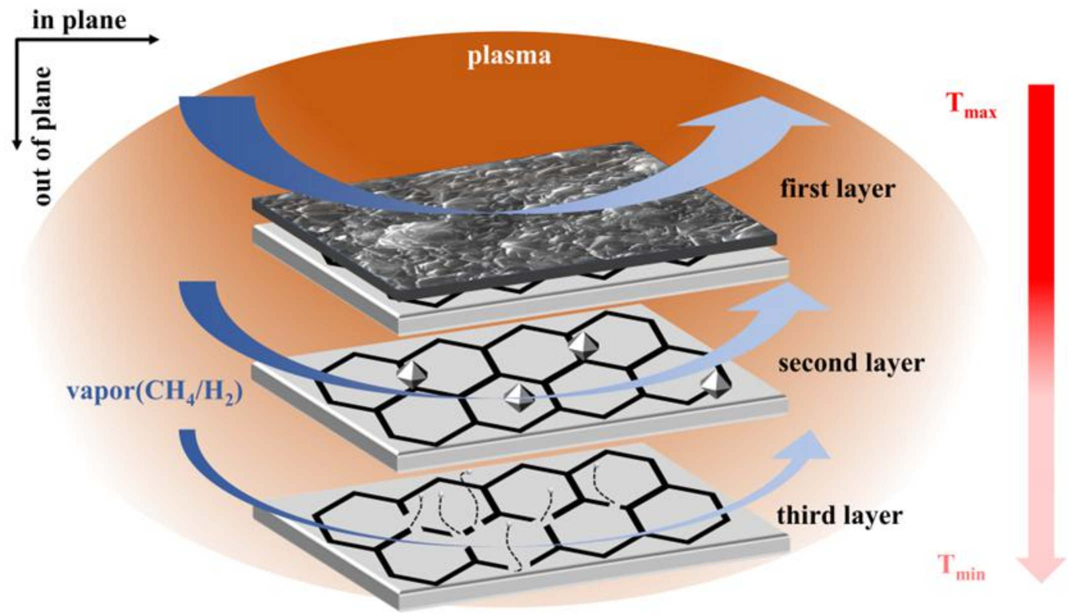
Presenting Type: Poster

Study on the Growth Mechanism of 3D Diamond Skeleton by Chemical Vapor Deposition

Ge Gao[1]、Mingqi Sun[2]、Bing Dai[1]、Kang Liu[1]、Guoyang Shu[1]、Jiecai Han[1]、Jiaqi Zhu*[1,3]
1. Harbin Institute of Technology
2. The School of Material Science and Engineering, Harbin University of Science and Technology
3. Key Laboratory of Micro-systems and Micro-structures Manufacturing, Ministry of Education, Harbin Institute of Technology

The demand for high-performance heat dissipating materials is gradually increasing with the development of electronic information era. 3D diamond skeleton attract attention due to its high thermal conductivity and light weight. In this work, the continuous and high-quality 3D diamond skeleton was successfully prepared by chemical vapor deposition using nickel foam as a metal template and graphene as a thermal expansion transition layer between metal and diamond. In addition, the growth process of the 3D diamond was analyzed, and the mechanism was established. It provides a novel growing method of 3D diamond as an ideal high-thermal-conductivity filler of the thermal interfacial materials.

Key words Diamond; Three-dimensional material; Graphene; Carbon nanotubes; Microstructure;



Session: Carbon Composites

Presenting Type: Poster

Mechanical model and deformation mechanism of carbon nanotube fibers with hierarchical helical structures

Yangfan Wu、Pengfei Wang*
University of Science and Technology of China

Due to unique geometric structures, twisted fibers with multi-level helical structures have found wide-ranging applications in energy harvesters, actuators, and artificial muscles. However, most previous research has been primarily focused on the multifunctional design and application of such fibers through the modification of fiber materials and the addition of polymers, with little attention given to the analysis of their deformation mechanisms, mechanical properties, and structural optimization design. In this study, ribbon-like carbon nanotube fibers were twisted into multi-level helical structures possessing distinct geometric parameters. Utilizing tensile experiments at various strain rates and in-situ experiments under scanning electron microscopy, the deformation process and failure mechanisms of the fibers were investigated. The experimental results indicated that twisting the materials into multi-level helical structures can significantly enhance the fracture strain of materials but reduce their failure strength. During the stretching process, the fiber was partially straightened, followed by necking, and ultimately broke at the straightened point, while the spiral section remained in its original spiral morphology even after fracture. Additionally, geometric parameters such as twist angle, radius, and pitch experienced initial reductions during the fiber's stretching process and partially recovered after it was straightened. Moreover, the diameter ratio of the spiral structure at different levels was found to significantly affect the mechanical properties of the fiber. The result of this study describes the deformation and failure mechanisms of twisted fibers possessing multi-level helical structures and provides a reference for the structural optimization design of fiber.

Key words multi-level helical structure; strain rate; in-situ experiment

Session: Carbon Composites

Presenting Type: Poster

MnCo-MOF-74 derived porous MnO/Co/C heterogeneous nanocomposites for high-efficiency electromagnetic wave absorption

Xue Zhang*、Zhihui Zeng
Shandong University

Metal-organic frameworks (MOFs) have attracted more and more attentions for preparing electromagnetic wave (EMW) absorption materials because of the porous structure, high specific surface area, and designable configuration. Herein, a series of MOF-74 derived nanocomposites were synthesized by hydrothermal process and subsequent carbonization. The EMW absorption performance and the functions of each component were investigated in depth. Moreover, the inherent EMW absorption mechanisms were comprehensively revealed. Benefiting from the synergistic effect of constituents and microstructure, the MnCo-MOF-74 derived MnO/Co/C nanocomposites delivered a minimum reflection loss value of −68.89 dB at the thickness of 2.64 mm and an effective absorption band of 5.3 GHz at the thickness of 2.3 mm. The high EMW absorption performance was ascribed to the optimized impedance matching and multiple attenuation mechanisms including interfacial and dipole polarization loss, magnetic loss, conductive loss, and multiple scatterings capability. This study shed light on exploring high-efficiency MOF-based EMW absorption materials with rational design of components and structure.

Key words MnCo-MOF-74, carbon-based nanocomposites, porous structure, electromagnetic wave absorption

Session: Carbon Composites

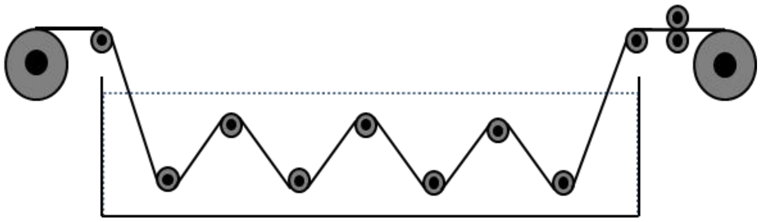
Presenting Type: Poster

Solution-impregnated-based processing of polyetherketoneketone (PEKK) toward high performance carbon fiber composites

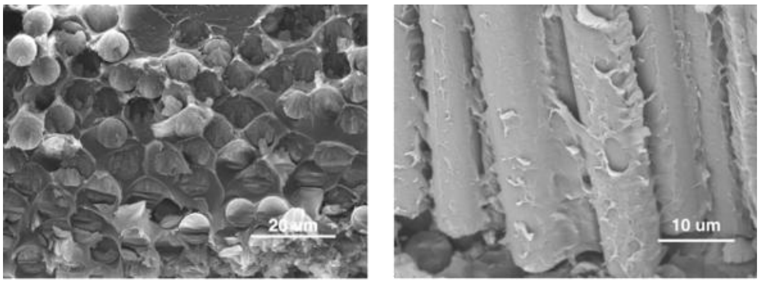
Yan bo Li、Yanbo Zhang、Feng Zhang、xin Wang、Yiting Qu、Xiaohua Zhang*
Donghua University

High-temperature engineering thermoplastics are receiving increasing attention because they not only provide a lightweight solution, but also impact the manufacturing process and efficiency. Polyaryletherketones (PAEKs), as a family of high-temperature semi-crystalline thermoplastics, have attracted much attention in composite materials due to their excellent properties such as high-temperature stability, high mechanical properties, radiation resistance, chemical resistance, and impact resistance. It is widely used as the matrix of carbon fiber (CF) composite materials in the fields of , biology, medical equipment and so on. Among them, polyetherketoneketone (PEKK) is another important member of polyaryletherketone (PAEK) family besides polyetherketone (PEEK). So far, the impregnation of PEKK and PEEK has been dominated by powder strategies, which severely limits their composition with reinforcing fibers. Due to the polymer polarity of PEKK, we achieved a breakthrough in dissolving PEKK in fluorinated and/or chlorinated solvents. Therefore, we completely dissolve PEKK in fluorine- and/or chlorine-containing solvents to form a colloidal solution containing tiny colloidal particles, which can be effectively and uniformly impregnated in the fiber CF bundles, with PEKK deep inside the CF bundles, Provides an even and thin coverage. All CF, composite structures are almost ideal for carbon fiber to maintain high strength in composites. Therefore, an ideal combination is achieved between PEKK and carbon fiber (CF), and the tensile properties of CF can be efficiently utilized up to 95%. Furthermore, in this ideal composition, a strong confinement effect was observed, leading to the inhibited crystallization of PEKK. The interfacial shear performance is significantly improved, and the shear strength can reach 100 MPa.

Key words solution immersion, PEKK, tensile property, shear performance



Impregnation process



Impregnation effect

Hangzhou, PR China 25-28 April, 2023

Session: Carbon Composites

Presenting Type: Published only

Finite Element Prediction of the Influence of the Stitching Process on the Elastic Modulus in the Composite In-plane

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Nanjing glass fiber research and Design Institute Co., Ltd

In this paper, a three-dimensional finite element model of carbon fiber satin reinforced composite with different stitching densities and thickness was established, respectively predicting the in-plane elastic modulus of all and partial damage at the stitching implant, which is verified experimentally. The results showed that with the stitching density, the in-plane elastic modulus of the composite decreased by about 44% while the change in Poisson ratio was small. The thicker stitching reduces the tensile and shear elastic modulus of the composite, and the change in internal elastic modulus of the material corresponding to the thinner stitching is small. Compared with unstitched, thicker stitching makes the tensile and shear modulus of the composites lower while finer stitching has less effect on the internal elastic modulus. The experimental results are consistent with the law predicted by finite elements.

Key words Eight five-flying satins; Stitching thickness; Stitching density; A 3-dimensional finite-element model; In-plane elastic modulus

Session: Carbon Composites

Presenting Type: Published only

Effect of PDA/Fe3O4 sizing agent on the mechanical properties of carbon fiber reinforced polyamide 6 thermoplastic composites

Xiaopeng Wu[1]、Tao Huang[1]、Weiyi Kong[2]、Xuan Zhang[2]、Huiming Ning*[1]
1. Chongqing University
2. AECC Commercial Aircraft Engine Co., Ltd.

The interfacial properties between carbon fiber (CF) and polyamide 6 (PA6) thermoplastic resin were modified by a newly developed sizing agent to improve the mechanical properties of CF reinforced PA6 thermoplastic composites. Through the oxidative self-polymerization of dopamine, a polydopamine/nano ferric oxide coating (PDA/Fe_3O_4) was successfully constructed on the surface of carbon fiber. The surface properties of carbon fibers before and after modification were characterized and analyzed. The results showed that the PDA/ Fe_3O_4 coating can effectively improve the surface roughness and chemical activity of carbon fibers, and enhance the mechanical engagement and chemical interaction between the fibers and the resin matrix. Compared with unmodified CF/PA6 composites, the prepared modified CF/PA6 composites exhibit excellent mechanical properties, with tensile properties increased by 27.8%. The corresponding failure characteristics and reinforcement mechanisms were also analyzed.

Key words Carbon fiber; Polyamide 6; Polydopamine; Nano-Fe_3O_4; Interfacial Properties

Session: Carbon Composites

Presenting Type: Published only

Quasi-static and dynamic tensile mechanical properties of 2.5D C/C-SiC composites

Liting Yang、chengxing Yang*
Central South University

2.5D C/C-SiC composites with a density of 2.4 g/cm3 were prepared by chemical vapor infiltration (CVI). The tensile mechanical properties of 2.5D C/C-SiC composites at 5 strain rates (0.01, 156, 294, 498 and 740 s-1) were investigated by using a high strain rate testing machine and a medium-low temperature mechanical testing machine; The failure fracture and failure mechanism of 2.5D C/C-SiC composites at different strain rates were analyzed by scanning electron microscopy (SEM); The constitutive equations for 2.5D C/C-SiC composites including damage and strain rate was established. Results show that the stress-strain curves of the 2.5D C/C-SiC composites show nonlinear characteristics under dynamic loading. The tensile strength of the 2.5D C/C-SiC composites decreases from 127.87Mpa to 68.40 Mpa, down by 46.5% with the increase of the strain rate. The indicates that the tensile strength of the 2.5D C/C-SiC composite has a strong strain rate effect, which makes the 2.5D C/C-SiC composite form different failure modes under quasi-static and dynamic loading.

Key words C/C-SiC composites; dynamic tensile; strain rate effect; Constitutive equation

Hangzhou, PR China 25-28 April, 2023

Session: Carbon Composites

Presenting Type: Published only

Effect of preload on the low velocity impact behavior of composite laminates

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2. Xi'an Jiaotong University

This study aims to investigate the influence of preloads on the Low Velocity Impact（LVI）behavior of composite laminates in the finite element analysis. Implemented by the user-defined VUMAT subroutine in ABAQUS, a three-dimensional progressive damage model is established, which is verified by non-preload low velocity impact test. Then the LVI performance of composite laminates under six groups of different preload conditions are predicted. The results show that the effect of preload on LVI damage of composite laminates is obvious. The pre-tensile load increases the maximum impact force of laminates, while the pre-compressive load decreases the maximum impact force. Similarly, matrix cracking, fiber fracture and delamination are alleviated by pre-tensile load. On the contrary, the damages are aggravated by pre-compressive load. It is worth mentioning that the pre-load affected the energy dissipation distribution of composite laminates evidently. The pre-tensile load reduces the interlaminar damage energy dissipation and increases the intralaminar damage energy dissipation. In contrast, pre-compressive load raises the interlaminar damage energy dissipation and lessens the intralaminar damage energy dissipation. The numerical simulation method is used to research the influence of preload on LVI of composite materials, which provides basic data reference for the impact resistance of aircraft structure composites under actual working conditions.

Key words Preload; Composite laminates; Finite element analysis; Low velocity impact

Session: Carbon Composites

Presenting Type: Published only

A prediction model for high-temperature properties of three-dimensional needled C/C composites based on a multi-scale approach

ZhuoYu Song[1]、Li Tong*[1]、Haoqi Wang[1]、Bo Wang[2]
1. Dalian University of Technology
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The microscopic failure mechanism of C/C structures at high temperatures is not clear. The text investigates the failure mechanism of needle-punched C/C composites at high temperatures in order to predict the elastic properties of three-dimensional C/C needle-punched composites in high-temperature environments. Based on the multiscale approach, a two-scale analytical model of three-dimensional needle-punched C/C composites was established, and a script for generating microscale RVEs containing random fibers was written in Python to realize the calculation of the equivalent elastic modulus, Poisson's ratio, and linear expansion coefficient for RVEs at different temperature conditions in the commercial finite element software Abaqus. Based on the results of microscale RVE mode calculations, mesoscale modeling of the braided body is jointly performed using TexGen and Abaqus to achieve performance transfer at both scales. In this paper, the UMAT subroutine is written to implement temperature-dependent simulation of material elastic-plastic behavior and failure quasi-imposition.

At the same time, this paper adopts domestic T800 6K five-pattern carbon cloth, compounded with domestic T700 12K carbon fiber mesh tires for needling, and the thickness direction is made into a prefabricated body with T800 6K carbon fiber single strand bi-directional stitching, and the high-temperature test specimens are cut out and tested in high-temperature tensile and compression, etc. The key failure parameters are measured, the damage analysis determination criteria suitable for C/C structures are established, and the structural microscopic failure models under different temperature conditions and loads are verified and compared with the test results. This study will have important implications for the design and application of C/C structures in high temperature environments.

Key words Multiscale, 3D needled C/C composites, High temperatures, Failure mechanism, Representative Volume Element (RVE)

Session: Carbon Composites

Presenting Type: Published only

Carbon Dots Promise New Photoelectrocatalysts

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Carbon dots (C-Dots) are defined as spherical-like carbon particles (graphitic fragments) with sizes less than 10 nm. In 2010, we developed a facile electrochemical approach for the large-scale fabrication of high quality and purity C-Dots using graphite rods and pure water as the starting materials. These well crystalline C-Dots show size-dependent photoluminescence and rich photoelectrocatalytic properties. The relationships between the structure, surface composition and photoelectrochemical properties of C-Dots were clarified. Especially, we have proposed a simple semi-empirical equation for determining the conduction bands and valence bands of the C-Dots calculated from their band gaps. A series of carbon-based, highly efficient photocatalytic, electrocatalytic and photoelectrocatalytic systems for energy and environmental applications were designed and prepared. C-Dots show high catalytic activities for many reactions not only by themselves but as functional components. We proposed a new design concept of a cheap electrocatalytic catalyst for a tunable, stable, selective and efficient production of syngas, made of three components: a HER catalyst, a CO2 reduction catalyst towards CO and a catalyst which stabilizes the active hydrogen (H•) necessary to trigger both HER and CO2 reduction reactions. A new method to analyze the electron transfer number of photocatalysis by forced kinetic process under steady-state photoexcitation was proposed for the first time, and then demonstrated a new mechanism of "two-step two-electron pathway" for efficient overall water photo-splitting. We also proposed a new in-situ and transient photoelectrochemical analysis system, by which we found a new photoelectrochemical property of C-Dots, namely, salt-enhanced electron sink effects. The ions in seawater ionize the functional groups of CDs, which enhances the electron sink effect of CDs, making the photocatalytic activity in seawater better than that in the pure water. C-Dots promise highly efficient new photoelectrocatalysts towards clean and new energy catalysis and the conversion from solar energy to chemical energy.

Key words Carbon Dots; Photocatalysis; Electrocatalysis; Photoelectrochemical property.

Session: Textile-Based Composites

Presenting Type: Oral-Invited

Impact-Resistance Bioinspired Helicoidal Composites

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Due to the introduction of continuous fibers in the thickness direction, the three-dimensional (3D) braided composites obviously improve the shortcomings of the traditional laminated composites such as poor interlayer performance and easy delamination, and have the advantages of excellent comprehensive mechanical properties and strong designability. 3D braided composite materials are mostly made of high-toughness resin matrix and fabric. The shape of the fabric is variable, and the internal meso-structure is complex and highly non-uniform. The high non-uniformity of the meso-structure leads to obvious elastic-plastic damage behavior of the matrix material, resulting in various failure modes and complex failure mechanisms of the braided composite structures under external loads. Meanwhile, the braided composite structures have macro-meso-micro multi-scale characteristics, and the structural damage behavior under external load also has multi-scale characteristics, which makes the non-linear behavior analysis and failure process simulation of braided composite materials and structures extremely difficult. Firstly, a virtual fiber is constructed to simulate the forming process of the preform by using flexible rod and beam elements, and the real yarn path and cross section form, size and content distribution are quantitatively characterized, and a high fidelity meso-geometry model is established considering the real fabric geometry. Secondly, the anisotropic damage tensor and plasticity function are introduced into the expression of the thermodynamic potential energy function, and the elastic-plastic damage constitutive equations of meso-constituent materials are established. Finally, the model reduction is realized by using the clustering reduction idea that considers both the strain concentration tensor and the local material orientation of the fiber bundle, and the elastic-plastic damage constitutive equations and the discrete Lippmann-Schwinger equations are coupled to solve. Then, The data-driven self-consistent clustering analysis (SCA) method considering elastic-plastic damage is developed to efficiently calculate the non-linear response of RVE, which extends the application of SCA in the analysis of RVE with complex meso-structure. Furthermore, a micro-RVE is coupled at each Gaussian integration point of the fiber bundle, and the SCA method is used to solve the non-linear mechanical behavior of the micro-meso-scale RVE. A concurrent three-scale scheme FE-SCA2 for the non-linear mechanical behavior of braided composite structures is proposed to realize the analysis and evaluation of multi-scale damage and failure of 3D

braided composite structures, which greatly reduces the computational costs and avoids the issue of the curse of dimensionality caused by two-way coupling between macro-meso-micro scales.

Key words Braided composites; Multi-scale; Macro-meso-micro damage; Mechanical property; Evaluation method

Session: Textile-Based Composites

Presenting Type：Oral-Invited

Off-Axis Fatigue Behavior and Failure Characterization of 3D Braided Composites

Pibo MA*、Ma Pibo
Jiangnan University

Warp-knitted spacer fabric composite is famous for its excellent mechanical properties and has been applied in many potential applications, such as automobile industry and aerospace field. In this study, the preparation and application of three kinds of 3D warp-knitted spacer fabric reinforced composites is introduced. Such as auxetic warp-knitted spacer fabric composite, lattice warp-knitted spacer flexible inflatable composites, and the cement-based composite.

Key words 3D warp-knitted spacer fabric； flexible composite; auxetic warp-knitted spacer fabric composite ; lattice warp-knitted spacer flexible inflatable composites; cement-based composite

Session: Textile-Based Composites

Presenting Type: Oral-Invited

Three-Dimensional Needling Technology

Sha YIN、Sha Yin*
Beihang University

Inspired by the unique helicoidal structures observed from the scale of coelacanth and dactyl club of the stomatopods, which have shown extraordinary impact resistance under impact, a series of bioinspired composites have been designed and studied in this work. Mimicking the orthogonal double helicoidal structure on the scales of coelacanth, orthogonal double-helicoidal composites with laminated unidirectional carbon fiber reinforced PA6 were designed and prepared. Three-point bending and Charpy impact experiments were adopted to evaluate the impact resistance. Energy absorption was found 26.5% higher than that of the corresponding single-helicoidal composites. Besides, mimicking the Herringbone-like pattern found in the impact region of the dactyl club of the stomatopods, composites with sinusoidally periodic helicoidal (Herringbone-type) fiber architectures were fabricated using multimaterial 3D-printing. Dynamic compressive properties of Herringbone-type and corresponding straight fiber helicoidal (Bouligand-type) structures were studied. The results shown that Herringbone-type structures introduce larger failure strain and more uniform stress during compression and exhibited greater energy absorption. Furtherly, helicoidal composites with helicoidal patterned fibers revealed more complex damage modes deducing greater energy dissipation capabilities. This study would provide guidance and promote the development for future impact-resistant composites materials.

Key words Bioinspired composites, Impact resistant, Helicoidal, Architecture

Session: Textile-Based Composites

Presenting Type：Oral-Onsite

Textile-Targeted Development of Light-Weight and High-Strength Carbonene-Based Fiber

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Zhejiang Sci-Tech University

In practical field, fiber-reinforced polymer (FRP) composite structures are suffering from the erroneous manufacturing and assembly, improper service conditions, and aging, which are inevitably deteriorating the structural performance of FRP structures over their service life. Besides traditional structural health monitoring techniques of utilizing the acoustic emission, fiber optical sensors, strain gages, etc., advances in carbon nanotube (CNT) based composites over the past decade have demonstrated broad potential of utilizing them as multifunctional sensors because of their unique electrical properties. Here, we introduce a series of CNT-functionalized nonwoven sensing composites that possess excellent application scalability, customizability, and conformability. In specific, a thin, porous nonwoven fabric was selectively utilized as the CNT carrier and then hybridized with CNTs following an economic, facile water-based impregnation method. Particularly, the locally integrated CNT coating establishes a broad piezoresistive network that is highly sensitive to both physical and chemical stimuli, simply enabling a large-area versatile sensor. In this presentation, we highlight and demonstrate the multifunctional applications of the CNT-functionalized nonwoven sensing composites as in situ, real-time sensors for life-cycle monitoring of FRP composite structures covering from their manufacturing process to the in-service loading scenarios, where the key results based on the piezoresistive responses of those nonwoven sensing composites for the flow and cure monitoring, temperature and strain sensing, spatial damage detection, and pressure mapping are demonstrated.

Key words Nonwoven Sensing Composites, Carbon Nanotubes, Multifunctional Sensors, Life-Cycle Monitoring

Session: Textile-Based Composites

Presenting Type: Oral-Onsite

Electro-Thermal Coupling Behavior and Temperature Distribution of 3-D Braided Composite under Direct Current

Peng LIU、Zhenqiang Zhao、Chao Zhang*
Northwestern Polytechnical University

Textile composites are widely used to manufacture large structural components of aircraft or aero-engine, because of its convenient forming, excellent mechanical properties, and better impact resistance. Aircraft and aero-engine structures will inevitably suffer high-speed impact load during their service life. It is an urgent technical problem to evaluate the applicability of large-scale textile composite structures against impact loads. Experimental validation and certification processes are time and economy costly due to the large number of specimens and tests. Therefore, it is necessary to introduce computational methods to improve the design efficiency for impact resistance of composite structures.

In this study, a highly efficient meso-scale finite element (meso-FE) model is developed to enable the damage and failure prediction of a two-dimensional triaxially braided composite (2DTBC) panel that is subjected to impact loading. Considering the huge computational cost of meso-FE model in impact simulation, a modified modeling strategy, integrating proper meshing verification and parameter correlation, is proposed. The modified meso-FE model reduces the computational time by 96.8% in quasi-static simulations. Ductile failure and progressive damage models are introduced to enable impact failure simulation, together with deformation-gradient based element deletions rules. The meso-FE model is validated based on experimental results to further implement in the impact simulation of the large-scale 2DTBC panel. Impact damage distributions were obtained by extracting damage contour maps for different failure modes. The simulation results show the excellent capacity of the meso-FE model in visualizing the complex deformation and failure pattern of the braided composite, especially in understanding the internal damage and failure mechanism in each component of the composite (fiber tows, pure matrix and the intra- and inter-layer interfaces). It is found that the damage zones of pure matrix and interlaminar interface are close to each other, and the area of interlaminar interface delamination is much larger than that of intralaminar interface damage.

Key words two dimensional triaxially braided composite, finite element method, mesoscale, impact, progressive damage behavior

Session: Textile-Based Composites

Presenting Type：Oral–Onsite

Multi-scale Study of Ballistic impact of Hierarchical Textile composite Panel

Yanfei Yang*、Zihu Wang、Ji Li、Ming Zhang
Zhongyuan University of Technology

In order to improve ballistic performance and reduce the areal weight of ballistic armor panel, optimization of the armor panel structure is one of efficient and available measures at present. The armor-grade textile composite panel possesses typical hierarchical structure (fiber-yarn-fabric-panel). However, the interaction between hierarchies, load distribution on hierarchies and the influence of hierarchies on ballistic performance has not been fully understood. This result in the armor panel design has been limited to macro structure, which cannot be optimized through bottom-up material-performance design method. This study aims to identify the influence of hierarchical structure of textile composite panel on ballistic performance. Ballistic responses of each hierarchical structure in armor panel and their ballistic mechanism has been investigated. Ballistic responses of armor panels will be investigated at different scales through multi-scale Finite Element (FE) analysis, which will be combined with experimental methods for validation. These results will provide a theory guide for the armor panel design.

Key words Hierarchical Textile composite Panel, Finite Element (FE) analysis, Ballistic responses, armor panel design

Session: Textile-Based Composites

Presenting Type: Oral-Onsite

A Data-Driven Multi-Scale Analysis Method for The Damage Behavior of The Three-Dimensional(3D) Braided Composites and Structures

Zhongxiang PAN*
Zhejiang Sci-Tech University

Textile composites are structural materials that can be widely used in the field of high-altitude or high-speed engineering applications and endure complex dynamic loads at present and for a long time in the future. Textile-based composites are fiber reinforced by taking textile fabrics as preforms and embedding them in matrix materials. Based on the actual engineering demands, the performance analysis of textile composites always need to follow the building block approach that serves as a pyramid framework for designing composite structures. In this work, the coupon-level and element-level study of various textile-based (including 2D/3D woven, warp-knitted, and 2D/3D/triaxial braided) composites are conducted under dynamic loads. With the help of high-speed camera, infrared thermography, and finite element analysis technology, the mechanical behavior, deformation, and progressive damage mechanism of coupons, panels, tubes, beams, sandwichs and some special section members were investigated. It is found that the dynamic mechanical performance of coupons and structures of textile-based composites has numerous distinctive features not be discovered in the unidirectional composite laminates, which may be closely related to the fabric configurations, material hybridization, shear modes, kinking bands, braiding patterns, spatial orientation and distribution, et al. Therefore, the design and application of textile-based composites is a complex system engineering. The fundamental design confidence would rely on detailed and extensive mechanical property research at the coupon and element levels.

Key words Textile composites; Dynamic mechanical behavior; Coupon/element levels

Session: Textile-Based Composites

Presenting Type：Oral-Onsite

Developing 3D Woven Weft Interlock CFRP/CAFRP Composites and Experimental Investigation on Their Out-of-Plane Flexural Performance

Xiaoming CHEN*、Tianlei Yao、Kaijie Wu
Tiangong University

Three-dimensional needled composites overcome the shortcomings of laminate composites that are easy to delaminate, and have been widely used in aerospace, rail transit, new energy and national defense. The research status of 3D needling technology was introduced, including the structures of 3D needled preform, the preparation technology of special-shaped needled preform, and the characterization technology of 3D needled composites. Finally, the bottleneck problems currently faced by 3D needling technology were summarized, and the future research directions were prospected.

Key words 3D needling; Preform structure; Preparation technology; Characterization technology; needled composite

Session: Textile-Based Composites

Presenting Type：Oral–Onsite

Failure mechanisms of three-dimensional braided composites subjected to different strain rates

Xingzhong Gao*
Xi'an Polytechnic University

Three-dimensional (3-D) braided composites have been widely used in aerospace and transport. Braided composites show significantly different damage evolution under varied strain-rate loadings. A bridge which can connect the strain rate variation to different damage evolution of composites is urgently needed for composite design. This research demonstrated how the strain rate variation induced the change of damage evolution and failure mode of 3-D braided composite. A high-speed camera system was used to capture damage process information. A micro-scale rate-dependent finite element model (FEM) was established to study the underlying mechanisms. The results show that the velocity gap between yarns and resin became more obvious at higher strain-rate loading. Damage morphology of composite under lower strain rate is resulted from the higher transverse stress at the output-bar area. Higher strain-rate loading induces plastic deformation occurred more earlier in composite. The deformation distributes more haphazardly under higher strain-rate loading. An optimizing strategy is proposed to ensure the dynamic mechanical performance of 3-D braided composite satisfy the designed requirement.

Key words 3-D braided composite; Strain rate; Damage evolution; Finite element analysis

Session: Textile-Based Composites

Presenting Type：Oral–Onsite

A study of pore defects on the mechanical properties of 3D braided composites by a novel two-scale method

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Northwestern Polytechnical University

With the rapid development of trans-atmospheric vehicle, thermal barrier problem needs an urgent solution. The needle-punched braided quartz/phenolic composite is a new kind of thermal protection material with the property of very high resistance to high heat flux, high shear environment and long re-entry time. So, it is of great significance to study the surface ablation properties of needle-punched braided quartz/phenolic composites in high temperature environments. By carrying out the high temperature test of the needle-punched braided quartz/phenolic composites under oxygen-acetylene flame, the extreme thermal environment during the re-entry process can be simulated. In this way, the linear ablation rate and surface temperature of needle-punched braided quartz/phenolic composite can be obtained. With the help of microscopic observation and detection method such as SEM, EDS, XRD, etc., we can detect the types of elements and substances in key areas on the surface of original materials and ablation samples, so that the chemical reaction path on the material surface during the ablation process can be deduced. Based on the liquid layer theory of silicon-based composites, the mass conservation and energy conservation equations for the ablated surface of needle-punched braided quartz/phenolic composite in high temperature environment are established. Considering the influence of the thermochemical reaction of the air boundary layer and the thermal blocking effect, a coupled prediction model of the surface ablation and thermal response of the needle-punched braided quartz/phenolic composite are constructed. The predicted value of linear ablation rate is in good agreement with the experiment results (relative error 13.2%). Finally, refined design, performance improvement and reliability evaluation of needle-punched braided quartz/phenolic composite can be provided by this research.

Key words needle-punched braided composite; surface ablation model; liquid layer; thermochemical reactions; linear ablation rate

Session: Textile-Based Composites

Presenting Type: Oral-Onsite

Concurrent Multi-Scale Finite Element Modeling of Tearing Behavior of Flexible Woven Composite

Yonglin CHEN、Weidong Yang*、Yan Li
Tongji University

Flexible woven composites have been increasingly used in membrane structures, inflatable building, airship envelopes and so on. However, flexible woven composites are prone to tear attributed to inevitable defects caused by fabrication process, abrasion or folding. To reveal the behavior details of fibers and yarns during tearing process, a concurrent multi-scale finite element modeling technique is presented to simulate the tearing behavior of woven composite. The woven composite model involves fibers bundles in micro-scale, yarns in meso-scale and membranes in macro-scale. Several fiber bundles with truss elements represents the primary yarns in the local region of the fabric around a defect, while, in the global region, membrane elements simulate the woven composite. Yarns with solid elements connects the fiber bundles and membrane. This model was validated against tearing test results and then used to investigate the influence of defect lengths and the biaxial load ratios on the biaxial tearing properties of the woven fabric. The simulation results also revealed the meso-scale tearing mechanism of fiber bundles, that is, the interaction between fiber bundles affects the force transmission and stress distribution around the defects. The work can provide a reference for studying mechanic mechanism of flexible woven composites.

Key words Flexible woven composites, Concurrent Multi-Scale Finite Element Modeling, Tearing Behavior, Meso-scale mechanics mechanism

Session: Textile-Based Composites

Presenting Type：Oral-Onsite

Textile-Targeted Development of Light-Weight and High-Strength Carbonene-Based Fiber

Ruidong WU、Chao WU、Lik-ho TAM*
Beihang University

Polypropylene (PP) has been widely used in various engineering fields, which are commonly subjected to dynamics loads. The limited ductility of PP under dynamic loads leads to the unexpected material failure. Carbon nanotube (CNT) with excellent mechanical properties has been regarded as an ideal reinforcement filler to improve the dynamic performance of PP materials. However, the CNT fillers form aggregation with increasing additions. In this work, the effect of CNT aggregation on the mechanical response of CNT/PP nanocomposite under dynamic loads is investigated using molecular simulation. The aggregated CNT at different weight percentages are added into the PP matrix to generate the nanocomposite models, which are subjected to different cycles of loading-unloading compression process. By comparing the dynamic performance of CNT/PP nanocomposite at different weight percentages, the effect of CNT aggregation on the dynamic response of nanocomposite is examined. This study provides nanoscale insights into the CNT aggregation on the dynamic response of CNT/PP nanocomposite, which contributes to the optimized design of nanocomposite materials.

Key words Nanocomposite, carbon nanotube, aggregation, dynamic loads, molecular simulation

Session: Textile-Based Composites

Presenting Type：Oral-Onsite

Enhancement on Mechanical Properties of the Jute Fiber Mat/Polylactic Acid（PLA) Composites by Plasma Treatment

Jiahua YANG、Xinjuan Cai、Lan Yao*
Donghua University

Jute fiber reinforced polymer composite materials play a decisive role in automobile interior decoration area. However, the interfacial problems always exist when the jute fiber was infiltrated by the resin. In this study, the surface of jute fiber mat was modified by plasma treatment in order to improve the interfacial properties between jute fiber and polylactic acid. The results showed that with the increase of plasma treatment power and treatment time, the roughness of the fiber surface increased significantly. Plasma treatment can realize the conversion of the fiber surface from hydrophilic to hydrophobic, and the contact angle increased from 46.7° to 137.4°. After plasma treatment, the mechanical properties of composite materials were effectively improved, and the shear, tensile and bending properties were enhanced by 38%, 14%, and 29% respectively. The after- fracture morphology of the composite's cross section was observed by SEM and the results showed that the bonding between fiber and resin of the treated sample was better than that of the untreated one.

Key words Jute fiber Mat; Polylactic Acid; Composite; Plasma Treatment; Mechanical Properties

Session: Textile-Based Composites

Presenting Type: Oral-Onsite

High Performance and Multifunctional 3D Woven Structural Composites with Super Light-Weight and Structural Integrity

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Donghua University

The composite structures with lightweight, excellent mechanical and multifunctional properties are crucial to their applications in the fields of industrial, civil as well as aerospace engineering. Traditional laminate composites which are mainly made of fiber or fabric, are prone to lamination failure of low-speed impact or shear to load. Three-dimensional (3D) woven fabric reinforced composites, due to the existence of vertical binding yarn, exhibit extraordinary structural integrity and delamination resistance. Furthermore, the multi-layer integrated structure of 3D woven fabric provides a proper environment for the embedded functional fibers. In this speech, mechanical, thermal as well as dielectric properties of the 3D woven composites will be introduced. Moreover, some multifunctional structures based on 3D woven composites, such as 3D textile antenna, 3D woven sensing and E-heating composites will be presented.

Key words 3D woven composites; 3D spacer composites; multifuctional compsites

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Session: Textile-Based Composites

Presenting Type: Oral-Onsite

Study on The Correlation between The Mechanical Property of Textile Composites and The Bearing Capacity of Special-Shaped Structure

Chao ZHANG*、Ang LI
Jiangsu University

3D braided composites have been widely applied in the aerospace, automotive and other high-tech industries because of their excellent comprehensive properties. Fatigue is an important factor leading to structural failure during the service. In this paper, a meso-scale nonlinear finite element (FE) model is developed to study the fatigue behavior and predict the fatigue life of 3D braided composites subjected to off-axis tension loadings. Stress analysis, failure criteria and material properties degradation scheme in the meso-scale model are implemented by a user-material subroutine UMAT based on ABAQUS/Standard solver. The fatigue damage initiation and propagation process of 3D braided composites under typical off-axial loadings are analyzed in detail and the fatigue life is obtained from the predicted S-N curve. This work provides new insights and transferable modeling technique for studying the off-axial fatigue problems in other textile composites.

Key words 3D braided composites; fatigue; off-axial loading; progressive damage analysis; FE modeling

Session: Textile-Based Composites

Presenting Type：Oral-Onsite

Structural Design and Manufacturing of 3D Textile Composites

Yongjie YAN*、Qi Ni、Jiale Zhang、Sheng Wan
Zhejiang Sci-Tech University

Carbonene is a type of carbon material which contains π-π congugated structure. High-energy C-C bonding makes it expectable in preparing high-performance carbon materials. Common carbonene materials consist of graphene and carbon nanotube. They have received much attention in recent years, but no large-scale applicable products were developed. Carbonene-based fiber is a currently developed new-type carbon fiber, and has the properties of light-weight and high-strength, thus making it applicable in some extreme fields such as aerospace, unmanned aerial vehicle and wind-power blade. This report introduced the progress of the carbonene fiber from the points of view of synthesis methods, structure property, and mechanical performance.

Key words carbonene, fiber, mechanical, carbon nanotube, graphene

Session: Textile-Based Composites

Presenting Type: Oral-Onsite

Experimental and Numerical Analysis of Three-Dimensional Five-Directional Braided Composites for Tensile Properties and Failure Mechanisms

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Three-dimensional five-directional (3D5d) braided composites have been paid great attention in many fields, such as aviation, industry and civilian use and so on, due to their excellent mechanical properties. However, due to the additional fifth-axial yarns along the braiding direction, their mechanical behaviors, especially in the braiding direction, are quite unique and critical, which is of great importance to structural design in practical application. Experimental study of longitudinal tensile behaviors for 3D5d braided composites with different braiding angles were carried out at room and elevated temperatures, and their failure modes were investigated. 3D5d braided preforms with different braiding angles were reinforced with epoxy resin via Vacuum Assisted Resin Transfer Molding (VARTM) method. The failure modes of the damaged specimens at room and elevated temperatures were characterized with SEM. Simultaneously, the parametric finite element model (FEM) of the braided composite was established, which considering the relationship of the yarn space contact. The tensile properties of FEM at room temperature were calculated based on the model, and the predicted results agreed well with the experimental data, which showed that the established FEM could effectively predict the mechanical properties and progress damage of the 3D5d braided composites. The results showed that both the braiding angle and temperature significantly affected the tensile properties of the composites. Small braiding angle composite at room temperature possessed the best tensile properties. As the temperature increased, the tensile properties of the both composites with different braiding angles decreased. Meanwhile, the interfacial debonding of fibers and epoxy was more obvious at high temperature. This experimental and simulation study of tensile properties and failure modes is of great significance for the structural design of 3D5d braided composites with specific parameters in practical applications.

Key words Braided composite; Tensile properties; Failure mechanism; Strength prediction

Session: Textile-Based Composites

Presenting Type: Oral-Onsite

A study of pore defects on the mechanical properties of 3D braided composites by a novel two-scale method

Zhiqiang Yang*、Jianjin Gong
Harbin Institute of Technology

Pore defects have appeared inevitably during the manufacturing process of braided composites, which significantly influence the mechanical properties of 3D braided composites. A novel two-scale method has been developed to predict the mechanical properties and strength properties of 3D braided composites with pore defects. The multiscale approach combining the theoretical model and the finite element method (FEM). In microscale, the theoretical model consists of Mori-Tanaka method and extended double-inclusion method, which were used to predict the effects of pore defects and interfaces on the mechanical properties of yarns. Then, the Chamis model was modified to take account of pore defects to predict the strength of yarn. In order to validate the theoretical model, it was used to calculate the mechanical properties of unidirectional fiber reinforced composites and compared with experimental data. The results of the theoretical model and experimental data are in good agreement. Also, the modified Chamis model was verified by FEM. In mesoscale, the mechanical properties of porous matrix in 3D4DB composite were calculated by Mori-Tanaka method. The strength prediction, stress and strain field of 3D4DB composites with pore defects were investigated by means of finite element simulation based on the progressive damage theory in ABAQUS, which compared the simulation results with experiments. The innovation of this work is to establish the constitutive model and finite element model of 3D braided composite with pores and predict the mechanical properties and the strength of 3D braided composite with pore defects. This work may have important significance for further manufacturing and defect prediction of composites.

Key words 3D braided composites, pore defects, Mori-Tanaka method, extended double-inclusion method, progressive damage theory

Session: Textile-Based Composites

Presenting Type：Oral-Onsite

Surface Modified Carbon Fibre Reinforced Composites for Electromagnetic Shielding

Yan SUN、Tao Liu、Wei Fan*
Xi'an Polytechnic University

This paper reports a novel manufacturing processing of preparing the 3D multiaxial braided composites (3DMBCs) and the effects of various defects generated in the manufacturing process on the compressive properties of 3DMBCs through the experimental and numerical methods. The five-step fabrication process of the 3D multiaxial braided preform was firstly introduced in detail. Then, the influences of various defects such as voids, waviness, and fiber breakage defects on the compressive properties of 3DMBCs were discussed. It was found that the fiber breakage defect and waviness defects are the two primary factors on the decrease of compressive properties of 3DMBC. Void defects in the resin and interface have little effect. When the fiber breakage defect content was 25% and the waviness was 7°, the composite compressive modulus decreased by 51%. The progressive damage process and failure mechanism of the composites under 90° compressive loading confirmed the validity of the numerical by comparing with the experiments.

Key words 3-Dimensional reinforcement; Defects; Mechanical properties; numerical model; CT analysis

Session: Textile-Based Composites

Presenting Type：Oral-Onsite

Multi-scale Study of Ballistic impact of Hierarchical Textile composite Panel

Jiawen QIU*
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With the development of intelligent communications and stealth technology in the military field, the electromagnetic interference issue cannot be ignored, and the electromagnetic shielding and absorbing materials are getting more and more attentions from researchers. This project aims to synthesize carbon fiber reinforced composites with excellent electromagnetic shielding characteristics and good mechanical properties. A surface modification method of carbon fiber have been designed and prepared. By adjusting the ratio between precursor and carbon source, as well as the reaction time and temperature of surface treated carbon fiber, the purpose of in-situ growth of 3D graphene structure on the surface of carbon fiber can be achieved. The precursor finally produces the synergistic effect of dielectric loss and magnetic loss with the 3D graphene structures in the form of ferrous sulphate. The electromagnetic shielding mechanism of 3D structures formed by the graphene-related structure and the precursor and the dielectric properties of surface modified carbon fiber would be studied. The effect of the proportion of the surface modified carbon fibers in the composites on the electromagnetic shielding and mechanical properties of the materials would also be studied.

Key words surface modification, carbon fibre reinforced composites, electromagnetic shielding

Hangzhou, PR China 25-28 April, 2023

Session: Textile-Based Composites

Presenting Type: Oral-Onsite

Experiment investigation on rate-dependent tensile response of individual fiber tow composites

Jiahui Gu、Zhenqiang Zhao、Chao Zhang*
Northwestern Polytechnical University

Textile composites have been applied widely in aircraft structure, such as fan blade and case of aero-engine. For textile composites, fiber tows, as the main-bearing component, have a critical effect on the dynamic performance of textile composites and even the structures. However, Intrinsic properties of individual fiber tow composite mainly rely on theoretical and numerical predictions, and their effectiveness is the lack of direct experimental verification.

To investigate the rate-dependent tensile response of individual fiber tow composites, an experimental methodology for dynamic tensile test was developed based on the Split Hopkinson tensile bar system combined with an ultra-high-speed camera. The tensile tests of the tow composites were conducted at quasi-static and dynamic loading rates respectively, to analysis the effect of the rate dependence, fiber counts and gauge length. Moreover, the difference in mechanical properties and failure mode of tow composites were investigated at different strain rates, and the fracture morphology reveals the enhancement of fiber-matrix interfacial shear strength at higher strain rates. Additionally, a modified Weibull model is proposed to describe tensile strength distribution affected by gauge length and strain rates.

Key words Tow composite; dynamic tensile test; strain rate

Session: Textile-Based Composites

Presenting Type：Oral−Virtual Platform

Experiment investigation on rate-dependent tensile response of individual fiber tow composites

yousong XUE、Baozhong Sun

Temperature rise and distribution from Joule heat are important for multifunctional application of carbon fiber reinforced composite. Here we studied the electro-thermal coupling behavior of 3-D braided composite under direct current. The temperature from Joule heat reduced electric resistance and contact resistance in the composite. The reduction range depends on temperature effect on electrical conductivity. We also developed a finite element analysis (FEA) model to show temperature distribution in the composite applied with a current density of 32 kA m−2. The temperature of two ends of the composite sample decreased to lower values of the center region. The Joule heat generated from the electric resistance of carbon fiber tows contributes to the large amount of temperature rise. The Joule heat generated from the contact resistance leads to non-uniform temperature distribution.

Key words Textile composites, Electrical properties, Finite element analysis (FEA) , Infrared thermography, Electro-thermal coupling

Session: Textile-Based Composites

Presenting Type: Oral–Virtual Platform

Study on the correlation between the mechanical property of textile composites and the bearing capacity of special-shaped structures

Bing Wang*、Guodong Fang
Harbin Institute Technology

The textile composite twisted structure under cantilever load is studied using experimental and multiscale numerical methods. The uncertain geometry parameters inside the twisted specimen are identified using Micro-CT scanning technology, and quantified using multivariate Gaussian random field theory. A high-fidelity meso-RVC database after data clustering is established using these uncertainties, in which the warp and weft yarns are no longer regular orthogonality, the yarn cross-sectional area and the yarns gap exhibit variability. The non-orthogonal finite element (FE) model is proposed to investigate the effects of yarns angle on the stiffness and strength. An efficient multiscale method coupling FEM and fast Fourier transformation (FFT) method considering the statistical uncertainty quantification is developed to predict the mechanical behaviors and reveal the damage and failure mechanisms. The stiffness distributions of the twisted composite structures are determined by using the FE analysis combining with the experimental results. There is a cubic polynomial function relationship between the macroscopic local twisted angle and the local textile composites stiffness, which are used to correct the homogenization material properties obtained by initial ideal RVC.

Key words Textile composites; Correlation; Multiscale analysis; FFT; FEM

Session: Textile-Based Composites

Presenting Type: Oral-Virtual Platform

Enhancement on Mechanical Properties of the Jute Fiber Mat/Polylactic Acid (PLA) Composites by Plasma Treatment

Junchao CAO、Chao Zhang*
NorthWestern Polytechnical University

Due to the lack of reinforcement in the thickness direction, delamination has become a major damage form of composite laminate, which may be affected by some environmental factors, such as temperature and humidity. Under impact loading, the composite laminate is prone to rapid delamination growth, which is significantly different from the crack growth characteristics under quasi-static loading. Therefore, this paper aims to study temperature dependency on the interlaminar delamination of composites under quasi-static and dynamic loading. In this work, quasi-static and dynamic double cantilever beams (DCB) tests of T300/7901 carbon fiber/epoxy resin unidirectional composite laminates were carried out under different temperatures (-20°C-110°C). The dynamic loading adopted a uniaxial bidirectional electromagnetic Hopkinson bar, and the pure mode I interlaminar crack initiation and propagation was realized by stretch-stretch symmetric loading, with loading rate of 15 m/s and 24 m/s. Kirana high speed photography and crack propagation gage were used to monitor the crack initiation. Hybrid experimental-numerical method was performed to determine the dynamic initial fracture toughness using the virtual crack closure technique (VCCT). The main conclusions are :1) Environmental temperature has a significant effect on mode I interlaminar fracture toughness. As temperature increases, the fracture toughness increases, probably due to the increasing ductility of epoxy resin; 2) The use of uniaxial bidirectional electromagnetic Hopkinson bar can achieve the pure mode I dynamic crack initiation and propagation of DCB specimens； 3) Under all test temperatures, the mode I initial fracture toughness increases with increasing loading rate. However, the effect of loading rate is relatively weak at the quasi-static loading; 4) There is a difference of the temperature effect on crack propagation speed between quasi-static and dynamic loading. Under quasi-static loading rate, the crack propagation speed decreases with the increase of temperature. However, the temperature has little effect on the dynamic crack propagation speed, which remains almost unchanged under different temperatures.

Key words Mode I delamination; Temperature effect; Loading rate dependency; Crack propagation speed

Session: Textile-Based Composites

Presenting Type: Oral-Virtual Platform

Failure mechanisms of three-dimensional braided composites subjected to different strain rates

Q QIN、xiaoling wei、han hu、yiwei ouyang、xiaozhou gong*
WUHAN TEXTILE UNIVERSITY

In order to solve the problem of weak out-of-plane impact resistance of laminated composite materials, the structure of composite fabric preform was optimized, and the three-dimensional fabric structure of integral forming stiffened plate was designed. The SGA598 sample loom was used for weaving, and the fabric preform was prepared into composite materials by vacuum assisted resin transfer molding process. The impact resistance of reinforced three-dimensional fabric was tested by drop hammer impact tester. The geometric model and material model of composite material were established and simulated by finite element software ABAQUS. The T-shaped stiffened plate composite preform was successfully woven by a small sample loom. The actual rib height was consistent with the design rib height. The buckling shape of each yarn in the composite material was consistent with the theoretical design shape. With the increase of impact energy, the damage of stiffened plate composites increases, and the damage area is mainly concentrated in the contact area between material and punch. Circular pits are formed on the impact surface, and matrix cracking and fiber fracture appear around the pits. The damage on the back of the impact is mainly matrix cracking and fiber tensile fracture, and no obvious delamination is observed. In the finite element simulation, the composite material is assumed to be a defect-free material with complete resin infiltration, which is different from the actual material. The simulation results are close to the experimental results, and the failure mode in the cloud picture of the simulation results is consistent with the actual failure mode. Subsequently, the simulation accuracy can be improved by optimizing the material model and establishing the material constitutive relation.

Key words stiffened plate；three-dimensional fabric；composites；low velocity impact；finite element method

Session: Textile-Based Composites

Presenting Type: Oral-Virtual Platform

Functionalized Nonwoven Composites as Distributed Sensors for Life-Cycle Monitoring of FRP Composite Structures

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Three-dimensional (3D) woven textile composites with binder yarn running in the composite through-thickness direction have drawn much attention because of their specific geometries, improved interlayer strength, and impact-resistance performance. In this study, three types of 3D woven structures with different binder-yarn paths and ratios were designed and fabricated based on a dobby-weaving loom with a special weft-interlock structural design in which part of weft insertions serves as binder yarns. Carbon/aramid fiber-reinforced plastic (CAFRP) composites with carbon warp, weft, and aramid binder yarns, as well as carbon-fiber-reinforced plastic (CFRP) composites were reinforced using the three types of woven structures and consolidated with epoxy resin using vacuum-assisted resin transfer molding technology. Out-of-plane quasistatic three-point bending tests and dynamic low-velocity drop-weight impact tests were conducted on these woven composites to study the effect of woven structure and hybridization on their flexural performance. Nondestructive ultrasonic C-scan and X-ray microcomputed tomography were applied to characterize the failure modes of the post impacted composites. We found that woven structures affect the flexural performance and failure mode of the developed CFRP composites, these structures with lower in-plane and binder yarn waviness exhibited higher quasistatic flexural performance; structures with higher in-plane and binder yarn waviness exhibited better impact resistance. Woven structure and aramid binder yarn have a significant impact and a coupling effect in the flexural performance of hybrid composites. Introducing aramid binder yarn in the 3D woven CAFRP composites lowers the quasistatic flexural performance to a certain extent but increases the impact performance significantly. The specific woven structural design combined with hybridization is an advanced technique for achieving higher flexural properties for specific engineering applications.

Key words 3D woven composite, CFRP, Flexural performance, Low-velocity impact

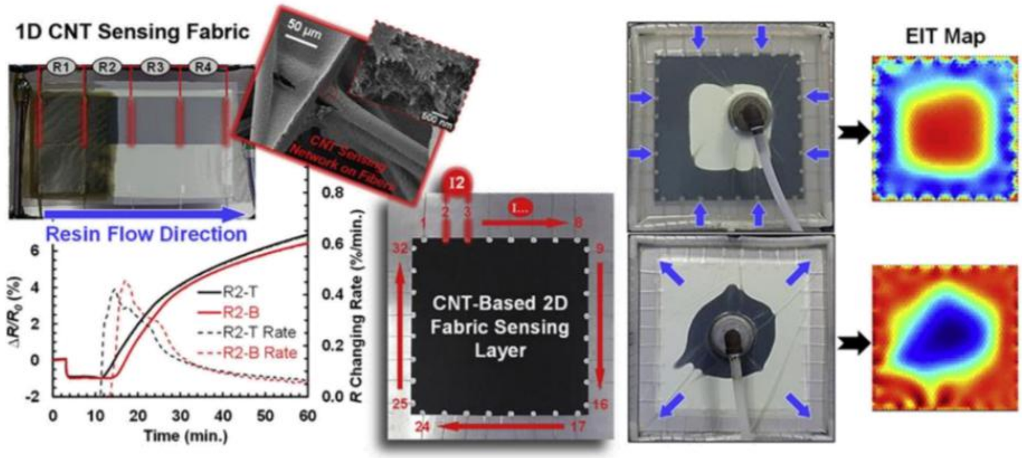

Fig. 1. The distributed CNT-functionalized nonwoven composite sensors for monitoring the VARTM process of manufacturing GFRP composite panels.

Session: Textile-Based Composites

Presenting Type: Poster

Modeling the braiding parameters and strain rate on dynamic mechanical behaviours of 3D braided composites

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2. Peking University

Three-dimensional (3D) braided composites have been widely used in structural applications owing to their excellent mechanical properties and anti-layered architecture. In this work, 3D full size finite element model is established to investigate high strain rate response and strength prediction of 3D carbon/epoxy braided composites with respect to the interior, surface and corner regions. Firstly, the bridging matrix is introduced to predict the mechanical properties of the unidirectional fiber composite with different braiding parameters. Then, the elasto-plastic damage and exponential degradation models are proposed to separately reflect the plastic characteristics of the resin and the nonlinear degradation of the yarn, where strain rate effect and interface behaviour are considered simultaneously. Furthermore, the dynamic stress-strain curve, damage and stress distribution and evolution process are obtained to reveal the progressive damage behaviours and compression failure mechanisms of 3D braided composites with different braiding parameters under different high strain rates. Finally, the predicted results are well in agreement with the experimental data.

Key words Three-dimensional braided composites; high strain rate; Braiding parameter; Failure mechanism

Session: Textile-Based Composites

Presenting Type: Poster

Development of light-weight and high-strength nanocarbon-based fiber for Textile-targeted application

Yongjie Yan*、Yongjie Yan
Zhejiang Sci-Tech University

Carbonene is a type of carbon material which contains π-π congugated structure. High-energy C-C bonding makes it expectable in preparing high-performance carbon materials. Common carbonene materials consist of graphene and carbon nanotube. They have received much attention in recent years, but no large-scale applicable products were developed. Carbonene-based fiber is a currently developed new-type carbon fiber, and has the properties of light-weight and high-strength, thus making it applicable in some extreme fields such as aerospace, unmanned aerial vehicle and wind-power blade. This report introduced the progress of the carbonene fiber from the points of view of synthesis methods, structure property, and mechanical performance.

Key words carbonene, fiber, mechanical, carbon nanotube, graphene

Session: Textile-Based Composites

Presenting Type: Published only

Effect of interlaminar toughening of short carbon fiber on structural drawing performance of composite bolt

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Carbon fiber reinforced polymer (CFRP) occupies a large proportion of composite applications. Due to its high specific strength, stiffness, and excellent corrosion resistance, CFRP has gained popularity and become recognized as a prominent material for engineering applications in the past decades. Lightweight composite alternative to conventional materials in many structural and semi-structural automotive, aerospace, and other industrial applications. In this paper, 12K T700 carbon fiber filament and epoxy resin were used to prepare carbon fiber prepreg, laminates containing short-cut carbon fiber between layers were made with it, and finished products were obtained after autoclave molding. The effects of short fiber interlaminar reinforcement on tensile, compression, bending and interlaminar shear strength of carbon fiber composite laminates were studied. The prepreg formed by resin impregnation of carbon fiber filament was made into a prefabricated body with dimensions of 150×150×125mm by five different paving methods. Bolts were embedded in the prefabricated body, and the mechanical properties of the components were tested after high-temperature curing. The experimental results show that the bolt embedded perpendicular to the plane of the prefabricated body makes the bolt have higher bond strength, and the prefabricated with short fiber lamination has stable mechanical properties.

Key words interlaminar toughening; pulled off performance; CFRP

Session: Natural Fibers Green Composites

Presenting Type: Oral-Onsite

Mechanical Properties of Bamboo Fiber Enhanced Resin Composite Investigated by Mesoscale Finite Element Simulation, Machine Learning, and Deep Learning

Wenjing WANG*、Shuyi Wu、Yuchao Wu、Wendi Liu、Renhui Qiu、Xiaoqian Yan、Xin Huang、Yan Yang
Fujian Agriculture and Forestry University

Bamboo fiber enhanced resin composite has advantages such as environmental friendliness, light-weight, and high specific strength. However, the mechanism of mechanical properties remains unclear, which seriously limits the optimization and application of the composite. The main challenges of this issue include the complexity of the composite mesoscale models and the multi factors of the composite mechanical properties. In this paper, the mesoscale finite element simulation, machine learning analysis, and deep learning methods are established to investigate the mechanism of composite mechanical properties. First, based on the experiment results of the bamboo fiber enhanced palm oil resin composites, a mesoscale finite element method was established to analyze the stress distribution and failure modes of the composite. Second, using a data set consisting of experimental and simulation results, an ensemble machine learning method was used to analyze the main factor of the mechanical properties and predict the mechanical properties under different combinations of various parameters including the volume fraction of fiber, fiber length, fiber diameter, and resin properties. Third, the deep learning method was used to predict the location of maximum stress in the resin, which is critical for the mechanical properties of composites containing discontinuous fibers, and analyze the relationship between fiber distribution and the location of large stress. This study provides an approach combing the finite element method and intelligent prediction method to analyze the composite performance and more understanding of the mechanical mechanism of the composite.

Key words mesoscale finite element simulation, machine learning, deep learning

Hangzhou, PR China 25-28 April, 2023

Session: Natural Fibers Green Composites

Presenting Type: Oral-Onsite

Investigation of Spring-Back Behaviour on 3D-Printed Continuous Plant Fibre Composites

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2. School of Chemistry, Physics and Mechanical Engineering, Queensland University of Technology (QUT), Brisbane, Queensland 4001, Australia

Printing parameters are known to affect the mechanical properties of 3D-printed composites. In this work, a significant spring-back phenomenon is found during the 3D printed continuous flax fibre reinforced composites (CFFRCs). The printing speed is the critical factor in controlling the spring-back behaviour. It can affect the thickness, the fibre volume fraction and the void content of CFFRCS, thus influencing the mechanical properties. With the increase of printing speed from 5 mm/s to 15mm/s, the loss of the tensile properties of CFFRCs is up to 30%. The evolution of the spring-back behaviour of CFFRCs is analysed by electron microscopy at different printing speeds. The spring-back mechanism of the CFFRCs is further elucidated with the observation of temperature distribution during the printing process. It reveals that the spring-back of the compressed yarn with twisted structure could occur when the deposited thermoplastic matrix was above the glass transition temperature. The results and findings could contribute to the process optimization of 3D-printed continuous plant fibre composite parts with high mechanical properties and dimensional precision.

Key words 3D printing; continuous flax fibre reinforced composites (CFFRCs); printing speed; mechanical performance

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Natural Fibers Green Composites

Presenting Type: Oral-Onsite

Analysis of the Water Absorption Behavior and Assessment of Internal Stress of Jute Fiber Reinforced Poly (Lactide Acid) Composites

Ning JIANG*、Yaomin Li
Shandong University of Techology

This work focused on modelling the water absorption behavior of short jute fiber reinforced poly (lactide acid) composites. The pure PLA and jute/PLA composites were immersed in deionized water at 37 °C until saturation. The water diffusion parameters, water swelling parameters, internal microscopic structure and fiber orientation distribution of the composite were determined by water diffusion behavior test, scanning electron microscopy (SEM) and X-ray computed tomographs (XCT), respectively. The analysis of the experimental results proved that the water diffusion behavior of jute/PLA composites was in accordance with Fick's law. The water diffusion coefficient and the water absorption swelling coefficient of jute fiber were valued based on the inverse analysis method. A three-dimensional (3D) finite element (FE) modeling approach, which included the true internal microstructure of short plant fiber reinforced composites, was proposed to accurately simulate water diffusion behavior. Then the reversible water absorption behavior of pure PLA and jute/PLA composites was simulated, and the water absorption kinetic parameters of the materials were corrected. In addition, the evolution of the internal stress field caused by water swelling is quantified. Those areas with significant stress concentrations will become the starting point for potential damage which were in good agreement with experimental measurements.

Key words Plant fibre composites; Water absorption; Finite element analysis (FEA); X-ray computed tomographs (XCT)

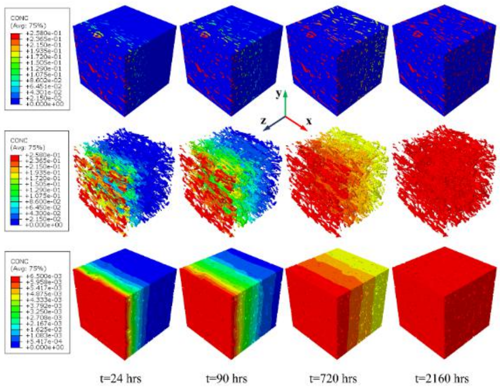

Fig. 1. Transient moisture distribution within (a) jute/PLA composite, (b) jute fiber and (c) PLA matrix is shown at four different times.

Session: Natural Fibers Green Composites

Presenting Type: Oral-Onsite

Study on the Preparation and Properties of Bamboo Chip Cement Block

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2. State Key Laboratory of Plant Fiber Functional Materials, State Forestry and Grassland Administration

In this article, bamboo sawdust based cement blocks (BCB) were prepared by pouring molding and pressurized molding with bamboo sawdust as the filling phase and Ordinary Portland Cement as the matrix phase. The differences between the physical and mechanical properties of the blocks prepared by the two molding processes were compared, and the effects of bamboo sawdust doping on the properties of the blocks were discussed. At the same time, in order to enhance weathering resistance and water resistance of the block, it is necessary to modify the block and bamboo sawdust, and a modified bamboo sawdust based cement block is prepared. The results show that the bamboo sawdust based cement block with a doping amount of 50% and the pressurized forming process has the best performance. Under these conditions, the loss rate and softening coefficient of the block after vacuum heat treatment of bamboo sawdust are 16% and 0.661, respectively, and the water absorption rate of the block for 24 hours by the internal and external coating method is 23.5%. Compared with the unmodified blocks, the modified bamboo sawdust based cement pressurized blocks have a dry density of 1.19g/cm3, a thermal conductivity of 0.228W/m ·K, and a compressive strength of 14.95MPa, which is suitable for indoor wall materials in hot summer and warm winter areas.

Key words Cement-based materials, bamboo sawdust, mechanical properties, block

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Natural Fibers Green Composites

Presenting Type: Oral-Onsite

Micro- and Nano-Scale Mechanisms of Enzymatic Treatment on the Interfacial Behaviors of Sisal Fiber Reinforced Bio-based Epoxy Resin

Ying YAO、Tao Liu、Wei Fan*
Xi'an Polytechnic University

In this study, the influence of enzymatic treatment on the interfacial properties of the sisal fiber (SF) and bio-based epoxy resin was investigated through experimental and numerical simulation methods. The results indicate that the enzyme treatment primarily causes the hydrolysis and cleavage of the pectin and hemicellulose, further reducing the tensile strength of SFs. However, the hydrolysis and cleavage effects also increase the roughness of the surface of SFs, causing the interfacial strength to increase by 108% when the SFs were treated by the enzyme for 6 h. Finally, the finite element model proved mechanical interlocking effect at the nano-scale is the primary reason for the increased interfacial behaviors caused by the enzymatic treatment.

Key words Sisal fiber; Enzymatic treatment; Fiber/resin interface; Finite element analysis

Session: Natural Fibers Green Composites

Presenting Type：Oral-Onsite

Effect of Fungi on the Properties of Jute/Poly(Lactic Acid) Composite

Tao YU*、Ding Ding
Tongji University

Natural fiber reinforced composites as green materials are economic and environmental friendly which can be used in many areas, such as aviation, automobile, shipping etc. Jute fibers are one of the plant fibers with good sound absorption, low density, no health risks. Poly(lactic acid) (PLA) as a biomass materials can be degraded into CO2 and H2O. Composites with jute and PLA have shown considerable potential to replace traditional synthetic fiber reinforced composites and use in automotive components and aerospace industry. However, jute fibers as plant fibers are more easily infected with fungi than synthetic fibers such as carbon fiber or glass fiber. And the degradation rate of PLA tends to increase in the fungi environment. Therefore, it is necessary to study the effect of fungi on the properties of jute/poly(lactic acid) composites. In this paper, Mechanics properties of composites including tensile strength ,bending strength and impact strength were found declined. Scanning electron microscope (SEM)and gel permeation chromatography(GPC) were used to observe the changes of composites.

Key words Natural fibers, Fungi, Composites, Poly(lactic acid)PLA

Session: Natural Fibers Green Composites

Presenting Type：Oral-Onsite

Rice Straw Cellulose Microfiber Reinforcing PVA Composite Film of Ultraviolet Blocking through Pre-Cross-Linking

Longxiang Zhu*、Zhaoxue Feng、Dan Xu
Qingdao University

Rice straw cellulose microfiber (CMF) was obtained through the gentle low-temperature phase transition method. Then, NaIO4 was utilized to modify CMF by selective oxidation to prepare aldehyde CMF (a-CMF) to improve the reactivity of the CMF. Finally, the a-CMF reinforced polyvinyl alcohol (PVA) composite films were prepared through a pre-cross-linking and solvent casting approach. The cross-linking network formed by a-CMF and PVA through the aldolization reaction significantly improved the mechanical properties of the a-CMF/PVA composite film. The tensile strength of a-CMF-2/PVA was 37.54 ± 0.77 MPa, which was higher than 25.88 ± 2.97 MPa of the pure PVA. SEM results showed that the fracture surface of the a-CMF/PVA composite film with the cross-linking network was smooth. In addition, prepared a-CMF-2/PVA composite films had a transmittance of over 80% in the visible light range, and also possessed excellent UV blocking property.

Key words rice straw; composite film; mechanical property; cross-linking; UV blocking

Session: Natural Fibers Green Composites

Presenting Type: Oral-Onsite

A Mechanistic Investigation on Influence of Cellulose Nanocrystals (CNCs) on Portland Cement Paste

Tengfei FU*[1]、Zhang Shangjin[1]、Yu Demei[1]、Zhang Hengchun[2]、Dai Ruiping[2]、Liu Wendi[1]、Qiu Renhui[1]
1. Fujian Agriculture and Forestry University
2. CSCEC Concrete (Fuzhou) CO., Ltd

Cellulose nanomaterials, used as enhancing materials in composite materials, has many advantages over traditional inorganic nanomaterials, for it is intrinsically sustainable, easy to disperse, low cost, and low health and environmental risks. Meanwhile, nanosize characteristics of CNs can significantly enhance cement-based materials in terms of workability, microstructures, and mechanical properties. In this study, cellulose nanocrystal (CNC) was made in the laboratory using acid hydrolysis method. The preparation of CNC-cement composites was attempted. Three hypotheses of enhancement were proposed and a series of experiments are designed to systematically study how the CNCs affect the cement hydration (isothermal calorimetry), microstructures (TEM), and mechanical strength (compressive and flexural strength tests). The results will provide insights on application of CNC (as well as other nano-additives) in cementitious materials.

Key words cellulose nanocrystal, Portland cement, hydration, microscopic analysis

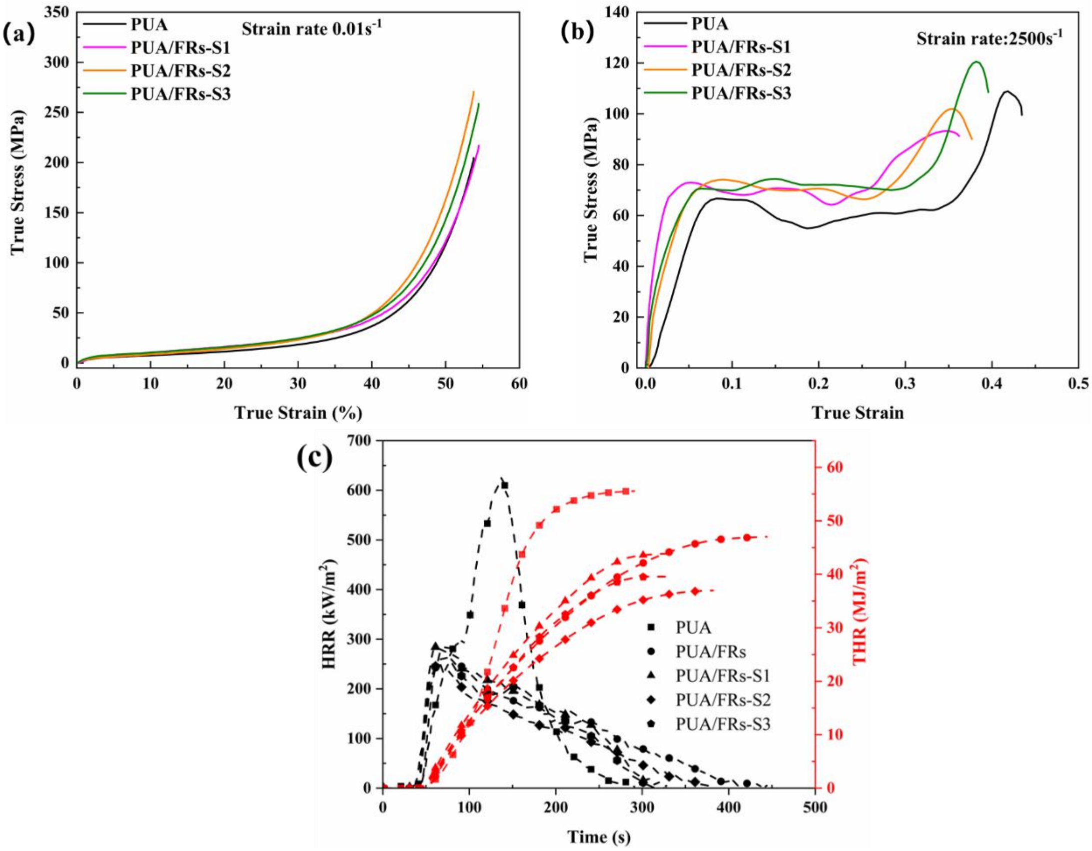

Fig. 1. Compressive mechanical properties of PUA and its composite: (a) Quasi-static compression; (b) dynamic compression; flame retardancy of PUA and its composites: (c) HRR and THR curves.

Session: Natural Fibers Green Composites

Presenting Type: Oral-Onsite

Changes in Stiffness of Unidirectional Flax Fiber Reinforced Composites after Moisture Absorption and Its Mechanism

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2. Key Laboratory of Advanced Civil Engineering Materials, Ministry of Education, Tongji University, Shanghai, 200092, PR China

This article mainly studies the changes in properties of flax fiber reinforced epoxy composites(FFRCs) after moisture absorption and explains why moisture content degrades the stiffness of plant fibers. Firstly, the flax fiber composites were prepared using a vacuum-assisted resin infusion molding (VARIM) technology and tested for hygroscopic deformation and tensile tests. The hygroscopic and swelling properties of FFRCs in different directions were obtained. Even though the experimental results show that the axial diffusion coefficient of flax fiber is much larger than its radial diffusion coefficient, the moisture absorption of plant fiber composites should belong to the 3D Fick diffusion problem， for unidirectional axial tensile test specimen, the moisture mainly diffuses from the thickness direction of the composite material, and the influence of lateral moisture absorption can be ignored. In addition, the hygroscopic problem of FFRCs can be analogized to the heat transfer problem. The hygro-elastic behavior is analyzed as the temperature-displacement coupling analysis, and the micromechanical method is used for the sequentially hygro -mechanical coupling analysis. It is concluded that the stiffness degradation of flax fiber after moisture absorption conforms to the exponential degradation law. Finally, the flax fiber is regarded as a symmetrical arrangement of multi-wall layers, and selecting a representative volume element (RVE) is taken for flax fiber modeling and stiffness calculation. When flax fibers absorb moisture, the stiffness decline is attributed to changes in the internal structure, mainly due to changes in the microfiber angle and softening of the matrix materials (hemicellulose and lignin). We obtain the variation laws of microfiber angle and matrix stiffness with relative moisture content through experiments and simulation calculations.

Key words Flax fiber composites; Moisture absorption; Anisotropic materials; Swelling; Elastic properties.

Session: Natural Fibers Green Composites

Presenting Type: Oral-Onsite

Meso-nano scale experiments and simulations on hierarchical interfaces of plant fiber reinforced composites

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Tongji University

Plant fibers possess the advantages of green environmental protection and rich sources. They have specific mechanical properties comparable to man-made fibers, and are expected to become an important reinforcement of composites. The unique hierarchical structures affect the load transfer mode of plant fiber reinforced composites. To serve the task of interfacial design of plant fiber reinforced composites (PFRCs), it is necessary to quantify the hierarchical interfacial properties. Firstly, by applying the nanoindentation technology, the mechanical properties of multi-layer interface of PFRCs, including modulus, hardness, energy dissipation and ability of crack initiation and propagation, were measured from single-step and multi-step static nanoindentation methods. Subsequently, the fatigue characteristics of multiple interfaces in PFRCs under cyclic loading were evaluated with nanoscale dynamic mechanical analysis. Finally, combined with the finite element simulation in the meso-scale, the multi-stage failure behaviors of the hierarchical interfaces in composites were presented by introducing the multiple interface performance parameters obtained at the nano-scale. The results showed that the failure at the multi-layer interface of PFRCs caused by crack initiation and propagation appeared in sequence. The experimental results in nano-scale provide a support and basis for in-depth analysis of the interfacial properties and failure mechanisms of composites in meso-scale.

Key words composites; plant fiber; hierarchical interface; finite element analysis; mechanical properties

Session: Natural Fibers Green Composites

Presenting Type：Oral-Onsite

Optimized Design of Plant Fiber Reinforced Composites on Interior Structure of Subway

Qian LI、Qian Li*
Tongji University

The material optimization design of subway body structure provides an effective solution to the noise reduction and environmental protection problems of subway. Plant fiber reinforced composites as interior structure not only have a certain bearing capacity, but also can absorb noise and vibration, which is more cost-effective than the traditional interior board with only decorative role. In this paper, hybrid fiber technique was employed and the composite mechanics laminates theory was applied on ABAQUS finite element software to establish a subway interior panel model. The bending properties of carbon fiber/flax fiber hybrid composites under five different stacking sequences based on the Hashin failure criterion were calculated to obtain the optimal stacking sequence. Based on the complex stiffness approach in the damping analysis of composites, the damping properties of carbon fiber/flax fiber hybrid composites with five different stacking sequences were simulated. The influences of the stacking sequences on the damping properties of hybrid composites was analyzed. Through computational comparison, the results showed that the hybrid composites can effectively balance the mechanical and damping properties that meet the requirements of subway body structure, and the stacking sequence has a significant impact on the performances. The composites prepared by mixing flax fiber with carbon fiber and placing flax fiber in the outermost layer have better damping properties, while the bending properties are significantly improved compared with pure flax fiber reinforced composites.

Key words hybrid composites; plant fiber; finite element analysis; mechanical properties; damping performances

Session: Natural Fibers Green Composites

Presenting Type: Oral-Onsite

Turning Basalt Rock into Golden Fiber

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Xinjiang Technical Institute of Physics and Chemistry, Chinese Academy of Sciences

Basalt is a kind of mineral distributed widely in China, and the majority of them are used as rubbles for the road and building construction with low technical value. In this presentation, we will present our practice in developing high-performance fiber using basalt as a raw material. Specifically, two key issues in preparing continuous fiber, i.e., how to inhabit the crystallization of oxides in basalt melt, and how to control the structural defects on fiber surface, will be presented with considerations on the regulation of the constitute of basalt rock (to homogeneralize the starting material), optimization on the spinning process (to inhibit the presence of crystal) and studies on the interfacial interaction between the fiber and sizing (to repair defects on fiber surface). The factors affecting the mechanical properties of basalt fiber, such as the properties of basalt melt, crystallization and migration of metal oxides in fiber, will be presented. The application of utilizing nanotechnology to repair surface defects on basalt fiber will also be introduced. Know-Why and Know-How techniques to obtain high-performance basalt fiber will be established. Based on our experience by using basalt mineral to develop fiber on the earth, the feasibility of in-situ utilization of lunar soil to develop lunar fiber will also be discussed, and the unique advantages of using such fiber to develop structural and functional materials for the construction of lunar base will be demonstrated. The implementation of this project will provide material solution to realize the dream of ancient Chinese Folk Story “Chang-E Flying to the Moon”.

Key words Basalt; High-performance fiber; Mechanical property; Sizing; Lunar fiber.

Session: Natural Fibers Green Composites

Presenting Type: Oral-Onsite

Strong and Tough Bacterial Cellulose Films Strengthened by Metal Ion Cross-Linking

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Cellulose nanofibril (CNF) has become a renewable and sustainable building block for functional and structural materials. Here, we will present a feasible and effective protocol to synthesize well-aligned bacterial cellulose (BC) films using the wet-drawing method and metal ion cross-linking strategy. Wet-drawing assists the alignment of CNFs, and multivalent metal ion cross-linking further improves the inter-fibril interactions. BC films cross-linked with Na+, Ca2+, Cu2+, Al3+, and Fe3+ all demonstrate improved mechanical strength than the as-received samples. Density functional theory (DFT) calculations reveal that besides the electrostatic forces between the metal ions and the adjacent carboxylate oxygen atoms, Cu2+ and Fe3+ can also form coordination bonds with the adjacent carboxylate oxygen atoms. Among all the five metal ions tried herein, we found that Fe3+ introduces the strongest cross-links between fibers through coordination bonds and electrostatic forces. The BC films cross-linked with Fe3+ exhibit high tensile strength and toughness of 451.51 MPa and 8.19 MJ·m-3, respectively. The synergistic effects of the fiber orientation from wet-drawing and the multiple cross-linking mechanisms induced by metal ions shed new insight on developing cost-effective and biodegradable materials with excellent mechanical performances.

Key words Cellulose Fibers; Cross-link; Strengthening; Thin Films

Session: Natural Fibers Green Composites

Presenting Type：Oral-Onsite

3D Printed Palm Oil-based Thermosetting Polymers and Their Composites

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Thermosetting polymers, owing to the intermolecular covalent cross-linked networks, typically exhibit superior mechanical properties, excellent thermal resistance and extraordinary electrical property. However, the conventional thermosetting polymers have many disadvantages such as brittleness, complicate process, poor deformation ability, and non-renewable raw material. Herein, we utilize photocuring 3D printing technology for the fabrication of highly mechanical strength and deformability palm oil (PO)-based thermosetting polymer through introducing a chemical “soft particles” in the cross-linked network. The PO-based photosensitive resin (MPOEA) which possess C=C closure and a long fatty acid chain can be prepared by a highly facile and efficient two-steps process from palm oil. Isobornyl acrylate (IBOA) with soft alkyl ring is selected as a comonomer. In the copolymers, due to the entanglement of compatibility between fatty acid chains form MPOEA and dangling soft alkyl rings from IBOA, the micro-phase structure should easily be constructed in the covalently cross-linked network during UV-curing process. The existence of chemical soft phase endows the MPOEAs polymer highly flexural strength (57.3 MPa) and flexural deflection (34.6 mm). The UV photocuring rate, gel content, dynamic mechanical property, thermal stability and morphology of the MPOEAs polymer were fully studied. In addition, 3D printed biocomposites were fabricated from bamboo fibers (BFs) and MPOEA resins.

Key words Palm oil, Biocomposites, 3D Printing, Bamboo fibers

Session: Natural Fibers Green Composites

Presenting Type：Oral−Onsite

Facile Synthesis of Isocyanate Microcapsule by Pickering Emulsion Templates and Its Application in Cottonseed Protein-based Cold-Set Wood Adhesives

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Abstract: Cold-set adhesives have been widely used for the production of wood-based composites. However, these adhesives are mainly derived from fossil fuel resources which cause serious environmental problems. In this study, organic-inorganic hybrid cottonseed protein-based cold-set adhesive was constructed by microcapsules and MgO. Microcapsules were successfully prepared via Pickering emulsion templates with isophorone diisocyanate (IPDI) as the core, and the cellulose nanofiber (CNF)/polyurea as the shell. The compact shell was used as a barrier to avoid the cross-linking reaction between IPDI and cottonseed protein for the promotion of the storage stability of adhesives. The encapsulated IPDI in the microcapsules was released under pressure which was crosslinked in situ with wood and cottonseed protein at room temperature (30°C). The alkaline environment provided by MgO could activate cottonseed protein, and the water-insoluble MgO/protein complex was formed with the cottonseed protein, which further enhanced the crosslinking density and bonding performance of cottonseed protein adhesives. The organic-inorganic hybrid strategy showed an outstanding wet shear strength of 0.98 MPa on three-ply plywood, meeting China's interior furnishing requirements (≥0.7 MPa). This research provides a novel strategy to develop an eco-friendly and high-performance cold-set adhesive for the wood industry.

Key words Cottonseed protein, Cold-set wood adhesive, Microcapsules, organic-inorganic hybridization, Bonding performance

Session: Natural Fibers Green Composites

Presenting Type：Oral-Onsite

Development of Sisal Fiber Reinforced Thermoplastic Pre-preg Tapes for Filament Winding

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Sisal fibers are renewable, light and strong, being considered as attractive materials in composite manufacturing. In the present work, a simple and effective method for preparing continuous pre-preg tapes from discontinuous sisal fiber bundles (50wt%) was developed and its application in winding forming was evaluated. The fiber bundles were wrapped with linear low density polyethylene (LLDPE) and high density polyethylene (HDPE), and hot-pressed in a designed mold, achieving unidirectional, uniform spreading and good impregnation in the continuous pre-preg. The LLDPE matrix on the surface of the pre-preg tape acted as an interlayer adhesive and melted at a relatively low temperature; the HDPE core layer maintained a certain tensile strength to achieve winding molding. When LLDPE: HDPE=1:4, the elongation at break, impact strength, and maximum allowable winding tension of fiber pre-pregs increased by 72.73%-82.20%, compared with HDPE-based pre-preg tapes (8.4%, 49.4kJ/m2, 54.22N). The calculated nominal pressure of sisal fiber pre-preg tapes wound pipes (nominal outer diameter: 76 mm, wall thickness 4.3mm) was 1.06MPa, reached the PE100 (1.00MPa) grade pipe specifications specified in the GB/T 13663.1-2017 standard (polyethylene PE pipe for water supply). The ring stiffness of sisal fiber pre-preg hoop-wound ring was 34.96kN/m2, higher than the S3 grade.

Key words Sisal fibers; Thermoplastic; Pre-preg processing; Filament winding

Session: Natural Fibers Green Composites

Presenting Type: Oral-Virtual Platform

Bio-waste Rice Husk Powder Additive as Supportive Reinforcement to Hybrid Natural Fiber (Basalt/Flax)/Polypropylene Composites for Improved Mechanical, Thermal, and Flame-Retardant Properties

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As a natural fiber - Flax fiber (FF), Basalt fiber (BF), and redundant biowaste resource - Rice husk powders (RHP) are attractive to reinforce thermoplastic due to their excellent mechanical performance. However, it is challenging to manufacture long unidirectional Flax fiber bundles (LFF) thermoplastic composites. A new process to manufacture various lengths for LFF thermoplastic composites was initially proposed to address this challenge. Polypropylene (PP) was used as a matrix for long Flax fibers pellets (from 5 to 20 mm long), and the BF and RHP can use twin extruder machines to manufacture supportive pellets for making Hybrid LFF thermoplastic composites. The extruded mixture supportive system was finally hot-pressed into plates. The compounding process was cut to strips by a mini cutting machine and scissors manual and used an injection molding machine to get the final achieved specimens. The optimal LFF plies and length in the composites strip were obtained when the LFF was two plies (~16%LFF) and 10mm in length. Finally, LFF2/30%BF/PP-6%RHP composite achieved improved tensile strength, tensile modulus and flexural strength, and flexural modulus by 36.64%, 40.31%, and 37.51%, 56,49%, respectively, compared to the composite reinforced with the long unidirectional Flax fiber. Also, LFF has high char residual of the composite of 19.18%. (higher than 83.26% comparison with LFF/PP). Flammability properties with cone calorimeter test showed high pHRR and THR with 36.41% and 11.73% increase, respectively. The results indicated that hybrid thermoplastic composites are a promising approach that provides potential applications of LFF in the automobile application field.

Key words Long Flax fiber bundles, short Basalt fibers, Rice husk powders, mechanical properties, flame-retardants

Session: Natural Fibers Green Composites

Presenting Type: Oral-Virtual Platform

Bio-inspired Approach: Mechanical and Self-Healing Properties of Natural Abaca Fiber Lumen Systems with Healing Agents

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Self-healing structures have gained a lot of interest in recent years in a variety of sectors. External stimuli, particularly in the mechanical engineering industry, cause damage to polymer composite systems. In this study, the abaca fiber's physical properties, as well as the lumen veracity for self-healing were evaluated. The healing resin is infused into the lumens using a specific setup. The fiber arrangement was kept in a pre-prepared metal mold that was sealed with double-sided sealant tape, and covered with a vacuum bag. The vacuum pump creates a vacuum inside the mold. A pressure of 0.04 MPa is applied for 15 mins to embed the healing cores. SEM analysis was used to undertake a comprehensive investigation into the fiber properties at various locations. The results provide clear information about the unidirectional abaca fiber and its lumen structure. The cross-section of the abaca fiber with empty lumens protruding with a vascular lumen network separated by a thick cell wall or middle lamella. A single fiber tensile test was conducted to assess the mechanical and self-healing properties of pure and core embedded abaca fibers, single fiber tensile test was conducted. The resin core fiber has an enhanced strength of 76 MPa. After the initial damage, the fibers heal at room temperature for 24 hours. By releasing a healing resin onto the damaged area, the spilled fibrils were mended, providing them a 100 MPa increase in strength. The tensile fracture surface has a healing core after tensile failures, which subsequently participated in the healing cycle after the fiber damage. After the tensile test, SEM and FESEM-EDX were used to confirm self-healing.

Key words Natural fiber lumen, Thermoset resin, Mechanical properties, Self-healing properties.

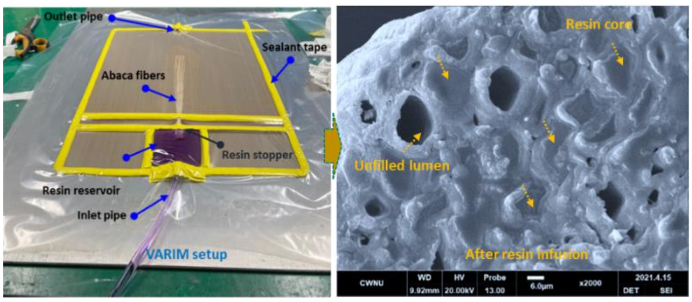

Fig. 1. Vacuum assisted Resin Infusion Method to infuse resin into the fiber lumens.

Session: Natural Fibers Green Composites

Presenting Type: Oral−Virtual Platform

Developing Jute and Bamboo Fiber Reinforced Thermoplastic Pre-preg

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Jute and bamboo are cellulosic materials with abundant reserves in nature, which have great potential in enhancing polymers in terms of mechanical and economic properties. In this study, we devloped pre-pregs via jute and bamboo fibers reinforcing polyolefin. These pre-pregs can be used for winding pipes and molding into profiles. The main problem we solved was to establish a flexible interface bond between non-polar polyethylene and polar cellulose fiber. To this end, an effective surface modifier (γ-APS-PAEE) was synthesized by polymerizing γ-aminopropyltriethoxysilane (γ-APS) with polyalkyl glycol allylepoxyl ether (PAEE). By the aid of γ-APS-PAEE, the bamboo fiber reinforced linear low density polyethylene (LLDPE) composite with a tensile strength of 45.6 MPa and an impact strength of 61.87 kJ/m 2 was fabricated.

Another problem that needs to be solved is the tendency of short fiber impregnation tape to break when heated and wound。 A new process was developed to cover the LLDPE on the surface of high density polyethylene based pre-preg. By this way, When the outer surface with lower melting temperature melts, the impregnating material still maintains high tensile strength and can withstand winding tension. LLDPE matrix on the surface of prepreg zone can be used as interlayer binder to achieve good interlayer fusion of toroidal winding composites. The circumferential tensile strength of the jute and bamboo fiber prepreg tapes is 80.03MPa and 66.50MPa, respectively. The calculated short-term hydrostatic strength is 9.60MPa and 7.98MPa, respectively. The ring stiffness is 29.55kN/m2 and 27.64kN/m2, respectively. The ring stiffness grade is meet the requirement of GB/T 13663-2000 Standard (POLYETHYLENE PE pipe for water supply) .

Key words Jute fiber; Bamboo fiber, Polyethylene, pre-preg

Session: Natural Fibers Green Composites

Presenting Type: Oral-Virtual Platform

Effects of Recovered Extracellular Polymeric Substances from Wastewater Sludge on Flammability Characteristics of Natural Fibre Reinforced Polymeric Composites

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2. Delft University of Technology

Recently, eco-friendly and innovative approaches have been implemented to design and produce new flame-retardant material systems. Recovery of extracellular polymeric substances (EPS) from the waste sludge, which is produced during wastewater treatment, has been addressed as an innovative solution for sludge disposal and resource recovery. However, actual chemical components and structures of EPS have not been fully understood for practical application. In this research, we successfully extracted EPS from aerobic granular sludge and investigated chemical components, thermal stability and fire performance of the biopolymer. Furthermore, flax fibres were coated with EPS solution and incorporated into a polymer matrix to prepare composites. A thermogravimetric analysis result of EPS showed that main decomposition occurred at approximately 290 °C and solid residue of 37.4 wt.% remained at 850 °C. The residue amount was higher than those of wool (24.1 wt.%) and ammonium polyphosphate flame retardant (29.1 wt%). Furthermore, the flax fabric coated with EPS demonstrated the self-extinguishment without any drips and afterglow. Fig. 1(a) shows fully compact structure of char after the burn test of the fabric. The cone calorimeter testing at 50 kW/m^2 heat flux showed that the addition of EPS coated flax fibres achieved the significant reduction of both peak heat release rate (35.4%) and CO production rate (60%) of composites compared to those of a neat polypropylene, Fig. 1(b). This research clearly indicated the potential of the wastewater-derived biopolymer EPS as a bio-based flame retardant to enhance fire performance of composites.

Key words Bio-based flame retardant, Wastewater-derived biopolymer, Flax, Composite, Flammability

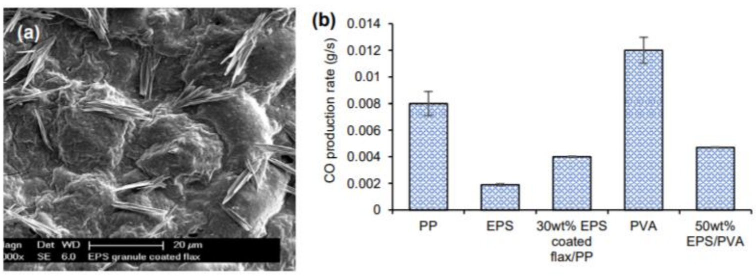

Fig. 1. (a) Microscope image of char surface of EPS coated flax fabric and (b) CO production rates of various samples.

Session: Natural Fibers Green Composites

Presenting Type: Poster

Highly effective multi-functional solar evaporator with scaffolding structured carbonized wood and bio-hydrogel

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Solar evaporator that utilizes solar radiation energy can be a renewable approach to deal with energy crisis and fresh water shortage. In this study, a solar evaporator was prepared by assembling composite carbonized wood of Melaleuca Leucadendron L. and biobased hydrogel. The multilayer MXene ($Ti_3C_2T_x$) was embedded in the scaffolding structure of the wood to form composite carbonized wood, where the loose and ordered scaffolding structure of the carbonized wood significantly improves the efficiency of water transportation with increased capillary force. The MXene adsorbed in the carbonized wood has high binding energy with water molecules, leading to reduction of vaporization enthalpy and contact angle. Moreover, the addition of MXene can improve the light absorbance, especially for the infrared and ultraviolet light bands. The hydrogel was fabricated by crosslinking konjac glucomannan and sodium alginate polysaccharides with Ca^{2+}, and it has a lower thermal conductivity than water and improves the evaporation efficiency by regulating the temperature distribution and concentrating the heat on the surface of the evaporator. This solar evaporator has an evaporation rate of 3.71 $kg{\cdot}m^{-2}{\cdot}h^{-1}$ and evaporation efficiency of 129.64% under 2-sun illumination, and is available to generate an open-circuit voltage of 1.8 mV after a 20 min hydro-voltaic, demonstrating a high performance and versatility. Also, experiment and numerical simulation were carried out to understand the mechanism and design principles of this solar evaporators.

Key words Solar evaporator, hydrovoltaic device, carbonized wood, scaffolding structure, MXene, hydrogel

Session: Natural Fibers Green Composites

Presenting Type: Poster

Preparation and performance of cellulose nanocrystals reinforced ultra-high performance concrete suitable for 3D printing

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Compared with traditional concrete construction methods, concrete 3D printing has numerous advantages and promising potentials to reduce carbon emission in concrete industry. In this study, cellulose nanocrystals (CNCs) were used to regulate the workability of ultra-high performance concrete (UHPC) and enhance the mechanical properties, in order to develop a 3D printable UHPC. Firstly, the optimal mixture proportion and preparation process of UHPC were determined. At present, the optimal mixture used freeze-dried cation modified CNCs. Then, the rheological properties, setting and hardening properties, compressive strength, flexural strength and shrinkage performance of UHPC with different CNCs dosage were tested. Finally, the microscopic analysis was carried out to reveal the regulation mechanism of workability and strength enhancing mechanism. Finally, the printability of CNC modified UHPC was evaluated on a desktop mortar 3D printer.

Key words cellulose nanocrystal, UHPC, rheology, 3D printing

Session: Natural Fibers Green Composites

Presenting Type: Poster

Effects of Hydrogen Bonds on Soybean Oil-based Thermosets and Their Bamboo Fibers Composites

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2. Fujian Jiangxia University

Biocomposites were fabricated from bamboo fibers (BFs) and acrylated epoxidized soybean oil (AESO) resins.Two reactive diluents (RDs), i.e., butyl methacrylate (BMA) and hydroxyethyl methacrylate (HEA), were used as comonomers for AESO, respectively. The effects of type and usage of RDs on the curing behavior, rheological and mechanical properties of AESO resins, the interfacial bonding between BFs and AESO matrix, and properties of the resulting BF/AESO composites were investigated. The formation of multimer induced by hydrogen bonds (Hbonds) in HEA-AESO resin greatly increased the free-radical polymerization rate of C=C bonds, hence reducing the curing temperature and activation energy. The H-bonds provide physical cross-linking points for the cured HEA-AESO network, which significantly increased the tensile strength, tensile modulus, storage modulus, and glass transition temperature of the thermoset. The polar groups of the resins form H-bonds with the hydroxyl groups of BFs, resulting in a good interfacial adhesion between fibers and matrix. The HEA-containing composites demonstrated significantly higher mechanical properties, storage modulus, and water resistance than BMA composites.

Key words Bamboo fibers, H-bonds, Biocomposites, Soybean oil

Session: Natural Fibers Green Composites

Presenting Type: Published only

Micro-mechanism of the high and low temperature performance of asphalt mixture enhanced by modified bamboo fibers: studied by experiments and molecular dynamics simulation

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The high and low-temperature performances of plant fiber-reinforced asphalt mixes can be enhanced by modifying the plant fiber interface. However, the mechanism by which the modification method affects the performance of the interface is unclear. In this study, acrylate epoxidized soybean oil (AESO) and 4,4'-diphenyl methane diisocyanate (MDI) were used to modify bamboo fibers. The high-temperature stability and low-temperature breaking resistance of modified bamboo fiber-asphalt blends were assessed by a rutting test and a low-temperature bending experiment. The scanning electron microscope was used to study the interfacial characteristics of modified bamboo fiber and asphalt. Molecular dynamics (MD) techniques were utilized to generate models with grafted molecular chain densities of 0, 1.11×10^{-7}, 2.21×10^{-7}, and 4.43×10^{-7} mol/m^2 at the bamboo fiber-asphalt interface. Adhesion and diffusivity of asphalt molecules on bamboo fibers were studied at various temperatures using interaction energy, diffusion coefficient, and relative concentration. The experimental results demonstrated that the dynamic stability of an asphalt mixture treated with AESO-MDI was enhanced by 28.46%, while the low-temperature flexural strength was enhanced by 13.84%. The simulation results revealed that a grafting density of 2.21×10^{-7} mol/m^2 offers the optimal interfacial properties. At 338 K, the interaction rose by 277.2% and the diffusion coefficient was reduced by 50.8% compared to unmodified bamboo fiber; at 258 K, the interaction increased by 159.3% and the diffusion coefficient declined by 27.8%. In conditions of this graft density, the grafted molecular chains get more entangled with the asphalt molecules. Too many grafted chains will limit the asphalt's mobility. This research provides a better understanding of the performance of the modified bamboo fiber-asphalt interface and offers recommendations for optimizing the high and low-temperature performance of asphalt mixtures reinforced with plant fibers.

Key words bamboo fibers, molecular dynamics simulation, pavement performance, interface performance

Hangzhou, PR China 25-28 April, 2023

Session: Natural Fibers Green Composites

Presenting Type: Published only

Study of the microscopic mechanism of the mechanical properties of the interface between modified bamboo fibres and epoxy resin

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Plant fiber-reinforced epoxy resin composites can be improved using interfacial modification at plant fibers.However, the mechanism about modification method affects the interfacial properties is unclear.In this work, bamboo fibers is modified with acrylate epoxidized soybean oil (AESO) and 4,4'-diphenyl methane diisocyanate (MDI) andγ-(2,3-epoxypropoxy) propyltrimethoxysilane (KH560).The interfacial properties of modified bamboo fiber and epoxy resin is observed using the scanning electron microscope.And molecular dynamics simulations is used to construct grafted molecular chain densities of 0 and 0.203molecules/nm2 with 0.606 molecules/nm2 in the bamboo fiber-epoxy resin interface,which can study molecular structure and molecular movement behaviour of the interface between modified bamboo fibres and epoxy resin.The interfacial characteristics of the epoxy resin and bamboo fibers are influenced by the grafting density of the molecular chains. A graft density of 0.606 graft/nm2 resulted in the optimum interfacial performance. The results show that the interaction energy of the 0.606 graft/nm2 graft density model is enhanced by 39.4% and the diffusion coefficient is decreased by 44.4%.With tensile and shear mechanical properties are represently developed by 21.5% and 13.7% when compared to the unmodified model at AESO-MDI graft situation. Compared to unmodified bamboo fiber, the interaction is enhanced by 8.7% and the diffusion coefficient is decreased by 34.3%.And tensile and shear mechanical properties are represently improved by 83.14% and 8.7% at KH560 graft situation. In conditions of this graft density, the grafted molecular chains get more entangled with the epoxy resin molecules.As the number of grafted molecular chains increases, the interfacial properties of the epoxy resin and bamboo fibres are enhanced.This work provides additional insight into the interfacial properties of modified bamboo fibres and epoxy resins and provides guidance for optimising the mechanical properties of plant fibre reinforced epoxy resin composites.

Key words Silane coupling agent modification； Epoxy resin； Interface performance； Mechanical properties；Molecular dynamics simulation

Session: Natural Fibers Green Composites

Presenting Type: Published only

In situ Raman spectroscopic study of plant fiber under tension deformation

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In this paper, the crystallinity of cellulose, microfibril angle (MFA) and the tensile properties of hemp, sisal, coir fiber were investigated by X-ray diffraction (XRD) analysis and single fiber tensile tests. Typical brittle failure mode for hemp and sisal fiber and ductile failure mode for coir fiber were founded from their stress-strain curve and scanning electron microscope (SEM) images of fracture morphologies after tensile tests. Both tensile strength and tensile modulus decrease with the diameter increases. The deformation mechanism of plant fibers was investigated in situ, combining tensile test and Raman spectroscopy measurement. The characteristic Raman peak located at 1095 cm-1 and 1610 cm-1 are recorded as a function of tensile deformation of the plant fibers. The shift rate of Raman peak at 1095 cm-1 of hemp and sisal fiber keep constant during tensile deformation. However, the Raman peak shift rate of coir fiber decreases with the tensile deformation, which indicates the multi-interface damage mechanism of the plant fibers.

Key words plant fiber; tensile properties; in situ Raman spectroscopy; deformation mechanism

Session: Nanocomposites

Presenting Type: Oral-Invited

Extraction of Nano-cellulose from Bio-waste paper Egg trays as potential to improve mechanical properties of Green composites as a supportive reinforcement

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Changwon National University

Nano-cellulose is the most important component of the most abundant green bio-recycling resources on the earth, which has great potential for the conditions of sustainable development of human production, health care, environmental safety, and carbon neutrality. At present, natural fiber composite materials exist Problems such as sustainable application and poor mechanical properties. The various percentage of extracted by chemical methods nano-cellulose were incorporated into Vinyl ester (VE)/Kenaf fibers (VE/KF) composites as a sympathetic additive and manufactured ENC-VE/KF composites through the vacuum-assisted resin transfer molding (VARTM). Initially, 2% alkali treatment was used in kenaf fiber (KF) to removed surface storage chemicals and impurities. Fourier transformed infrared spectroscopy (FTIR) was used to analyze the properties of pure and modified KF. The tensile strengths of 2% ENCVK, 3% ENCVK, and 2% CNCVK composites increased by 45.32, 73.79, and 44.72 %, respectively, and the tensile modulus of 2% ENCVK composite decreased by 4.42 %, and 3% ENCVK and 2% CNCVK composites increased by 25.21 %, and 18.16 % respectively. Besides, the bending strength of 2% ENCVK and 2% CNCVK composites was also 25.73 % and 11.61 % higher than that of VK composite. Compared with VK composite materials, the impact strength of 2% ENCVK composite increased by 110.01%. Overall, the experimental results provide an economical and intuitive source for extracting nano-cellulose, which has properties very similar to commercial nano-cellulose, and can be used as an auxiliary reinforcement material to improve the mechanical properties of natural fiber composites.

Key words Nanocellulose; Kenaf fiber; Vinyl ester; Polymer Composites; Mechanical properties.

Session: Nanocomposites

Presenting Type: Oral-Invited

Polyimide Aerogel Fibers for Personal Thermal Management

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Jiangnan University

Aerogel fibers combining the advantages of fibers and aerogels are prospective in intelligent thermal management fabrics. However, the scalable fabrication of polyimide aerogel fibers still remains challenging due to the slow gelation kinetics and the weak backbone strength. Herein, a novel strategy is developed for fast and scalable fabrication of crosslinked polyimide (CPI) aerogel fibers by wet-spinning and cost-effective ambient pressure drying via UV-enhanced dynamic gelation strategy. This technology achieves continuous production of CPI aerogel fibers (length of hundreds of meters) within 7 h, which is substantially efficient than those (> 48 h) of the previously-reported methods that suffer from sluggish gelation kinetics and necessitate supercritical drying or freeze-drying. The resulting CPI aerogel fibers exhibit low density and high porosity, which can render good versatility by integrating with other functional materials, opening a promisingly wide space for fast and scalable fabrication of intelligent thermal management fabrics and beyond.

Key words Polyimide, Aerogel Fiber, Intelligent Thermoregulating

Session: Nanocomposites

Presenting Type: Oral-Invited

Carbon and Polymer Materials for Contemporary Electrochemical Energy Storage

Jianxin Geng*
Tiangong University

Electrochemical energy storage technologies are of significantly importance to address the issues associated with energy shortage and environmental deterioration. Carbon and polymer materials play important roles as the key materials in electrochemical energy storage devices. In this talk, the speaker will present the newest research progresses achieved in his groups in the following aspects: (1) Biomass-derived porous carbons as sulfur hosts for lithium-sulfur (Li-S) batteries;[1-3] (2) non-covalent functionalization of graphene as a general strategy for designing single-atom catalysts as electrocatalytic sulfur hosts for Li-S batteries;[4,5] (3) covalent microporous polymers as carriers for single-atom catalysts as electrocatalytic sulfur hosts for Li-S batteries.[6-8] The aforementioned materials were designed to deliberately address the ever-lasting issues of Li-S batteries including the slow reaction kinetics of sulfur cathodes and the notorious shuttle effect of polysulfides. As a result, the devices prepared using the aforementioned materials as the key materials exhibit remarkable performance in the key terms such as specific capacitance, rate capability, and cycling stability.

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Key words Carbon materials, polymer materials, lithium-sulfur batteries

Session: Nanocomposites

Presenting Type：Oral-Invited

Multi-responsive shape memory polymer nanocomposites based on functional nanofillers

Ke-Ke YANG*、DAN LIU、LAN DU、HUI XIE、WEN XIA XIAO、YU ZHONG WANG
Sichuan University

Shape memory polymers (SMPs) have the ability of recovering from a temporary shape to the original shape upon external stimulus, such as heat, light, electric, magnetic and even chemical environments. This unique feature make it show great potential in biomedicine, intelligent textiles, aerospace and other fields. However, the traditional one-way dual shape SMPs that can only response to a single stimulus can hardly to fulfill the increasing demands of various application. The SMPs with multi-responsibility, multi-functionality and multi-actuating mode are highly expected.

As the thermal responsive SMPs are most mature type and easy to prepare, it has been considered as most convenient approach to achieve multi-responsive shape memory effect simply by introducing some functional fillers into the thermal responsive shape memory polymer matrices. Here, we designed a series of multi-responsive shape memory polymer nanocomposites by adding some functional nanofillers (such as conductive carbon nanotubes, graphene, magnetic Fe3O4 nanoparticles, etc.) into shape memory copolymers or cross-linked network matrices. As we expected, their conductivity or magnetism and photothermal conversion characteristics endow the materials with thermal, electrical, magnetic, light responsive SME. Moreover, utilizing nanofillers to create dynamic crosslinking network, not only tunable one-way and two-way SME but also self-healing and reprocessing can be realized.

Key words Polymer nanocomposites; Shape memory; Multi-responsive

Session: Nanocomposites

Presenting Type: Oral-Invited

Programmed deformation and locomotion of nanocomposite hydrogels

Zi Liang Wu*
Zhejiang University

Inspired by the natural activated systems, realization of programmed deformations and locomotion in artificial materials has recently attracted great interest due to their promising applications in biomedical devices, soft robotics, and flexible electronics. Photo-responsive hydrogels are recognized as one ideal material to construct soft actuators and robots owing to their drastic volume change induced by contactless light irradiation with high spatial and temporal resolutions. The challenge is how to construct composite hydrogel with gradient structure and dynamically activate the specific regions of the gel toward programmed deformation and locomotion. We present here a photolithographic method to fabricate patterned nanocomposite hydrogels with the assistance of electro- or magneto-orientation of nanosheets. Under photo irradiation, the swelling/contraction mismatch results in the built-up of internal stress and thus programmed deformations of the composite hydrogel. Furthermore, a moving light beam is imposed on the nanocomposite hydrogel to spatiotemporally actuate the gel that shows sophisticated motions, including crawling, walking, and turning. Experimental and simulation results reveal that multigait locomotion is realized by the mutual coordination of shape-morphing and dynamic friction of the gel against a substrate under the spatiotemporal light stimulation. The programmed deformations and motions of photo-responsive hydrogels should be instructive for the development of soft robots with advanced technologies and versatile applications.

Key words hydrogels, ordered structures, deformations, motions

Hangzhou, PR China 25-28 April, 2023

Session: Nanocomposites

Presenting Type: Oral-Invited

Tuning Thermal Conductance Across Two-dimensional Vertically Stacked van der Waals Materials via Interfacial Engineering and Ionic Intercalation

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The controllable tuning of thermal conduction of solids is of critical significance for the development of advanced electronics and the efficiency for thermal energy conversion. Two-dimensional (2D) material family with ultrathin thickness as a new rising star makes it possible to tune the thermal property at atomic-scale. We first reported a PEG-assisted TDTR method to evaluate thermal conductance (G) of atomic-scale-thin materials with improved sensitivity. Various vertically stacked van der Waals (vdW) materials using monolayer MoS_2/$MoSe_2$ films were prepared and G values of a series of 2D vdW materials has been investigated, in which $MoSe_2$-MoS_2-$MoSe_2$-MoS_2 heterostructure demonstrates the lowest G due to the rich interfacial mismatch and weak interfacial coupling effect. A roadmap to tune G via homo-interfacial mismatch, interfacial coupling, and hetero-interfacial mismatch, is further demonstrated. Based on the vertically stacked vdW materials, we reported an unconventional correlation between G and insertion of cations into the stacked vdW materials. The intercalation of K^+ is achieved via an electrochemical gating method, in which the K^+ concentration is controllably tuned via gate voltage (V_g). The calculated G values versus V_g demonstrate that G nearly linearly increases with the concentration of K^+, and reversibly decreases with the deintercalation of K^+ with an on/off ratio in G of ~200%. The unconventional interaction-dependent G may be originated from that inserted heteroatoms promote the transport of high-frequency phonons at vdW gap.

Key words van der Waals heterostructures; thermal conductance; interfaces

Hangzhou, PR China 25-28 April, 2023

Session: Nanocomposites

Presenting Type: Oral-Invited

Piezoresistive and Magnetoresistive polyaniline nanoarrays in-situ polymerized surrounding magnetic graphene aerogel

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Tongji University

In this talk, we present a novel three-dimensional nanocomposite aerogel (rGO/Fe_3O_4/PANINAs) with outstanding piezoresistance and magnetoresistance fabricated by in-situ polymerization of polyaniline nanoarrays (PANI NAs) surrounding magnetic reduced graphene oxide (rGO/Fe_3O_4) aerogel that was prepared through the combination of hydrothermal method and lyophilization method. This rGO/Fe_3O_4/PANI NAs nanocomposite aerogel with 60 wt% loading of PANI NAs well preserved the porous structure and gained a superior mechanical strength (121.04 kPa) compared with that of rGO aerogel, rGO/Fe_3O_4 aerogel, and rGO/PANI NAs aerogel (43.54, 58.12, and 116.98 kPa, respectively). The rGO/Fe3O4/PANI NAs nanocomposite aerogel could hold its original state with almost 100% recovery ratio after cycling compression tests under 80% of deformation strain at a suitable compression rate of 5 mm min^{-1}. The introduction of PANI NAs into the rGO/Fe_3O_4 aerogel also brought a satisfactory piezoresistive performance with a large gauge factor up to 2.83 and a superb stability for the electrical signal output (which was decreased only 5.80% after 500 compression cycles) to the rGO/Fe_3O_4/PANI NAs nanocomposite aerogel. The loading of Fe_3O_4 nanoparticles and PANI NAs also provided rGO/Fe_3O_4/PANI NAs nanocomposite aerogel with a negative magnetoresistance value up to −4.37%. The unique negative magnetoresistance and excellent piezoresistance make rGO/Fe_3O_4/PANI NAs nanocomposite aerogel a promising candidate for the development of advanced electronic devices.

Key words Magnetic graphene aerogel, Polyaniline nanoarrays, Magnetoresistance, Piezoresistance

Session: Nanocomposites

Presenting Type: Oral-Invited

High Performance Flexible Pressure Sensor with Graft-Copolymerized Pressure Sensitive

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Flexible piezoresistive sensors have shown great potential in clinical diagnosis and treatment, aeronautics and astronautics as well as other fields. The chain segments of traditional flexible pressure sensitive materials relax significantly to creep easily and make the signal drift. Besides, plastic deformation will probably occur to cause signal hysteresis, which will limit their application. This work proposed a high Tg pressure sensitive composite material, which is semiconductor nanostructure grafted on surface of micro-meter fibers. This composite will maintain the constant free volume state at the operating temperature and avoid α relaxation to ensure the stability of the mechanical and electrical properties. Replacing the bulk with microwires increases the specific surface area and sensitive points to ensure high sensitivity, which could enable the fibers to perform in high elastic or even general elastic deformation range and rebound well. The grafted semiconductor restricts the conformational change of the matrix segment by enhancing energy barrier to reduce relaxation to achieve high stability. This work systematically carried out research contents under instruction of molecular dynamics, including the design and synthesis of high Tg matrix PAI molecular structure, the controllable grafting polymerization of surface semiconductor nanostructures and the influence on interfacial mechanical properties, the relaxation and creep properties of composite materials and other research topics. The high performance of pressure sensitive composite has been achieved. The piezoresistive sensor as well as arrays have been constructed and high performance. This work could provide mechanical guidance advancing the application process in contact pressure detection.

Key words piezoresistive sensor; molecular dynamics simulation; grafting polymerization; creep;

Session: Nanocomposites

Presenting Type: Oral-Onsite

Broadband noise adsorption composite materials based on ceramic nanofibrous sponges with hierarchically entangled graphene networks

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The traffic noise pollution, which has led to a huge burden on the public health, ecological environment, and global economy, is a significant chanllenge to human worldwide. Among the existing methods to reduce the noise pollution, noise adsorption material is a low-cost and effective approach. However, the tranditional noise adsorbers always suffer from the drawbacks of heavy weights, narrow absorbing bands, and poor temperature resistance, which limit their extensive applications in this field. Here, we report a facile route to construct graphene/ceramic nanofiber compsite sponges (GCNSs) with unique hierarchical structures of opened cells, closed-cell walls and entangled networks by combining flexbile creamic nanofibers with graphene oxide (GO) networks. The strong π–π attraction among the rGO nanosheets and van der Waals force between the rGO and creamic nanofibers endow the composite sponges with high enhancement in the mechanical properties. The resulting GCNSs exhibit the integrated properties of ultralight properties (volume density of 9.3 mg cm-3), good superelasticity (4.3% plastic deformation after 1000 compressions at 60%), and robust temperature-invariant stability from -100 to 500 °C. Additionally, the hierarchically entangled sandwich structures of the GCNSs also enabled the enhaced broadband noise adsorption performance (high noise reduction coefficient of 0.56 in 63-6300 Hz), which could be used for effectively reducing traffic noise, industrial noise, and domestic nosie. The successful synthesis of the sandwiched GCNSs could break the bottlenecks of the narrow absorption band (>1000 Hz) faced by traditional noise absorbers, thereby paving the way for developing thermostable and high-efficiency composite materials for noise reduction.

Key words composite materials; ceramic nanofibrous sponges; graphene networks; superelasticity; noise adsorption

Session: Nanocomposites

Presenting Type：Oral-Onsite

Study on the preparation and sensing performance optimization of nanocomposites for flexible electronics

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Flexible nanocomposite piezoresistive strain sensors are attracting intensive focus owing to their unprecedent merits in sensing performance and stretchability, which can be feasibly employed in the fields of wearable electronics and structural health monitoring. In this work, three aspects including structural design, preparation methods and application prospects are briefly reviewed, where recent progress of composite piezoresistive strain sensors is mainly discussed by centering on materials chosen and structure configuration towards the sensing improvement. Crucial parameters in affecting the sensing performance as well as sensing mechanism have been initially analyzed in composite piezoresistive strain sensors. Subsequently, detailed discussion and analysis were performed on the recent advances of composite strain sensors by focusing on the main guideline of materials optimization-structural design/processing-performance improvement and practical applications. Recent achievements of finite element analysis (FEA) and artificial intelligence algorithm are also introduced to conduct the controlling and mechanism analysis of conductive network design (formation, overlapping and evolution) and multi-scale layered structural configuration in composite strain sensors, where both conductive network and structural configuration are playing a significant role in changing the sensing performance. Consequently, a multi-modality sensor with distinct sensing signal, high stability and low hysteresis is urgently needed to fulfill the demands of flexible nanocomposites for piezoresistive strain sensors, where main points towards future developments and future directions in composites strains sensors are also highlighted.

Key words Nanocomposites; Sensing performance; Conductive network design; Flexible electronics

Session: Nanocomposites

Presenting Type：Oral-Onsite

Flexible and Transparent Composite Thin Films Based on MXene for UV-light Shielding Applications

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Ultraviolet (UV) irradiation with short wavelength (10-400 nm) and high photon energy (3.1-124 eV) can generally destroy chemical bonds of organic substances, resulting in serious damage to stability of organic polymer materials and even health of human being. Developing high-performance UV-shielding materials is significant to greatly prolong storage stability and service life of polymer materials, which has attracted considerable attention from academic and industrial fields. MXene as novel two-dimensional (2D) materials possess typical layered structures and tunable band gap, showing great potential in high-performance electromagnetic shielding and UV-light absorption. In this work, we prepared ultrathin $Ti_3C_2T_x$ MXene nanosheets and fabricated MXene/poly (vinyl alcohol) composite films with high-efficiency UV shielding and high transparency. We characterized the microstructures, UV-vis absorption spectra, and UV-shielding performance of the nanocomposite films in detail. We found that the MXene/PVA composite films exhibited satisfactory UV shielding and high transparency. The 1.0 wt.% $Ti_3C_2T_x$ MXene/PVA films could shield nearly 90% UV light, and their visible-light transmittance still remained over 55%. Such high performance is mainly attributed to the tunable band gap, ultrathin thickness, layered structures, and high alignment of the $Ti_3C_2T_x$ MXene in PVA films. Besides, MXene-based hierarchical nanocomposites with high optical transparency and excellent electrical conductivity were further fabricated using a layer-by-layer spin-coating technique, and they exhibited desirable electromagnetic interference shielding performance. This work paves a way for fabrication of high-performance flexible and transparent thin films in the fields of packaging materials and wearable electronic devices.

Key words $Ti_3C_2T_x$ MXene nanosheets, poly (vinyl alcohol), nanocomposite films, ultraviolet shielding, transparency

Session: Nanocomposites

Presenting Type: Oral-Onsite

Mechanically Adaptive High-Performance Bioinspired Nanocomposites

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Zhejiang University

Biological materials are particularly inspiring for their unique combinations of stiffness, strength and toughness together with lightweightness. Wood, nacre and crustacean cuticles serve as examples, in which a correct arrangement of constituents with balanced molecular energy dissipation mechanisms allows to synergistic materials performance beyond additive behavior. These materials constitute paradigms for structural engineering, aiming towards ordered structures with high fractions of reinforcements to achieve high mechanical performance. A less addressed issue, however, is the incorporation of heterogenous patterns or capabilities for external adaptation – following bioinspired design principles of removing stress concentration via gradient structures or adaptive mechanical performance, respectively.

Here, we introduced a concept for molecular engineering of polymer phases in the bioinspired nanocomposites leading to high mechanical performance, and further adaptive reconfiguration of the mechanical properties using facile external triggers. This is realized for green, waterborne nanocomposites with ordered structures (e.g. layer, cholesteric and fibrillar morphologies), in which the polymer phase are rationally designed to implement tailor-made interactions to achieve excellent macroscopic mechanical performances. More importantly, we show adaptive mechanical behaviors that can be triggered using light and electricity, and tuned as a function of signal intensity. Moreover, such adaptive mechanical properties allow lateral mechanical patters via spatially selective softening of the nanocomposites, and even reconfigurations of mechanical patterns. The simple and generic approach opens avenues for bioinspired nanocomposites for facile application in adaptive damping and structural materials, and soft robotics.

Key words bioinspired nanocomposites, adaptive materials, nacre, nanocellulose, stimuli-responsiveness, mechanical properties.

Session: Nanocomposites

Presenting Type: Oral-Onsite

Flexible High-Performance Triboelectric Nanogenerators Based on Electrospun Nanocomposite Fibres

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Flexible nanogenerators that convert mechanical movement into electricity have been widely investigated due to their high potential for driving low-power electronics and self-powered systems. This work studies the effects of nanofillers on the performance of triboelectric nanogenerators (TENGs) constructed from electrospun PVDF-co-hexafluoropropylene (PVDF-HFP) nanofibre layer. Liquid metal (LM) Galinstan nanodroplets were introduced into PVDF-co-hexafluoropropylene (PVDF-HFP) electrospun nanofibres first. The peak open-circuit voltage and power density of the TENGs reached 1680 V and 24 W/m2, respectively, when the PVDF-HFP/2%LM nanofibre membrane was used as the negative tribo-layer and the thermoplastic polyurethane film was used as the positive tribo-layer. The high performance is attributed from multiple factors, including the improved surface potential, capacitance, charge trapping capability, and the secondary polarization inside PVDF-HFP nanofibre by the introduced LM nanodroplets. Secondly, the hybridization effect of silver nanowires (AgNWs) and perovskite oxide nanocrystals were studied. Mn-doped (Bi0.5Na0.5)TiO3-BaTiO3 (Mn-BNT-BT) nanocrystals were used as semi-conductive perovskite oxide fillers for the study. Electrospun poly(vinylidene fluoride-co-hexafluoropropylene) (PVDF-HFP) fibre mat with embedded hybrid fillers was applied as the tribo-negative layer. With 5% of AgNWs and 5% of Mn-BNT-BT nanocrystals, a high peak open-circuit voltage of 2170 V and a high-power density of 47 W/m2 was achieved by the TENG, which significantly exceeded the output values of the current PVDF-based TENGs. The conductive silver nanofillers and semi-conductive perovskite oxide nanofillers formed Schottky junctions, which facilitated with the charge movement from AgNWs to PVDF-HFP and reduced electron dissipation therefore maintaining a higher and longer lasting potential. These high performance TENGs have high potential to be utilized as viable power supply for portable and wearable electronic devices.

Key words Energy Harvesting, Nanocomposites, Nanogenerators, Self-powered

Session: Nanocomposites

Presenting Type: Oral-Onsite

Free vibration characteristics of functionally graded carbon nanotubes reinforced composites Kirchhoff plate on viscoelastic foundation in thermal environment

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The experimental results have confirmed that the decrease of the reinforcement scale can affect the properties of the composites. By considering the scale effect of carbon nanotubes (CNTs), free vibrations of an elastic matrix reinforced by oriented, straight CNTs resting on the viscoelastic foundation in a thermal environment had been performed in this study. Based on the nonlocal elasticity theory and Eshelby-Mori-Tanaka micromechanics method, the nonlocal Eshelby-Mori-Tanaka constitutive equation was derived to obtain the equivalent mechanical properties. To ameliorate the vibration characteristics, four distribution patterns of CNTs in the thickness directions were considered. Utilizing the Kirchhoff plate assumption, the free vibration governing equations and boundary conditions of functionally graded carbon nanotubes reinforced polymer composite plate situated on the visco-Pasternak foundation in a thermal environment had been formulated through the Hamilton principle. The semi-analytical solutions for the eigenfrequencies of functionally graded CNTs reinforced composites (FG-CNTRCs) plate at four-sided simply supported edges were obtained. Effects of the nonlocal parameter, volume fraction and distribution type of CNTs, environment temperature change, and visco-Pasternak foundation on the free vibration response of the FG-CNTRCs plate were scrutinized. The results show that: the inclusion of CNTs can significantly enhance the structural bending stiffness of FG-CNTRCs plate while considering the scale effect of CNTs will weaken the structural stiffness. The effects of CNTs volume fraction, and nonlocal effect parameters on FG-CNTRCs plate increase with the improvement of structural stiffness of plate, whilst the effects of environmental temperature change diminished with the enhancement of structural stiffness. Moreover, the critical damping parameter of the visco-Pasternak foundation grows by increasing the plate stiffness.

Key words nonlocal theory; Eshelby-Mori-Tanaka method; functionally graded carbon nanotubes reinforced composites; visco-Pasternak foundation; Kirchhoff plate

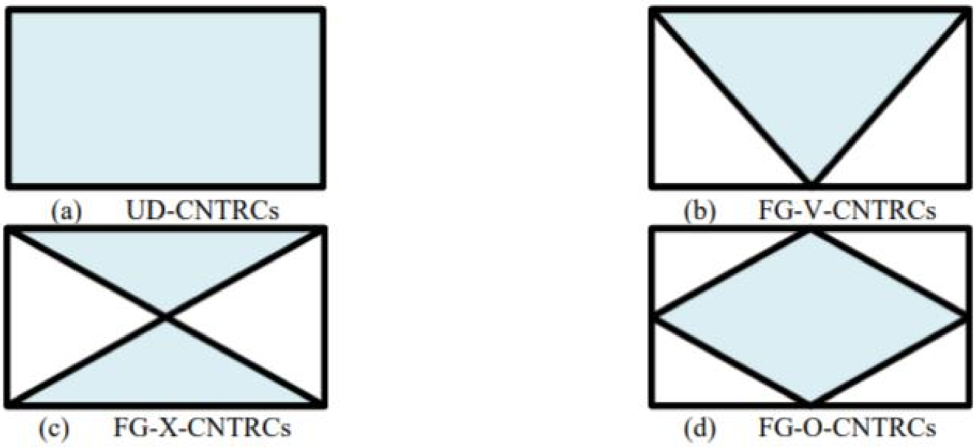

Fig. 1. Carbon nanotubes distribution patterns in the thickness direction of FG-CNTRCs plate

Table 1 Dimensionless complex eigenfrequency of FG-CNTRCs plate with various values of nonlocal parameter CNTs distribution forms, and frequency order

(m, n)	α	FG-UD	FG-V	FG-X	FG-O
(1,1)	0	−0.4074±1.5980i	−0.4061±1.5137i	−0.4074±1.7601i	−0.4074±1.4240i
	0.0500	−0.4074±1.5821i	−0.4061±1.5025i	−0.4074±1.7382i	−0.4074±1.4151i
	0.1000	−0.4074±1.5417i	−0.4062±1.4739i	−0.4074±1.6821i	−0.4074±1.3927i
	0.1500	−0.4074±1.4912i	−0.4064±1.4380i	−0.4074±1.6115i	−0.4074±1.3650i
	0.2000	−0.4074±1.4424i	−0.4066±1.4029i	−0.4074±1.5425i	−0.4074±1.3385i
(1,2)	0	−0.4074±3.2754i	−0.4040±3.0097i	−0.4074±3.7589i	−0.4074±2.7280i
	0.0500	−0.4074±3.1608i	−0.4042±2.9263i	−0.4074±3.6069i	−0.4074±2.6596i
	0.1000	−0.4074±2.9171i	−0.4048±2.7485i	−0.4074±3.2804i	−0.4074±2.5168i
	0.1500	−0.4074±2.6824i	−0.4055±2.5752i	−0.4074±2.9606i	−0.4074±2.3828i
	0.2000	−0.4074±2.5042i	−0.4062±2.4401i	−0.4074±2.7134i	−0.4074±2.2840i

Session: Nanocomposites

Presenting Type: Oral-Onsite

Development of multifunctional basalt fiber using nanocomposite sizing

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Basalt fiber (BF), a filament made from natural basalt rock, is known as a non-polluting and green material in the twenty-first century. While much progress has been achieved in developing BF as the reinforcement for composites, the wide applications of this material in fiber reinforced polymers (FRPs) is not achieved so far. One of the major concerns is that the measured strength of BF is significantly lower than its theoretical value (3000-4800 MPa). This is due to the existence of defects in the form of scratches, crystals and voids, which are commonly found in the brittle fibers. In this presentation, polymer nanocomposites made from epoxy and various nanoparticles were developed and used as a sizing for basalt fibre. Full-scale experiment with quantitative analysis on the stability, wettability, conductivity, and morphology of liquid was applied to obtain the optimum formulation of sizing. The surface, electrical and mechanical properties of basalt fibre before and after sizing were studied. The sizing gave significant increases on the electrical, mechanical and optical performance of basalt fibre, revealing the effectiveness of nanocomposites as a multi-functional material. The applications of the developed fiber for monitoring the structure defect in FRP structures, detection of hydrogen ions in solution as well as anti-counterfeiting behaviour will be demonstrated.

Key words Basalt fiber, sizing, nanocomposites, multifunctional basalt fiber

Session: Nanocomposites

Presenting Type： Oral-Onsite

Tailoring and functionalization of interfacial microstructures in multiple phase polymer system under external fields

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2. Chongqing University of Science and Technology
3. Sichuan University

Of late, the precise regulation of condensed state morphologies and microstructures aiming at the fabrication of functional devices during the polymeric melt processing, which contributes to the electronic information and surface chemistry field, is the most challenging and concerned topic in the scientific and industry community. Based on the understanding of the morphological revolution patterns under complicated external fields in multi-phase injection molding, herein the nature of inorganic particle migration and microphase separation at the phase interface during the multiple polymeric melt flows had been in-depth discussed and revealed. It was found that not merely the inorganic particles are supposed to migrate to the interfaces, but also the interlayer diffusion and phase separation can occur at the interface of two polymer melts during the multiple polymer melts flows, both of which are in favor of constructing fine microstructures at the interface of the injection molded parts. After facile postprocessing, the as-prepared microstructures possess great potentials in readily and massively preparing of functional materials, e.g., piezoresistive textile e-skins and superhydrophobic materials.

Key words microstructures; external fields; particle migration; microphase separation; piezoresistive; superhydrophobic

Session: Nanocomposites

Presenting Type: Oral-Onsite

Revealing the failure mechanisms of 2D material nanocomposites using Raman spectroscopy

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2. National Graphene Institute/Henry Royce Institute/Department of Materials, University of Manchester, Manchester, UK
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Composites are indispensable materials with wide applications. In recent decades, the development of 2D materials such as graphene offers composites new attributes due to its large surface area and functional properties. However, 2D materials are typically several orders of magnitude smaller than conventional fibres, therefore at present the failure mechanisms of nanocomposites are only estimated from bulk measurement, while the localized behaviors still remain unclear.

Raman spectroscopy has been demonstrated to be a powerful in-situ technique to investigate the interfacial micromechanics at the single 2D material flake level with spatial resolution <1 μm, using the correlation between the strain and the corresponding Raman band positions. More importantly, it is capable of showing the stress/strain distribution in the 2D material plane non-destructively, which is otherwise difficult for many other conventional micromechanical approaches. Using graphene as an example, three typical failure mechanisms - graphene fracture, matrix craze/crack and interface failure - have been quantitatively identified and compared micromechanically. It is shown that the graphene fracture and matrix/interface failure lead to opposite strain distribution in graphene, and the sequence of their occurrence depends on the competition between their strength. The initiation of craze or crack in poor interface or weak matrix results in heavy stress concentration in graphene over the crack region, similar to fiber bridging, with a stress concentration factor ~3. In contrast, first initiation of crack in defective and weak graphene leads to stress concentration at the crack tip in graphene. The associated strain field at the crack tip has been extracted to estimate the critical stress intensity factor of graphene as ~4.0 MPa·m^(1/2), in great agreement with previous simulation results. This work quantitatively reveals the failure mechanism in graphene nanocomposites, which is of crucial importance in the future design and practical applications of nanocomposites and devices using 2D materials.

Key words 2D Materials, Composites, Failure mechanism, Raman spectroscopy

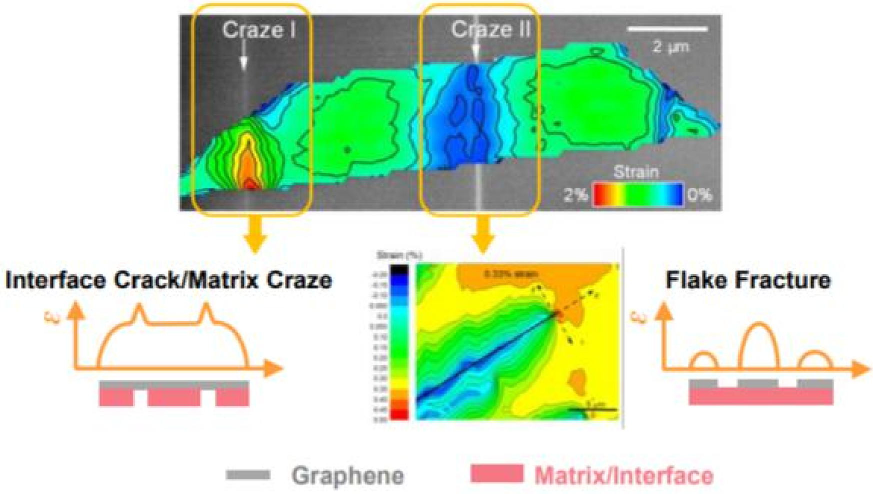

Fig. 1. Different failure mechanisms in 2D Material Nanocomposites.

Session: Nanocomposites

Presenting Type: Oral-Onsite

Enhanced thermal conductivity of polydimethylsiloxane-based composites using three-dimensional carbon fiber/graphene hybrid networks

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Highly thermal conductive carbon fibers (CFs) have been considered as promising candidates to prepare high-performance thermal interface materials for solving overheating issues of electronic devices. However, for CFs-filled polydimethylsiloxane (PDMS) composites, there are still some challenges of unsatisfactory thermal conductivity, uncontrollable orientation, and high interfacial thermal resistance. In this work, we have developed a vertically-oriented CFs skeleton using graphene oxide (GO) as inorganic bridging agent through directional-freezing technique, and infiltrated with PDMS to fabricate CFs-GO hybrid composites. The CFs-GO/PDMS composites showed a typical vertically-oriented structure, and their through-plane thermal conductivity was up to 7.61 W·m-1·K-1 at a low CFs loading of 13.8 vol%. The vertical orientation of CFs is beneficial to realizing rapid heat transport in through-plane direction, and the presence of GO which effectively combined CFs together can greatly reduce interfacial thermal resistance between CFs, consequently resulting in superior heat transfer performance and good thermal stability of composites. In addition, the porous structure of the CFs-GO skeletons can be easily deformed under applied forces for satisfactory compressibility. By virtues of the high thermal conductivity and good compressibility, the vertically-oriented CFs-GO/PDMS composites show great potential to be used as high-performance thermal interface materials.

Key words thermal interface materials, carbon fibers, thermal conductivity, vertically-oriented structures

Session: Nanocomposites

Presenting Type: Oral-Onsite

Nano-Toughening of Conductive Nanocomposites for Highly Stretchable and Sensitive Strain Sensors

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Stretchable and wearable sensor devices are attracting increasing attention due to their mechanical compliance and capability of detecting both subtle and large mechanical deformations, which enable new applications in human health monitoring, robots, and human-machine interactions. To achieve both high stretchability and high sensitivity, piezoresistive sensors have proven to be simple to make and highly robust. Piezoresistive sensors exploit the deformation-induced change in electric conductance between neighboring conductive nanofillers within an elastomeric matrix, where different strategies have been developed to improve sensing range and sensitivity of piezoresistive sensors, including segregated conductive networks of porous microstructure, microcracks, and hybrid conductive fillers.

In this work, we report a new method to effectively toughen conductive thin films of commonly used metals and conductive polymers to significantly improve their mechanical robustness for next-generation stretchable sensors (Figure 1).1-4 This new technique will overcome the major limitation of existing method of making stretchable electronics using wavy curves with unavoidable stress concentrations at the arc regions. By tackling the bottleneck issue of low stretchability and ductility of existing conductive material thin films, this work significantly expands the design space of flexible and stretchable electronic devices to beyond wavy curves constructed from low-ductility conductive materials. Furthermore, the new stretchable conductive thin films will facilitate low-cost manufacturing of micro- and nano-metre sized devices using conventional processes such as sputtering, ink-jet printing, and evaporation, which enables integration of miniaturized microelectronics.

Key words Toughening, conducitve nanocomposites, stretchable sensors

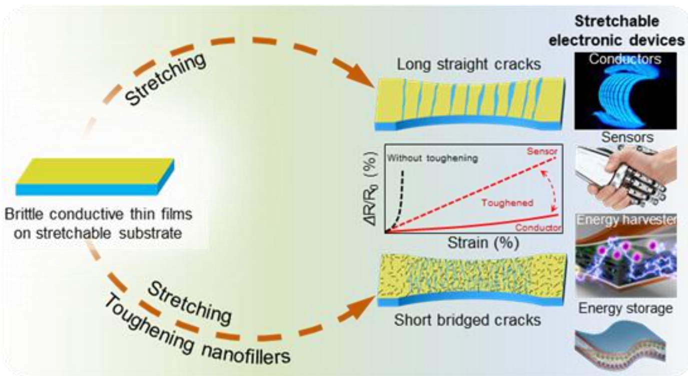

Fig. 1. Schematic illusion of toughened conductive composite thin films for stretchable electronics.

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Session: Nanocomposites

Presenting Type: Oral-Onsite

Graphene for moisture enabled electricity generation

Huhu Cheng*、Huhu Cheng
Tsinghua University

The transformation of energy in clean and renewable sources into mechanical or electric power is highly important for reducing environmental pollutions and satisfying the growing electricity demands in our daily life. As a widely existed power source, the energy embedded in moisture diffusion is huge and ubiquitous in atmosphere. However, the utilization of this unexplored energy source is a big challenge. With systematical regulation on graphene assemblies and so on, we have developed novel moisture-triggered actuators and moist-electric generator (MEG), which can make the device move or produce electric power when gaseous or vaporous water molecules diffuse from air to functional materials, transforming the energy in moisture into useful mechanical energy and electricity directly. The voltage of MEG unit has achieved to with a high value of ~1.5 V. Exceptionally high voltage (e.g., 20 V with 17 units) can be easily reached by simply scaling up MEG units in series, enough to drive many commercial electronic devices. Our effort on this new type of energy conversion device provides a new insight for design and development of functional materials and MEG, which will highly promote the efficient conversion of potential energy in environmental atmosphere to electricity towards practical applications.[1-4]

[1]Huhu Cheng*, Liangti Qu*, et al., Nature Nanotechnolgy, 2021, https://doi.org/10.1038/s41565-021-00903-6.
[2] Huhu Cheng*, Liangti Qu*, et al., Energy & Environmental Science, 2019, 12, 1848.
[3] Huhu Cheng*, Liangti Qu*, et al., Nature Communications, 2018, 9, 4166.
[4] Huhu Cheng*, Liangti Qu*, et al., Nanoscale, 2019, 11, 23083.

Key words graphene, moisture enabled electricity generation

ACM 12
Hangzhou, PR China 25-28 April, 2023

Session: Nanocomposites

Presenting Type：Oral-Onsite

Aggregation-induced separation of oil-water mixture with presence of polymer nanocomposites

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With continuous production and usage of petroleum products, accidents arising from oil spills occur frequently worldwide every year. Water pollution cases arising from these disasters lead to severe environmental and ecological problems. Therefore, materials that can effectively separate oil-water mixtures are in urgently needed. This paper will present our recent progress on developing polymer-based nanocomposites with multi-functionalities for efficient recovery of oil and organic liquids in/on water. Nanocomposites derived from polymer and natural material were prepared, and their morphologies were optimized to endow the materials with controlled dimension, superhydrophobicity, outstanding oil adsorption capacity as well as excellent recyclability and stability under the cyclic operations. Additionally, the unique structure and property of polymer nanocomposites led to the increase on the oil concentration in the liquid, which in turn enhanced the collision of emulsified oil droplets to aggregate into large ones in the emulsion and resulted separation from the water. Based on these findings, an aggregation-induced separation (AIS) process was proposed to explain the above phenomenon, and the mechanism was confirmed by studying the distribution of oil droplets in emulsion with a controlled separation degree. The advantages of polymer nanocomposites for oil-water separation are manifested by comparing their cost, adsorption capacity and applicability with those of commercial products. Based on the verification on the technical principle of AIS, an industrial-scale setup was performed, targeting on removing highly emulsified oil in wastewater. Engineering parameters on the practical application of AIS system were obtained

Key words Polymer nanocomposites; Aggregation-induced separation; Oil-water mixture

Session: Nanocomposites

Presenting Type: Oral-Onsite

2D Heterostructures: Rational Design for Energy Storage and Conversion

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Queensland University of Technology

Two-dimensional (2D) nanomaterials have offered an unprecedented opportunity for energy conversion and storage applications. Although significant progress has been made on 2D nanomaterials in energy-related applications, some major challenges still exist, such as the self-agglomeration, the low conductivity, the inactive reactivity, the operation complexity, and the structural instability, thus resulting in unsatisfying electrochemical performance. To address these issues, 2D heterostructures consisting of two or more 2D units have been developed. In our recent studies, some structural manipulation strategies, including adjusting interlayer spacing, changing chemical compositions, optimizing crystal structures, coupling with counterparts, increasing active sites, and activating inert surfaces, have been verified as effective solutions for promoting electrochemical properties of 2D nanomaterials. These research results are expected to meet the grand challenges for advanced nanomaterials in clean energy applications and thus provide access to exciting materials for addressing the current energy crisis.

Key words 2D Heterostructures; 2D Materials; Batteries; Electrocatalysis

Session: Nanocomposites

Presenting Type: Oral-Onsite

Ion-Selective Polymeric Nanofibrous Composite Membranes for Lithium Metal Batteries

Shujun Zheng、Ai-Long Chen、Yue-E Miao*、Tianxi Liu
Donghua University

Lithium metal batteries (LMBs) have the advantages of high theoretical capacity and energy density, but are still seriously restricted by the "shuttle effect" of lithium polysulfides (LiPSs) and dendrite growth in practical applications. As a vital component in batteries, the separators fundamentally determine the interfacial structure and internal resistance of batteries, which then affects the energy density, cycle performance and safety during long-term cycling. Compared with the traditional porous polyolefin separators, ion-selective polymeric nanofibrous separators with precisely directed ion diffusion paths are expected to achieve higher electrolyte wettability and ionic conductivity. In particular, the facile electrospinning technique has been applied to realize the controllable regulations of surface charge and porous structures of the fibrous membranes in this work. Besides, ion-selective modifications containing carboxyl groups and oxygen radicals were achieved on the surface of polymeric nanofibers. The introduced functional groups as well as precisely tuned porous structures can construct a uniform and negative electric field on the surface of separators to effectively suppress the "shuttle effect" of polysulfides and lithium dendrite formation. As a result, the LMBs demonstrate significantly improved cycle stability and rate performance. This work provides new ideas for the general design of advanced composite membranes with typical surface ion selectivity in applications of high-performance LMBs.

Key words Polymer Nanocomposites; Nanofibers; Ion-Selective Separators; Lithium Metal Batteries

Session: Nanocomposites

Presenting Type: Oral-Onsite

A Low-voltage-driven, Wearable, Valveless Microfluidic Pump Based on High-performance Ferroelectric Nanocomposites

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Microfluidic pumps play a key role in Lab-on-chips, which have demonstrated huge potential applications in biomedicine, liquid cooling, and precision driving, etc. With the development of flexible electronics technology, new target applications for microfluidic pumps have been focused on wearability and cost-effectiveness. In this work, a controllable, bendable, all-organic, and nozzle-diffuser microfluidic pump was designed, fabricated, and tested. Nevertheless, the ultrahigh operating voltage (usually more than 1000 V) is required to drive the microfluidic pump which mainly attribute to the property of the vibration membrane. This leads to the serious safety concerns and hinders the practical applications of the device in living organisms. Consequently, to resolve this crucial issue, the ferroelectric polymer poly(vinylidene fluoride-trifluoroethylene) (P(VDF-TrFE)) modified by the core-shell structured Al_2O_3@CNT nanoparticles was investigated. The microfluidic pump integrated with optimized membrane achieved obviously decreased operating voltage (from 1000 V to 160 V) and wider range of flow rates (13 to 135 μL/min) than these of the reported results, which were associated with the higher strain and higher output pressure of the optimized ferroelectric vibrating membrane. Importantly, owing to the low filler content, the designed microfluidic pump still possessed excellent controllability of the fluidic processes, though it underwent a large bending up to 74°. Consequently, the extremely promising application of the as-prepared microfluidic pump in wearable, biomedical devices was demonstrated.

Key words microfluidic pump, ferroelectric nanocomposites, electromechanical performance, core-shell structure

Session: Nanocomposites

Presenting Type: Oral-Onsite

Enhanced surface electrical conductivity of carbon fiber reinforced polymer composites using single-wall carbon nanotube films

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2. Liaoning Provincial Key Laboratory of Synthesis and Preparation of Special Functional Materials, Shenyang University of Chemical Technology
3. School of Materials Science and Engineering, University of Science and Technology of China

Carbon fiber reinforced polymer (CFRP) composites with low density, good corrosion resistance, high specific stiffness and strength have been widely applied in aircraft industry. However, the low surface electrical conductivity greatly limits their application as multi-functional composites. In order to obtain highly-conductive CFRP, we fabricated carbon fiber laminated composites by utilizing single-wall carbon nanotube (SWCNT) films as surface functional layers. Firstly, we prepared SWCNT nanofibers by a wet-spinning method and constructed non-woven SWCNT films with gradient structures. Next, the obtained SWCNT film was laminated onto carbon fiber prepreg by hot pressing. The microstructures and electrical conductivity of the CF/SWCNT laminated composites were investigated in detail. We found that the CF/SWCNT laminated composites exhibited a surface electrical conductivity as high as 2.27×10^5 S/m, increasing by three orders of magnitude in comparison with that of CFRP. Such high conductivity is mainly attributed to the high intrinsic conductivity of SWCNT nanofibers, gradient structure, and strong interfacial interactions. The CF/SWCNT laminated composites show great potential to be used as multi-functional materials in many fields such as lightning protection, electromagnetic shielding, and electro-thermal deicing.

Key words carbon fiber-reinforced epoxy composites; single-wall carbon nanotube; gradient structure; electrical conductivity

Session: Nanocomposites

Presenting Type: Oral-Onsite

Polymer nanocomposites and their related solid structures for electrocaloric effect refrigeration application

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2. School of Minerals Processing and Bioengineering, Central South University
3. School of Mechanical and Manufacturing Engineering, UNSW, Sydney, Australia

To successfully complete the design of high-performance electrocaloric devices for advanced flexible cooling systems, it is necessary to comprehensively consider the optimization of composite materials, structural design of nanocomposites, and device integration. The cooling power density and energy storage density of various structural configurated PVDF based polymer nanocomposites are investigated using phase-field model through the general formulation of a partial differential equation of COMSOL Multiphysics and finite element analysis through Maxwell's equation of conservation of charge. It is revealed that ferroelectric polymer nanocomposites composed of BNf+BCZT@BaTiO3(f)+PVDF possess the optimal result regarding their cooling power as well as the energy storage density. The cooling power density of the core-shell structured BNf+BCZT@BaTiO3(f)+PVDF nanocomposites is evaluated as a function of volume content, frequency, and electric field, where a remarkable cooling power density of 162.2 W/cm3 is achieved at 4 Hz with energy storage density of 33.4 J/cm3 under 500 MV/m field. Therefore, by performing the systematic study of electrocaloric effect in structural configurated ferroelectric polymer nanocomposites for solid-state refrigeration, this opens an avenue for developing a remarkably improved power density with reduced weight in aerospace energy storage technology.

Key words Nanocomposites; finite element analysis (FEA); COMSOL Multiphysics; electrocaloric effect; solid-state refrigeration

Session: Nanocomposites

Presenting Type：Oral-Onsite

Simple Design of a Porous Solar Evaporator for Salt-Free Desalination and Rapid Evaporation

Yamin Pan*、Xianhu Liu、Chuntai Liu、Changyu Shen
Zhengzhou University

Abstract: Solar-driven interfacial evaporation is considered to be one of the promising and efficient ways of producing clean water in recent years. However, it remains a challenge to develop solar evaporation devices with high solar evaporation rates and salt-free blocking properties. Here, a porous solar evaporator with directed water transport and salt-free desalination through excellent photothermal conversion and purposefully guided migration of the salt solution was developed. The designed porous photothermal sponge with the synergistic effect of MXene and polypyrrole can achieve evaporation rates of 1.47 and 2.27 kg m^{-2} h^{-1}, respectively, in the capillary model and siphon model water-transporting solar evaporation devices. More interestingly, the designed zigzag-shaped device with an evaporation rate of 2.45 kg m^{-2} h^{-1} was achieved. In addition, the evaporator can operate stably under 9 h in the siphon model solar evaporation device and achieves the effect of salt-free desalination. The above design provides a good strategy for solar-powered desalination applications.

Key words porous photothermal sponge, photothermal conversion, solar evaporation, directional water transport, salt-free desalination

Session: Nanocomposites

Presenting Type: Oral-Virtual Platform

Modification of nanofillers on interfacial transition zone between aggregate and cement pastes

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Dalian University of Technology

Interfacial transition zone (ITZ) between aggregates and cement pastes acts as the weakest zone inside concrete at the mesoscale, thus having critical impact on the performance of concrete composites. In addition, the nanofiller has been certificated to be effective admixtures that can remarkably modify the microstructures of cement-based materials. Therefore, this study aims to investigate the modification of nanofillers on ITZ between aggregate and cement pastes. For this purpose, the interfacial microstructures and bond strength were characterized by scanning electron microscope, energy dispersive spectrometry, nanoindentation, statistical nanoindentation techniques, and three-point bend test. The experimental results indicated that the ITZ with nanofillers is characterized by narrow interfacial thickness, optimized intrinsic compositions, low calcium hydroxide contents, and dense microstructures. Meanwhile, the nanofiller content in the ITZ is 1.65–1.98 times more than that in the bulk cement pastes. Additionally, incorporating nanofillers increases the degree of hydration in the ITZ, reduces the contents of micro pores (MP) and low-density calcium silicate hydrate (LD C-S-H), and increases the contents of high-density C-S-H (HD C-S-H) and ultra-high-density C-S-H (UHD C-S-H). In particular, a new phase, named nano-core induced super-high-density C-S-H (NCISHD C-S-H), with a superior hardness of 2.50 GPa and an indentation modulus similar to those of HD C-S-H or UHD C-S-H, is identified in this study, as shown in Fig. 1 (a). Owing to the modification of interfacial microstructures, adding nanofillers increases the bond strength between aggregates and cement pastes, as shown in Fig. 1 (b). These findings indicated that nanofillers tend to enrich in the interfacial area due to migration and wall effects, which is conducive to the nano-core effect in the ITZ (Fig. 1 (c)). On the one hand, the enriched nanofillers can form numerous nano-core-shell elements by adhering calcium ions and silica tetrahedron, thus modifying the properties of hydration products in short range. On the other hand, the nano-core-shell elements integrate with surrounding hydration products through the interaction between particles to further improve the interfacial performance in long range.

Key words Interfacial transition zone (ITZ); Nanofillers; Microstructures; Bond strength; Modification mechanisms

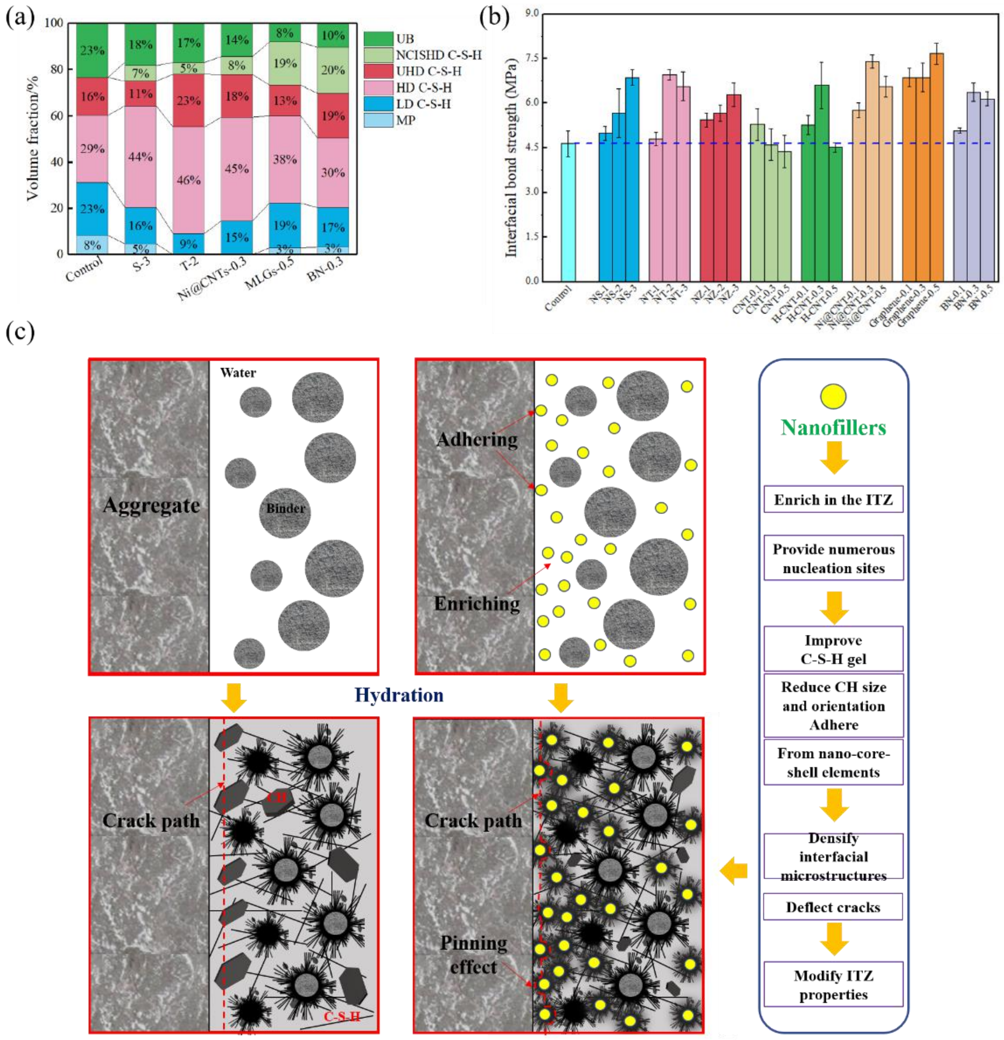

Fig 1. Modification of nanofillers on the ITZ between aggregates and cement pastes.

Session: Nanocomposites

Presenting Type: Oral-Virtual Platform

Investigation on the Corrosion Resistance Performance of Graphene Composites Coatings from the Laboratory to the Offshore Field

Mohd Shamsul Farid Samsudin*、Norfarah Diana Aba、Muzdalifah Zakaria、Azmi Mohammed Nor
Petronas Research Sdn Bhd

Researchers have widely reported on the use of graphene as a barrier additive in polymer coating materials. Coating performance study focused primarily on water resistance and mechanical performance such as adhesion, abrasion, and impact resistance. According to the findings, the use of graphene enhanced the coating's water barrier performance as well as its mechanical performance. Nonetheless, the number of research, including long-term salt spray and ultraviolet (UV), were conducted in a control lab environment using ISO or ASTM standard methods, and very few studies reported the performance of graphene coating in the actual field, where the conditions were most likely different from those in the lab. In this work, the performance of graphene composites coating was evaluated by exposing coated coupons to actual splash and spray zone conditions at offshore field for six months. The performance was compared to that of a coupon tested under laboratory control conditions. The performance of the coating was investigated by introducing 0.05 wt.% fine graphene particles GNP into a commercial epoxy glass flake (GF) paint. Electrochemical impedance spectroscopy (EIS), corrosion creepage after long-term saltwater and UV exposure were used to assess corrosion resistance performance. The coating’s mechanical performance was quantitatively evaluated using the pull-off adhesion test and abrasion. Overall, the addition of small amounts of graphene at 0.05 wt% significantly improved the corrosion resistance properties of the coating, as evidenced by a higher impedance value from the EIS and a decrease in corrosion creepage after prolonged field exposure as disclosed in Figure 1 and 2. The adhesion performance of the modified graphene paint after field exposure, as determined by visual inspection and pull-off adhesion test, remained superior to that of an unmodified paint, with less surface blistering and corrosion underneath, demonstrating the benefits of graphene as a barrier material for coating. The performance of the graphene paint was also consistent with the laboratory test conditions, in which the corrosion creepage was reduced by a factor of two and adhesion and abrasion consistently indicated improved performance compared to the control paint system.

Key words Graphene Coating, Corrosion Resistance, Durability , Offshore Field

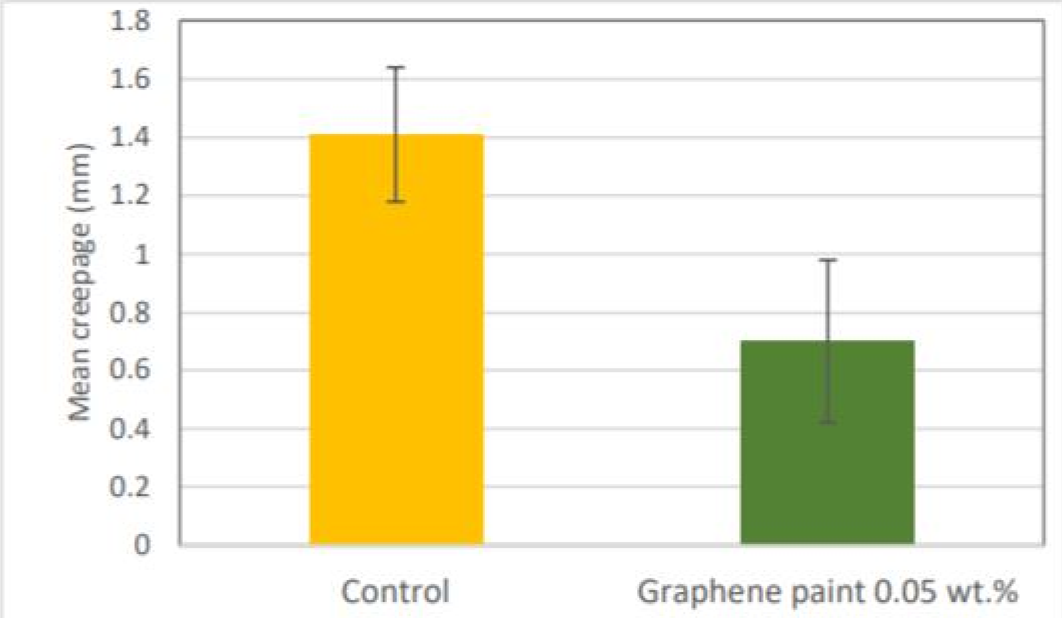

Fig. 1. Corrosion creepage after 6-month exposure at offshore field.

	
Control sample	Graphene paint at 0.05 wt.%

Fig. 2. Appearance of corrosion creepage on the scribed plate after 6-month offshore Exposure.

Session: Nanocomposites

Presenting Type: Oral−Virtual Platform

Effect of the core-shell structured CNT-Al2O3 on the electromechanical performance of electroactive polymers

Jie Zhang*、Fengwan Zhao、Xiaoming Chen
Xi'an Jiaotong University

Dielectric elastomers and ferroelectric polymers are the typical electroactive polymer, which can be rapidly deformed under the external electric filed. Thus, they have demonstrated significant potential in the fields of the flexible actuator, soft robots, artificial muscle. However, the high driving voltage has been a long-standing obstacle for their safety utilization. To resolve this issue, in our works, the novel core–shell structured CNT–Al2O3 nanoparticles grown via atomic layer deposition were used to improve the electromechanical properties of electroactive nanocomposites under low applied fields. The achieved balance among a high εr, high Eb, and stable Y in our system can assure a high actuation strain under a low driving field, stable stiffness, and improved safety for electroactive polymers. By numerically calculating electric field distribution and polarization, it was understood that the higher induced strain and lower driving voltage resulted from the enhanced interfacial polarization. Our studies provide a new route to improve the performance of electroactive polymers and holds great promise for their applications with low operating voltage in portable microfluidic and the flexible actuators.

Key words Electroactive polymers; Core–shell structure; Interfacial polarization; Electromechanical property

Session: Nanocomposites

Presenting Type: Poster

A Facile Method to Construct Go/Zinc Silicates Composite Layer on Lithium Metal Anode for Dendrite-free Lithium Deposition and Uniform Li-ion Flux

liu hongjun*、Jin Qu、Xiao-Feng Li 、Zhong-Zhen Yu
Beijing University of Chemical Technology

As one of the most promising anode materials, lithium metal anode has drawn much attention recent years due to its high specific capacity and the lowest reduction potential. However, safety issues caused by uncontrollable lithium dendrites and terrible reversibility caused by parasitic reactions hinder its practical applications. Herein, a multifunctional artificial SEI layer is designed through an automatic transfer process. Graphene oxide/zinc silicate nano-membranes modified separator is constructed by facile doctor-blade method and then the composite layer can transfer on the surface of Li metal anode once in contact with anode. The Go/Zinc silicate nano-membranes is prepared through one-step synthesis process and then the nano-membranes are uniformly covered on commercial PP separator. The modified layer on separator can automatically separate from PP separator and cover on lithium metal anode to form a protected layer. The composite layer can achieve stable interface by modulating the lithium deposition morphology and uniform Lithium-ion flux. The electronegative GO nano-membranes can regulate lithium-ion transportation. Also, zinc silicates are capable of in-situ reaction with lithium metal anode to generate a lithiophilic layer providing active sites for lithium nucleation and lowering lithium deposition energy barrier. As a result, the Li anode protected by composite layer can achieve lower polarization and longer cycle life with no short circuit in symmetrical cells. In addition, full cells also show more stable coulombic efficiency and longer cycle life than bare Li anode. This work designs a facile method to construct a multifunctional composite layer for protecting lithium anode by combining GO and zinc silicates and provides new sights into the designing of protected layer for lithium metal anode.

Key words dendrite-free lithium metal anode; PP separator; artificial SEI film; protected layer

Session: Nanocomposites

Presenting Type: Poster

One-Pot Synthesis of Chemically Integrated Nanofiber-Reinforced Hydrogels with High Modulus and Ionic Conductivity

Xuyan Lu[1,2]、Yang Si[1]、Shichao Zhang[1]、Jianyong Yu[1]、Bin Ding*[1]
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2. Donghua University

Mechanically robust ion-conducting hydrogels have gained widespread attention as sensing materials for applications in human-machine interfaces, wearable devices, health monitoring, and soft robotics; however, the preparation of such materials is still a huge challenge. We demonstrate a one-pot synthesis strategy for developing the chemically integrated nanofiber-reinforced hydrogels with enhanced mechanical and electronic performances by integrating flexible silica nanofibers, vinyl silane crosslinker, and sodium alginate/polyacrylamide hydrogels. The robust interfacial chemical bonding between silica nanofibers and PAM chains is in situ constructed along with a free radical polymerization process. The resultant silica-fiber-reinforced hydrogels (SFRHs) exhibit a tensile strength of 0.3 MPa and Young's modulus of 0.11 MPa similar to that of natural skin. Moreover, the SFRHs show high ionic conductivity of 3.93 S m-1, high sensitivity to a wide range of strains (0.5-1100%), and pressures (1-28 kPa), and ultra-durable sensing performance over 10000 uninterrupted compression cycles. The successful synthesis of such fascinating material opens new pathways for the design of tough and stretchable ionic conductive hydrogels for various applications.

Key words nanofibers; hydrogels; mechanically robust; ionic conductivity; multiple sensors

Session: Nanocomposites

Presenting Type: Poster

Amorphous Carbon from Phthalonitrile Resin with Controllable Magnetoresistance

Junling Zeng、Hongbo Gu*
Tongji University

In this work, an amorphous carbon prepared from phthalonitrile (PN) resin/4-(4-aminophenoxy) phthalonitrile/4-(2-allylphenoxy) phthalonitrile with controllable magnetoresistance (MR) is reported. A series of carbonized PN resins with dominating phthalocyanine structure are fabricated under different annealing temperatures. The samples exhibit the semiconducting characteristics and their MR properties are investigated systematically. We have exploited the degree of disorder obtained from Raman spectra and $C(sp^2)/C(sp^3)$ ratios from X-ray photoelectron spectroscopy (XPS) to analysis the charge carrier transport behavior of these carbonized PN resins.

Key words magnetoresistance, phthalonitrile resin, amorphous carbon, semiconductor, phthalocyanine

Session: Nanocomposites

Presenting Type：Poster

Ultralight mullite nanofibrous aerogels with temperature-invariant compressibility and flexibility

Xiaota Cheng、yi-tao liu、Jianyong Yu、bin ding*
Donghua university

Ceramic aerogels are attractive for many applications owing to their low density and thermal conductivity, high specific surface area and thermal inertness. However, ceramic aerogels are generally brittle and often tend to structurally collapse under large external strain and in extreme environments. In this work, we design mullite nanofibrous aerogels with wave-structured nanofibers and lamellar structures that endow the aerogels with compressibility, flexibility and high temperature. The 3D structure of the aerogel is manufactured by a modified electrospinning method. The unique mullite aerogel exhibited suprior mechanical properties including 90% compressive strain and bending strain recovery, high temperature stability from -196 to 1400 °C, robust restoring capacity up to 60% compressive or 90% bucking strain for 1000 cycles, and a low thermal conductivity of 0.0232 W m-1 K-1 in air. This work would enable the innovative design of high-performance ceramic aerogels for practical applications in extreme environments.

Key words mullite nanofibrous aerogel; compressive; extreme environments

Session: Nanocomposites

Presenting Type：Poster

Hierarchical structured flexible silica nanofibrous aerogels with temperature invariant superelasticity for high-temperature sound absorption

Dingding ZONG、Shichao ZHANG、Jianyong YU、Bin DING*
Donghua University

The rapid development of transportation and industry has brought serious noise pollution problems, which have caused serious harm to human health and the ecological environment. The existing sound-absorbing materials have the problems of a narrow absorption frequency band, high weight, and poor temperature resistance, which seriously limit their practical application. Here, we developed a simple strategy to fabricate hierarchically structured flexible silica nanofibrous aerogels (FSNAs) with temperature-invariant superelasticity ranging from −100 to 1000 oC by integrating directional freeze-casting and in-situ cross-linking techniques. Most importantly, the obtained FSNAs can absorb ultra-broadband noise from 63 to 6300 Hz while maintaining lightweight properties (8 mg cm-3), with a noise reduction coefficient of up to 0.5. This strategy paves the way for the development of high-temperature sound-absorbing materials for extreme environments.

Key words flexible silica nanofiber, nanofibrous aerogels, temperature invariant superelasticity, sound absorption

Session: Nanocomposites

Presenting Type: Poster

Strawberry-like Co3O4-Ag bifunctional catalyst for overall water splitting

Yi Feng*
Tianjin University

Water electrolysis has been proven as an effective means to produce clean hydrogen energy, and such a process can be accelerated by active bifunctional electrocatalysts for both hydrogen evolution reaction (HER) and oxygen evolution reaction (OER). In this work, we adopted a laser ablation technique to prepare a strawberry-like Co_3O_4-Ag bifunctional catalyst (SLC) for HER and OER, which exhibits outstanding overall water splitting performance.

The strawberry-like metal-oxide/metal composite, with Co_3O_4 clusters embedded in Ag nanoparticles, achieves the ingenious mutual regulation of Co_3O_4 and Ag. Experimental and theoretical results demonstrate that the embedded Co_3O_4 significantly improved the hydrogen adsorption energy of Ag substrate by changing its coordination number and tensile strain. Combining the excellent water dissociation ability of Co_3O_4 with the optimized hydrogen adsorption of Ag substrate, the strawberry-like metal-oxide/metal composite presents excellent alkaline HER activity, with a low overpotential of 51 mV at 10 mA cm^{-2}. At the same time, the electron transfer from Co_3O_4 to Ag facilitates the oxidization of Co_3O_4 and improves the OER performance, leading to a low OER overpotential of 206 mV at 10 mA cm^{-2}. Ultimately, an ultralow potential of 1.49 V for overall water splitting has been achieved at 10 mA cm^{-2}, outperforming Pt/C+RuO_2 couple.

Our work demonstrates that laser ablation is a powerful technique to improve the catalytic activity of inactive components through mutual regulation of the components. We believe that this elegantly designed composite will open a new avenue for the development of highly active catalysts and the advancement of industrialization.

Key words water electrolysis, mutual regulation, tensile strain, coordination number, electron transfer

Session: Nanocomposites

Presenting Type: Poster

Dual-nanograins composite ceramic nanofibers with super-elasticity for thermal protection in extreme environments

Fan WU、Yi-Tao Liu、jianyong Yu、Bin Ding*
Donghua university

Ceramic is not optimal for use in complex situations because of the intrinsic brittleness and flaws-sensitivity. Especially in high-temperature environments, the microstructure of the ceramic is highly susceptible to destabilization and failure due to the uncontrolled growth of grains. Here, we designed mechanical robust, super elasticity, dual-nanograins composite ceramic nanofibers (DNCC-NFs) with dependable structural and thermal stabilities. In contrast to traditional ceramic materials, the dual-nanograins composite structure in DNCC-NFs is able to inhibit the growth of grains with continuous energy input, and endows multidimensional flexibility and elasticity of ceramics from deep-cryogenic (-196 ^{o}C) along the way to ultra-high temperature (1600 ^{o}C). Moreover, The DNCC-NFs possess superior structural strength that can resist thousand large-scale buckling or compressive cycles. This work not only developed elasto-flexible ceramic materials for thermal insulation in harsh conditions, but also offers a fresh theoretical understanding of the elasticity in ceramics.

Key words Super-elastic ceramic nanofiber, Dual-nanograins compositestructure, harsh environment

Session: Nanocomposites

Presenting Type: Poster

Nanoporous-Engineered Sponge Fiber Molecular-Sieves with Ternary-Nested Structure for Precise Molecular Separation

Feng Zhang、Yang Si、Jianyong Yu、Bin Ding*
Donghua university

Polymeric fibrous molecular-sieving membranes (PFMs) with ultrahigh surface area, well-defined hierarchical nanoporous structure, and superior self-standing property are of great interest for molecular-level separation applications; however, creating such PFMs has proven extremely challenging. Herein we report a novel strategy to create sponge-like PFMs with hierarchical, tailorable, and molecular-defined nanoporosity by combining self-crosslinking, controllable swelling, and space-confined hyper-crosslinking. The robust micropores (< 2 nm) are in situ constructed on the macro/mesoporous skeletons of electrospun fibers with tunable pore size distribution. The resultant PFMs exhibit the integrated properties of ultrahigh surface area (859.60 m2 g-1), large pore volume (0.6 cm3 g-1), self-standing, and excellent molecular sieving performance in acetophenone/phenyl ethanol separation, hydrogen peroxide purification, ethyl acetate separation, and CO2 adsorption. The fabrication of such PFMs may open novel avenues to the design and development of polymeric fibrous sieves for molecular separation in large-scale chemical, energy, and environmental processes.

Key words nanoporous fiber, sponge fiber, molecular sieves, ternary-nested architecture, molecular separation

Session: Nanocomposites

Presenting Type: Poster

Over 80% Weight Reduction by Adopting Super-aligned Carbon Nanotube Films towards Lightning Strike Protection for Fiber-Reinforced Composites

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2. University of Science and Technology of China

Carbon nanotube (CNT) films, as potential alternatives to the aluminum or copper used in lightning strike protection (LSP) for the aircrafts, have directed the attention in the past decade for their excellent electrical, thermal, and mechanical properties. However, the anticipated performance of CNT films boosted LSP applications are not realized despite of some laboratory demonstrations. The processing technique of fiber-reinforced composites with CNT films is not fully resolved, and the comprehensive understanding of the protection mechanism upon lightning strike is not yet available. Herein, we increase the impregnation of the resin into the super-aligned CNT film by preparing the super-aligned CNT/resin epoxy prepregs, mitigating the delamination of CNT films on fiber-reinforced composites. The carbon fiber reinforced composites protected by the super-aligned CNT films can withstand the laboratory simulated lightning strike with a current peak up to 200 kA, over 80% weight reduction compared to the copper mesh. Damage assessments, including ultrasonic detections and residual strength tests are conducted. Theoretical analysis based on the experiments is proposed to elucidate the complex physical process of lightning strike. The synergetic effects of super-aligned CNT film on LSP are revealed by a succinct scaling relation. In addition, a numerical model with the multi-physics coupling is constructed to assess the LSP performance for both the conventional metal mesh and the carbon nanotube films protected fiber reinforced composites. Finally, a guideline for LSP design is outlined.

Key words Lightning strike protection, carbon nanotube films, fiber reinforced composites, multi-physics simulations

Session: Nanocomposites

Presenting Type: Poster

Hierarchical N-halamine aerogels with π-conjugation channels enable rechargeable decontamination of vesicants

Zishuo YAN、Yang SI、Jian YU、Bin DING*
Donghua University

Poisons and poisoned weapons are significant threats to human peace and global safety. Most of the personal protective equipment in service used to barrier toxicants is devoid of decontamination activity. We propose robust lamellar conjugated aerogels that provide interconnected channels for dispersion of contaminated fluid and suitable cages for physical confinement and chemical degradation of toxic molecules. The obtained system is composed of ternary pores with a long-span size from micron to sub-nanometer: (1) the primary micron cells (10-15 μm) derived from solvent crystals formation and sublimation; (2) the secondary pores (27-93 nm) on the crumpled cell walls; (3) tertiary pores on the nanofibers (0.6-3.4 nm). With their tridimensional ultralight configuration, resilient compressibility, hierarchical interpenetrating pores, π-conjugated electronic structures, and rechargeable N-halamine groups, we expect these exceptional aerogels to have far-reaching technical ramifications in detoxifying materials for chemical warfare agents adsorption and decontamination. On the other hand, we conducted density functional theory and molecular dynamics simulations to provide insight into the fundamental mechanisms of the mechanically robust formation of π-conjugated composite and the "adsorption- degradation" behavior of mustard gas simulants in the aerogels. The systematic studies on π-π interactions sufficiently suggest the non-covalent interactions in the aerogels. The visualized result of dispersion dominated weak interaction between graphene and mustard gas simulants, the accommodation of simulant guests in the molecular cages, and the theoretical thermodynamics of the oxidation explain the underlying causes of the excellent detoxification. The concept of pore-reorganizing opens the door for addressing performance trade-offs between productivity (low filtration resistance) and reaction efficiency (rapid degradation).

Key words nanofibers; N-halamine; chemical warfare agents; aerogels

Session: Nanocomposites

Presenting Type: Poster

A design strategy of all-sprayable ultrablack coating

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Although ultrablack surfaces are urgently needed in wide applications owing to their extremely low reflectance over a broadband wavelength, to obtain simultaneously the ultrablackness and mechanical robustness by simple process technique is still a great challenge. Herein, by decoupling different light extinction effects to different layers of coating, we design an ultrablack coating that is all-sprayable in whole process. This coating presents low reflectance over VIS-MIR wavelength (av. R≈1% in VIS), low multi-angle scattering (BRDF≈10-2~10-3 sr-1), together with good substrate adhesion grade and self-cleaning ability, which are superior to most reported sprayable ultrablack surfaces. The light extinction effects of each layer are discussed. This method is also applicable in other material systems.

Key words ultrablack, spray-coating, carbon nanomaterials, multiple scattering, intermediate layer

Session: Nanocomposites

Presenting Type: Poster

Extreme electrical properties of carbon nanotubes and their application in composites

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Carbon nanotubes (CNTs) have excellent electrical properties with an electrical conductivity of 2×10^7 S m^{-1} and an ampacity as high as 10^9 A cm^{-2}, which can be used in many emerging cutting-edge electrical applications such as fast response artificial muscle, fast-charging energy storage system, lightning strike protector, surge protector, interconnects, etc. First, we studied the electrical failure mechanisms of CNT ribbons and found that the main failure mechanism of the sample at high electrical stress rates is thermal ablation instead of thermal oxidation, which is beneficial to lightning strike protection. Then we designed a miniature tip discharge system (MTDS) to simulate the lightning strike environment in the laboratory and studied the failure mechanism of CNT film-based advanced LSP composite systems. The introduced isolation layer also contributes to the LSP effect, mainly by electrical insulation, thermal resistance, and thermal insulation. Finally, the advanced lightweight lightning strike protection (LSP) composites were fabricated by using CNT films and new isolation layers, the "complementary effect" between the conductive layer and the isolation layer was revealed. Compared with typical CNT-based LSP laminate samples made of buckypaper/BN/epoxy layer or SA-CNTF/glass fiber, the weight can be reduced by at least ~30% and ~38%, respectively.

Key words Carbon nanotubes and nanofibers, Polymer-matrix composites, Electrical properties, Failure, Lightning strike protection

Session: Nanocomposites

Presenting Type: Poster

Well-designed structure of sandwich-like composite films based on hollow polyaniline and MXene with enhanced electromagnetic wave absorption

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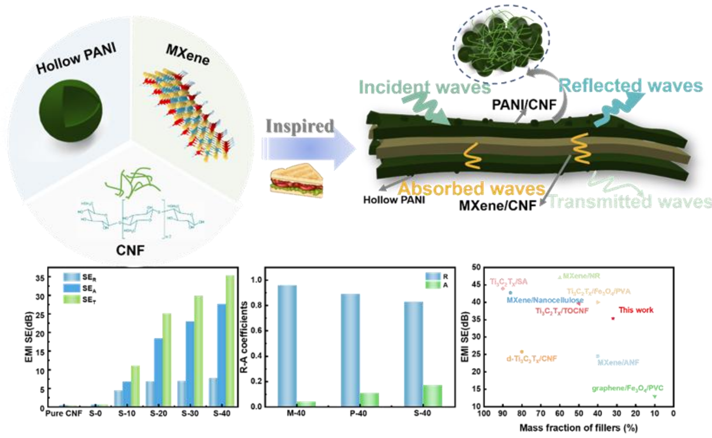
Zhejiang University of Technology

With science and technology developing rapidly nowadays, intellective, carriable, and wearable electronic devices have also developed quickly. So far, the demand for composite films with remarkable electromagnetic interference (EMI) shielding performance is increasingly urgent. In this paper, a sandwich-like EMI shielding composite film was prepared by alternating vacuum-assisted filtration method, where hollow polyaniline (h-PANI)/cellulose nanofiber (CNF) in the surface layers and MXene/CNF in the intermediate layer. Due to the successful construction of the sandwich structure, when the proportion of MXene is just 8 wt% and h-PANI is 24 wt%, the EMI SE of the sandwich-structured composite films achieved 35.3 dB, which is better than that of the homogeneously blended film (17.3 dB) and the improvement of the SET is mainly caused by the increase of SEA. Besides, the EMI SE of the composite film did not reduce observably even after the sustained physical attack, indicating that it has good EMI shielding stability. More interestingly, the absorption coefficient of the sandwich-structured composite films with h-PANI was improved by 325% contradistinguish to that of the pure CNF layer structure. This novel sandwich composite film exhibits excellent EMI shielding performance with broad application prospects in intelligent, portable, and wearable fields.

Key words Sandwich-structured; Electromagnetic interference shielding; Cellulose nanofiber; MXene



Session: Nanocomposites

Presenting Type: Poster

To accelerate the reaction kinetics of sulfurized polyacrylonitrile nanofibers by iodine doping

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Donghua University

Sulfurized polyacrylonitrile (SPAN) is a promising cathode material in the current lithium-sulfur battery system due to its unique chemical structure and excellent electrochemical performance. However, SPAN still suffers from the slow reaction kinetics resulting from its insufficient electronic conductivity. In this work, we modify the chemical structure of freestanding fibrous SPAN by iodine doping to accelerate reaction kinetics. According to Raman and X-ray photoelectron spectroscopy, sulfur and iodine atoms existing in the form of C−S/S−S and C−I bonds in the iodine-doped sulfurized polyacrylonitrile (I-SPAN), respectively. The electrochemical tests reveal that the transfer rate of electrons and ions in I-SPAN increase significantly. A high reversible specific capacity of 1283 mAh g^{-1} is achieved after 200 cycles at 800 mA g^{-1}.

Key words sulfurized polyacrylonitrile, iodine doping, conductivity, reaction kinetics, battery

Session: Nanocomposites

Presenting Type: Poster

Electrocatalytic degradation of tetracycline in wastewater by electrospun perovskite manganite nanoparticles/carbon nanofibers nanocomposites

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Tongji University

In this work, we developed a perovskite manganite ($La_{0.7}Ca_{0.3}MnO_3$) nanoparticles/carbon nanofibers (LCMO/CNFs) nanocomposites by annealing the electrospun polyvinylpyrrolidone (PVP) mixed with nitrates (manganous nitrate, lanthanum (III) nitrate, and calcium nitrate) for the electrocatalytic degradation of tetracycline (TC). The results show that the LCMO/CNFs nanocomposites fabricated with annealing at 250 °C for 120 min in the air atmosphere and subsequent calcination at 650 °C for 60 min possess an excellent TC degradation performance. The TC degradation percentage (DP%) could reach 94.0% for 10 mg L^{-1} of TC solution with 0.1 mol L^{-1} Na_2SO_4 as the supporting electrolyte within only 1 h at a bias voltage of 1.0 V (*vs*. SCE). After five cycles of electrocatalytic process, the TC DP% of LCMO/CNFs modified electrode only changed from 87.8 to 84.8%, implying an excellent durability, recyclability, and reusability. The TC degradation mechanism and pathways have also been explored. The results exhibit that TC could be thoroughly degraded into carbon dioxide and water electrocatalyzed by LCMO/CNF. This work provides a novel material for the treatment of antibiotics wastewater.

Key words Perovskite manganite nanoparticles, Carbon nanofibers, Tetracycline, Electrocatalytic degradation

Session: Nanocomposites

Presenting Type: Poster

Ultrablack Surface with Omnidirectional and Broadband Light Absorption Based on Magnetically Driven Self-Assembly

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Ultrablack surfaces with stable light absorption over a wide spectral range are fundamentally important for applications concerning strict optical requirements, from high-end optical to solar-heat conversion devices. Inspired by nature, array-like structures are proven effective for improving light absorption performance. However, the existing array-like ultrablack surfaces have inherent limitations on preparation conditions, hindering their widespread applications. Herein, we report an ultrablack surface prepared via magnetically driven self-assembly with the help of the convenient spraying method. Under an external magnetic field, composite ink spontaneously assembled into needle array structures (NAS) on the substrate with high regularity and small feature size. As a result, ultrablack surfaces were prepared with a hemispherical reflectance of <0.3 % over a wide spectral range of 300-2000 nm, combing with stable omnidirectional absorption. The exciting light absorption performance can be attributed to structural absorption caused by multiple scattering between array units and the magnetic particles for light propagation and absorption. At the same time, NASs exhibit excellent solar harvesting, self-cleaning and flexibility performance, beneficial for further applications. Such a convenient processing method paves a new way for constructing ultrablack surfaces for practical applications.

Key words ultrablack surface, array structure, omnidirectional absorption, magnetically-driven self-assembly

Session: Nanocomposites

Presenting Type: Poster

Nanofibrous Membranes with High Transparency for Efficient Air Filtration

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Donghua University, shanghai

Transparent film materials always play a key role in the fields of optoelectronics, energy, environment, medical and health. However, most current transparent films are solid, lacking connected pore structure and high specific surface area which lead to the bad breathability and poor adsorption performance. Here, a novel and effective structure is designed to create the high visible light transmittance fibrous membranes (HTFMs). The obtained HTFMs display excellent optical transparency (>80%) and high porosities (>80%). The formation of the structure with high light transmittance and the mechanism of light propagation in fibrous membrane structure are clarified. Besides, this work also demonstrates the transparent fibrous air filters prepared by HTFMs. Combined with special structure of high light flux, the transparent air filters show high transparency (>80%), low pressure drop and high $PM_{0.3}$ removal efficiency (>90%). Therefore, this work may give a new way to develop the transparent and functional fibrous membrane materials.

Key words Transparent; Nanofibrous Membranes; PM0.3 Removal

Session: Nanocomposites

Presenting Type: Poster

Superb electromagnetic shielding polymer nanocomposites filled with 3-dimensional p-phenylenediamine/aniline copolymer nanofibers@copper foam hybrid nanofillers

Feichong Yao、Hongbo Gu*
School of Chemical Science and Engineering, Tongji University

The polymer nanocomposites with 3-dimensional (3D) nanofillers can form a 3D network and attain a uniform distribution of nanofillers, which benefits the transfer of charge carriers and phonons as well as the dispersion of stress at a very low loading of nanofillers. These polymer nanocomposites with high mechanical properties would have great potential for thermal and electrical conduction as well as electromagnetic interference (EMI) shielding. In this paper, the 3D epoxy nanocomposites are manufactured by stuffing epoxy resin into 3D p-phenylenediamine-aniline copolymer nanofibers@Cu foam (P-PANI@f-Cu) hybrid nanofillers that are constructed by electrophoretic deposition of phosphoric acid doped P-PANI copolymer nanofibers onto the surface of sodium hydroxide oxidized Cu foam. Benefiting from the 3D continuous network of P-PANI@f-Cu hybrid nanofillers, the electrical conductivity and thermal conductivity of 3D P-PANI@f-Cu/epoxy nanocomposites with the P-PANI loading of 0.262 wt% could achieve 7.71±0.04 S cm^{-1} and 5.4670±0.0085 W $m^{-1}K^{-1}$, respectively, which are much better than that of pure epoxy (insulator and 0.2310±0.0017 W $m^{-1}K^{-1}$, respectively) and epoxy composites filled with only Cu foam (4.46±0.03 S cm^{-1} and 2.7907±0.0057 W $m^{-1}K^{-1}$, respectively). Meanwhile, with a thickness of 1.8 mm, the average total EMI shielding effectiveness (SE_T) of 3D P-PANI@f-Cu/epoxy nanocomposites in the X-band range reaches a high value of 66.14 dB, which is capable of effectively shielding the electromagnetic signal between Bluetooth earphone and smartphone in the practical application. Furthermore, the 3D P-PANI@f-Cu hybrid nanofillers can efficiently prevent the crack growth in the epoxy nanocomposites and improve their mechanical properties including hardness and elastic modulus.

Key words 3D Cu foam hybrid nanofillers, p-phenylenediamine-aniline copolymer nanofibers, epoxy nanocomposites, electrical conductivity, thermal conductivity, electromagnetic interference shielding

Session: Meta-Composites

Presenting Type: Oral-Invited

How to Adjust and Control the Weakly Negative Permittivity of Metacomposites in Broad Frequency Range?

Kai Sun*、Runhua Fan
Shanghai Maritime University

Metacomposites are usually fabricated by conventional methods and possess novel electromagnetic properties especially including negative permittivity behavior, which have great potential in the field of electronic devices, microwave absorption and sub-wavelength image, etc. In previous studies, it has been a challenge that how to obtain a weakly negative permittivity especially epsilon-near-zero in a broad frequency range. This presentation is mainly focused on the effects of chemical composition, microstructure and external fields on weakly negative permittivity and frequency dispersion. It can contribute to enriching the fundamental theory and universal regulatory mechanism of radio-frequency negative permittivity property, and provide a theoretical basis for practical applications.

Key words Metacomposites; Negative permittivity; Epsilon-near-zero; External fields

Session: Meta-Composites

Presenting Type: Oral-Invited

Copolymers of aniline and phenylenediamine with controllable magnetoresistance and negative permittivity

Hongbo Gu*
Tongji University

In this work, three types of phenylenediamine (PDA), including o-PDA, m-PDA, and p-PDA, and different contents of PDA have been incorporated into the PANI polymer backbone by the interfacial copolymerization of aniline with PDA. The results demonstrate that different types and contents of PDAs could disclose the distinct effects on the chemical structures, crystalline structures, and morphologies for copolymers of aniline with PDA affirmed by Fourier transform infrared (FTIR) spectroscopy, solid-state ^{13}C nuclear magnetic resonance (^{13}C-NMR), X-ray diffraction (XRD), scanning electron microscope (SEM) and transmission electron microscopy (TEM). The molecular weight of all copolymers is reduced by several orders of magnitude relative to pure PANI nanofibers confirmed by gel permeation chromatography (GPC). The resistivity variations for the copolymers of aniline with different types of PDAs are well explained from the point view of their molecular structures based on the first-principle simulations (i.e. intrachain electrical conductivity) and degree of crystallinity gained from XRD (i.e. interchain electrical conductivity). A tunable room-temperature magnetoresistance (MR) and a controllable negative permittivity are discovered in the copolymers of aniline with different types and contents of PDAs.

Key words aniline, phenylenediamine, copolymer, magnetoresistance, negative permittivity

Session: Meta-Composites

Presenting Type：Oral–Invited

Chiral materials to induce broadband microwave absorption and multi-spectral photonic manipulation

Lingxi Huang、Yuping Duan*
Dalian University of Technology

Chirality, in which electro–magnetic character that asymmetric polarization is expected to realize broadband absorption for microwave absorption materials (MAMs). Herein, inspired by the microstructure of nepenthes, we report a scalable approach for fabricating hierarchical–chiral helical carbon fibers with broadband microwave absorption as–well–as multispectral chiral manipulation. The chiral potential barriers were established by applying helically distributed stress to the fiber, which induce helical electric dipoles via positive and negative charges accumulated at the potential barriers. The states of polarization loss by Debye relaxation were 2, 3, and 4 in the samples with achirality, single–chirality, and dual–chirality, respectively; the polar vector of achiral electric dipoles was transformed into pseudovectors through chiral potential barriers to improve the synergistically magnetic loss, and the grade of chirality was quantified based on symmetry breaking theory. The single–chiral fibers reached strongest absorption peak value of −30.67 dB at 2.96 GHz (carbon content was 50ωt%), and the dual–chiral fibers achieved effective absorption bandwidth (RL ≤ −10 dB) of 8.8–18 GHz. In addition to microwaves, the chiral photonic manipulation was played role in near ultraviolet and visible spectra. Present discovery points to a pathway for using chiral model to open up new microwave absorption mechanism and integrated application.

Key words microwave absorption, chiral polarization, hierarchical helical materials, bionics.

Session: Meta-Composites

Presenting Type: Oral-Invited

Regulation of RF epsilon-near-zero in composites

Qing Hou*[1]、Peitao Xie[2]、Kai Sun[3]、Runhua Fan[3]
1. University of Shanghai For Science and Technology
2. Qingdao University
3. Shanghai Maritime University

Dielectric materials are basic materials in electromagnetic fields such as wave transmission, capacitors, and waveguides. epsilon-near-zero properties have important potential applications in electronic devices, information transmission and other fields due to their extraordinary response characteristics such as high directional radiation effect, tunnelling effect and high transmission rate. In this work, we present the realisation and precise tunning of epsilon-near-zero by controlling the carrier concentrations and enhancing the electron mobility.

Key words epsilon-near-zero; composites; carrier concentrations

Session: Meta-Composites

Presenting Type: Oral-Invited

RF epsilon-near-zero in percolative composites

Qing Hou*[1]、Peitao Xie[2]、Kai Sun[3]、Runhua Fan[3]
1. University of Shanghai For Science and Technology
2. Qingdao University
3. Shanghai Maritime University

Dielectric materials are basic materials in electromagnetic fields such as wave transmission, capacitors, and waveguides. epsilon-near-zero properties have important potential applications in electronic devices, information transmission and other fields due to their extraordinary response characteristics such as high directional radiation effect, tunnelling effect and high transmission rate. In this work, we present the realisation and precise tunning of epsilon-near-zero by controlling the carrier concentrations and enhancing the electron mobility.

Key words epsilon-near-zero; composites; carrier concentrations

Session: Meta-Composites

Presenting Type: Oral-Onsite

Design and properties of multi-phase mechanical metamaterials

Junjie You、Sha Yin*
Beihang University

Strong and tough mechanical metamaterials are highly demanded in engineering application. Nature inspired dual-phase metamaterial composites was developed and examined, by employing architectured lattice materials with different mechanical properties respectively as the constituent matrix and reinforcement phases. Then, the reinforcement phase was incorporated into the matrix phase with specific patterning. The composite metamaterials were simply fabricated using additive manufacturing. From quasi-static compression tests, the strength and toughness could be simultaneously enhanced after the addition of reinforcement phase grains. Through simulation modeling, effects of dual-phase distribution, elementary architecture, parent material and defects on mechanical properties of dual-phase mechanical metamaterials were investigated. The results shown that the dual-phase distribution pattern affected the distribution of shear bands, lattice fracture toughness, and the energy dissipation during the phase boundary slip. Meanwhile, defects could also guide the deformation mode and help protect the functional phase therein. Additionally, enhancing reinforcement and connection phases, could dramatically improve mechanical properties and energy absorption. Accordingly, the designing rationale for dual-phase metamaterial composites was proposed, and results in this study provided a novel pathway for multi-functional architectured metamaterials.

Key words Mechanical metamaterials, Bioinspired design, Toughening mechanism, Additive manufacturing, Multi-functionality

Session: Meta-Composites

Presenting Type：Oral-Onsite

Achieving wave absorbing and load bearing integrated sandwich composites with metamaterial absorbers embedded

Lan Yao*、Xinyi Ruan、Jiahua Yang、Yiping Qiu
Donghua University

To achieve the wave absorbing and load bearing integrated composite materials, the metamaterial absorber was designed and the simulated results including normalized impedance, permittivity and permeability showed that it had metamaterial characteristics. The designed metamaterial absorber was fabricated according to the simulated sizes and then integrated into the sandwich composite to form wave-absorbing composite structure. In the composite structure, the upper and bottom layers were glass fiber epoxy and carbon fiber epoxy composites respectively. The middle three layers were the aformentioned metamaterial absorber sandwiched by the two Polymethacrylimide (PMI) foams. Three types of composites were finally achieved including the single-band, double-band and broad-band composite materials. The thickness of the upper layer foam was optimized among 1mm, 2mm and 3mm in the single-band wave-absorbing composite, and 1mm was finally determined. The absorptivity of the three types of composites were measured by the free space method. The results showed that all the composites had the absorptivities higher than 90%, showing the design was effective. For the broad-band composite, the maximum value of absorptivity reached as high as 99.91% in 8.25-11.61 GHz frequency range. Moreover, in the single-band wave-absorbing composite material, it was found that the incident angle had great influence on the absorptivity. Also, the mechanical properties including tensile and bending properties of the composites were tested and the significant analysis was used for comparison. SEM was used for detecting the after-fracture cross-sectional morphology of the composites.

Key words Metamaterial absorber; sandwich composites; wave absorbing; mechanical properties; absorptivity;

Session: Meta-Composites

Presenting Type: Oral-Onsite

Mie-resonant thermally tunable all-dielectric metamaterials with high-temperature tolerance based on strontium titanate

Runni Zhao[1]、Yongzheng Wen*[1]、xiaobo Wang[2]、Jun Zhou[3]、Weijia Luo[1]、Chen Wang[1]、Shiqiang Zhao[1]、Yichen Wang[2]、Kaixin Yu[1]、Xiaoxuan Peng[1]、Ruiqi Liang[1]、Ji Zhou[1]

1. State Key Laboratory of New Ceramics and Fine Processing, School of Materials Science and Engineering, Tsinghua University
2. Research Center for Metamaterials, Wuzhen Laboratory
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Metamaterials, initially proposed by Veselago in 1967, were experimentally confirmed three decades later and have since attracted significant attention. However, their function is typically difficult to adjust after fabrication, limiting their practical application. To address this challenge, semiconductors, transparent conducting oxides, ferroelectric materials, liquid crystals, graphene, phase change materials, pin diodes, varistors and other integrated components have been introduced into the design of metamaterials. However, these methods often fail in extreme environments, such as high-temperature or strong oxidizing environments, due to material destruction. As a typical functional oxide dielectric ceramic, strontium titanate (STO) has a high melting point, temperature-sensitive and high dielectric constant, low dielectric loss, and excellent chemical stability, which is used in this work to construct thermally tunable metamaterials that are resistant to high temperatures. In the structural design of these metamaterials, Hole arrays are employed to achieve a transmission peak located at 9.6 GHz with a transmittance of 70% at room temperature. As the temperature rose gradually from room temperature, the tuning bandwidth could exceed 1 GHz, while the peak transmittance increased gradually. These metamaterials have good high-temperature resistance and can withstand temperatures as high as 1200°C without any structural or performance damage. The study's results are expected to facilitate the development of metamaterials constructed solely from insulating oxide ceramics and offer ideas for the development of tunable metamaterials in extreme environments. These thermally tunable metamaterials show promise for applications in microwave communications, radar detection, and high-sensitivity detection. In addition, their extremely simple structural design helps facilitate integration with other electromagnetic systems.

Key words metamaterial, all-dielectric, thermally tunable, high-temperature tolerance

Session: Meta-Composites

Presenting Type: Oral-Onsite

Single-Step-Lithography Micro-Stepper Based on Chiral Mechanical Metamaterial

Xiaojun Tan*
Northwestern Polytechnical University

Stepper motors and actuators are among the main constituents of control motion devices. They are complex multibody systems with rather large overall volume due to their multifunctional parts and elaborate technological assembly processes. Miniaturization of individual parts is still posing assembly problems. In this paper, a single-step lithography process to fabricate a micro-stepper engine with an accurate micrometric rotation axis and an overall sub-millimeter size is demonstrated. The device is based on the frictional contacts and chiral metamaterials to get rid of the dependence on the accuracy of parts. The functional aspects of fabricated samples are discussed for many rotation cycles and for different frictional surfaces.

Key words Single-Step-Lithography, Micro-Stepper, Chiral Mechanical Metamaterial

Session: Meta-Composites

Presenting Type：Oral-Onsite

Optical wood with switchable solar transmittance for all-round thermal management

Hongbo Xu*、Hongbo Xu
Harbin Institute of Technology

Technologies enabling passive daytime radiative cooling and daylight harvesting are highly relevant for energy-efficient buildings. Despite recent progress demonstrated with passively cooling polymer coatings, however, it remains challenging to combine also a passive heat gain mechanism into a single substrate for all-round thermal management. Herein, we developed an optical wood (OW) with switchable transmittance of solar irradiation enabled by the hierarchically porous structure, ultralow absorption in solar spectrum and high infrared absorption of cellulose nanofibers. After delignification, the OW shows a high solar reflectance (94.9%) integrated over the solar spectrum (250-2500 nm) and high broadband emissivity (0.93) in the infrared region (2.5-25 μm). Owing to the exceptional mass transport of its aligned cellulose nanofibers, OW can quickly switch to a new highly transparent state following phenylethanol impregnation. The solar transmittance of optical wood (OW-II state) can reach 68.4% from 250 to 2500 nm. The switchable OW exhibits efficient radiative cooling to 4.5 °C below ambient temperature in summer (81.4 W m-2 cooling power), and daylight heating to 5.6 °C above the surrounding temperature in winter (heating power 229.5 W m-2), suggesting its promising role as a low-cost and sustainable solution to all-season thermal management applications.

Key words radiative cooling,Optical wood with switchable

Hangzhou, PR China 25-28 April, 2023

Session: Meta-Composites

Presenting Type: Oral-Onsite

Designing carbon fibre reinforced composite lattice with good thermal-dimensional stability using additive manufacturing

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High thermal-dimensional stability is crucial for high precision applications, e.g., unmanned monitoring of Moon surface environment, etc. This study designs a novel carbon fibre reinforced plastic (CFRP) composite planar lattice with high thermal-dimensional stability using additive manufacturing. The CFRP composite lattice is designed with a continuous carbon fibre reinforced polyamide (PA) central cross-lattice interlocked with four short carbon fibre reinforced PA outer-strips, fabricated via fused filament fabrication (FFF). Finite element analysis (FEA) models are established using continuum shell elements with thermo-elastic constitutive relations to describe the thermal behaviours of the layup characteristics introduced by FFF. Specific experiments were performed to validate the design and modelling results. The results indicate that the CFRP composite lattice presents high thermal-dimensional stability, where the effective CTEs are 4.6×10−6/°C by experiments and 5×10−6/°C by FEA, respectively. Mechanism analyses based on FEA show that, a triangular mechanism between the central cross-lattice and outer-strips and a central cross-lattice made of rotated cross-ply of unidirectional CFRP, contribute to the high thermal-dimensional stability of the composite lattice. The outcomes demonstrate the capability enabled by additive manufacturing using continuous and short carbon fibres in constructing structural parts with high thermal-dimensional stability.

Key words Continuous carbon fibre; 3D printing; finite element analysis; coefficient of thermal expansion; thermal-dimensional stability.

Session: Meta-Composites

Presenting Type: Oral-Virtual Platform

Magnetic Medium Metasurface Absorber for Ultra-wideband Microwave Absorption

Jiangyong Liu、Yuping Duan*
Dalian University of Technology

Microwave absorbing materials can convert microwave energy into thermal energy or other forms of energy, so the threat of electromagnetic pollution can be fundamentally eliminated. However, due to the limitation of Planck-Rozanov limit, the traditional Salisbury microwave absorbing materials based on different loss mechanisms, multi-layer Jaumann structure design, and metasurface absorbers are difficult to achieve effective absorption (absorption rate reaches 90% and above) in a wider frequency, especially in the range of 2-18 GHz. Therefore, considering the stability of traditional absorbing materials and the advantages of flexible and reconfigurable design of metasurface, an effective absorption structure with almost 2-18 GHz full-band was designed, and the attenuation mechanism of microwave energy was discussed from several perspectives. This work provides a new way to widen the effective absorption bandwidth of microwave absorbing structural materials.

Key words microwave, metasurface absorber,

Session: Meta-Composites

Presenting Type: Oral-Virtual Platform

Crossover in electrical frequency response through an insulator-metal transition

Zaixin Wei、Yao Liu*
Shandong University

The development of negative permittivity materials in multifunctional applications requests expansion of their operating frequency and improvement of stability of negative permittivity. Low electron density is beneficial to reduce plasma frequency so that negative permittivity is achieved in kHz region. Negative permittivity achieved by percolating composites is restricted in practicality due to its instability nature at high temperatures. To achieve temperature-stable negative permittivity in kHz region, mono-phase La1-xBaxCoO3 ceramics were prepared, and the transition from dielectric to metal was elaborated in the perspective of electrical conductivity and negative permittivity. The plasma-like negative permittivity is attained in kHz region, which is interpreted by the collective oscillation of low electron density. The temperature-stable negative permittivity is based on the fact that the plasmonic state will not be undermined at high temperatures. In addition, zero-crossing behavior of real permittivity is observed in La0.9Ba0.1CoO3 sample, which provides a promising alternative to designing epsilon-near-zero materials. This work makes the La1-xBaxCoO3 system a source material for achieving effective negative permittivity.

Key words La1-xBaxCoO3 ceramics, Insulator-metal transition, Negative permittivity, Electrical conductivity

Hangzhou, PR China 25-28 April, 2023

Session: Meta-Composites

Presenting Type: Oral-Virtual Platform

Multilayer polymer dielectric material with simultaneous high dielectric constant and high breakdown strwngth

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In recent years, polymer dielectric materials have attracted increasing attention due to their ultra-high power density and fast charge-discharge capability. However, the random dispersion of high dielectric constant nanoparticles leads to a sharp drop in the breakdown strength of the polymer films. High dielectric constant and high breakdown strength are difficult to improve at the same time. To balance the requirements of high dielectric constant and high breakdown strength, we prepared multilayer polymer dielectric materials with improved comprehensive dielectric properties. 1. The dielectric constant of the polymer films is improved by introducing high dielectric constant ceramics, and the breakdown strength is further improved by hot pressing the linear polymer with high breakdown strength. 2. Synergistically improve the dielectric constant and breakdown strength of polymer films by introducing ultra-low content of metal interlayers.

Key words Polymeric dielectric materials; Multilayer structure; Dielectric constant; Breakdown strength

Session: Meta-Composites

Presenting Type: Oral−Virtual Platform

Amorphous Carbon from Phthalonitrile Resin with Magnetoresistance and Negative Permittivity

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In this work, an amorphous carbon prepared from phthalonitrile (PN) resin/4-(4-aminophenoxy) phthalonitrile/4-(2-allylphenoxy) phthalonitrile with controllable magnetoresistance (MR) and negative permittivity is reported. A series of carbonized PN resins with dominating phthalocyanine structure are fabricated under different annealing temperatures. The samples exhibit the semiconducting characteristics and their MR and permittivity properties are investigated systematically. We have exploited the degree of disorder obtained from Raman spectra and $C(sp^2)/C(sp^3)$ ratios from X-ray photoelectron spectroscopy (XPS) to analysis the charge carrier transport behavior of these carbonized PN resins.

Key words magnetoresistance, negative permittivity, phthalonitrile resin, amorphous carbon, semiconductor, phthalocyanine

Session: Meta-Composites

Presenting Type: Oral-Virtual Platform

Modular mass diffusion metamaterials

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The outstanding abilities of metamaterials to manipulate physical fields are extensively studied in various wave-based fields including electromagnetic field and acoustic field. Recently, metamaterials' design concepts and methods have been extended to non-waved diffusion field. Chemical diffusion behavior plays a key role in many fields of science and engineering. However, mass diffusion metamaterials, with the ability to manipulate diffusion with practical applications associated with chemical and biochemical engineering, have not yet been experimentally demonstrated. In this work, ion cloaking, concentrating, and selection in liquid solvents are verified by both simulations and experiments, and the concept of a "plug and switch" metamaterial is proposed based on scattering cancellation to achieve switchable functions by plugging modularized functional units into a functional motherboard. Plugging in any module barely affects the environmental diffusion field, but the module choice impacts different diffusion behaviors in the central region. Cloaking strictly hinds ion diffusion, and concentrating increase diffusion flux, while cytomembrane-like ion selection permits the entrance of some ions but blocks others. In addition, these functions are demonstrated in special applications like the catalytic enhancement by the concentrator and the protein protection by the ion selector. This work not only experimentally demonstrates the effective manipulation of mass diffusion by metamaterials, but also shows that the "plug and switch" design is extensible and reconfigurable. It facilitates novel applications including sustained drug release, catalytic enhancement, bioinspired cytomembranes, etc.

Key words metamaterials

Session: Meta-Composites

Presenting Type: Oral-Virtual Platform

Metamaterials with excellent microwave absorption and heat shielding performance

Huifang Pang、Hao Lei、Yuping Duan*
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In view of the practical demands and mechanistic conflicts between microwave absorption and heat shielding compatibility, a double-layer composite coating based on moth-eyed hexagonal anti-reflective structure is prepared by combining the advantages of metamaterials and coatings. The hexagonal periodic sequential configuration of the upper infrared shield layer (IRSL) can break the continuity of the electric field, induce a networked concentration of the surface current and internal electric field of the microwave absorption layer (MAL), thus optimize the impedance matching and counteract the attenuated absorption performance due to the high dielectric IRSL. In addition, the emissivity of IRSL can be tuned artificially by changing the filler composition and particle size. The structural double-layer composite coatings have a maximum effective absorption (reflection loss<-10dB) bandwidth of 7.4 GHz in the S-Ku bands at deep subwavelength thickness, while the infrared emissivity is 0.292. This work provides a novel approach for multispectral modulation in the field of advanced compatible protection systems.

Key words Microwave absorbing performance, infrared stealth, metamaterials, double layer

Session: Meta-Composites

Presenting Type: Oral-Virtual Platform

Negative Permittivity Behaviors Derived from Dielectric Resonance and Plasma Oscillation in Percolative Bismuth Ferrite/Silver Composites

Pengtao Yang、Kai Sun*
Shanghai Maritime University

Negative permittivity of materials can be obtained by plasma oscillation or dielectric resonance, but the relationship between these two negative permittivity behaviors has been neglected. Combining the advantages of two negative permittivity behaviors, the negative permittivity can be more tunable and is expected to realize epsilon-near-zero behavior. In this work, percolative bismuth ferrite/silver composites with different contents of Ag were successfully fabricated by a simple solid-state sintering method. With the addition of Ag, the Lorentz-like and Drude-like negative permittivity behaviors were successively observed in bismuth ferrite/silver composites. The reasons for the two types of negative permittivity behaviors are dielectric resonance and plasma oscillation, respectively. Further investigation revealed that the synergistic effect of dipole resonance and free electrons led to a change of resonance frequency, a decrease of magnitude, and a transition of two negative permittivity behaviors. Moreover, with the addition of Ag in percolative bismuth ferrite/silver composites, the electrical conductivity and thermal conductivity changed abruptly at a certain volume fraction, suggesting a percolation behavior.

Key words Negative permittivity, Plasma oscillation, Dielectric resonance

Session: Meta-Composites

Presenting Type: Oral−Virtual Platform

Colorful Daytime Radiative Cooling with Ultralow Absorption in the Visible Region

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Harbin Institute of Technolog

Coatings for passive radiative cooling applications are mostly based on the high reflection of solar light, and thus can hardly support any coloration without losing their functionality. In this work, we report a colorful daytime radiative cooling surface based on structural coloration. A designed radiative cooler with a bioinspired array of truncated SiO2 microcones is manufactured via a self-assembly method and reactive ion etching (RIE). The radiative cooler can exhibit multiple colors due to the varying scattering of the truncated microcone array between 400 nm and 760 nm while maintaining an average reflectance of 95% in the solar spectrum between 0.25-2.5 μm. Moreover, the bioinspired pattern suppresses the impedance mismatch between microcone array and air in the thermal infrared emission range, which greatly enhances the thermal emissivity. With high solar reflectance, combined with a very high thermal emissivity (ε) of 0.95 in the atmospheric window (8-13 μm wavelength range), the radiative cooler reached an estimated cooling power of ~143 W m-2 at an ambient temperature of 25 °C and a measured average sub-ambient temperature drop of 7.1 °C under direct sunlight. The great cooling performance of the designed colorful radiative cooler can be attributed to the bio-inspired pattern, which promotes both the aesthetics and cooling capacity of the daytime radiative cooler.

Key words Radiative sky cooling, Bioinspired surface, Thermal emissivity, Colorful radiative cooler, Refractive index matching

Session: Meta-Composites

Presenting Type: Oral-Virtual Platform

Epsilon-near-zero response derived from collective oscillation in the metacomposites with ultralow plasma frequency

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Shanghai Maritime University

Nowadays, negative parameters have been originally brought up and investigated in the electromagnetic metamaterial, where the epsilon-near-zero (ENZ) response was dominated by collective plasma frequencies and carrier concentration. However, the ENZ response frequency is missing at radio frequency region, leading to limitations on novel antennas and printed circuit board. Therefore, ternary copper/silica coated copper/polyvinylidene fluoride (Cu/Cu@SiO2/PVDF) composites were prepared to investigate the ENZ response at radio frequency. With increasing the content of Cu granules, a transition from positive to negative permittivity was observed in binary Cu/PVDF composites without any Cu@SiO2 granules, and the negative permittivity was related to the inductive character. On the contrary, the binary Cu@SiO2/PVDF composites without any uncoated Cu granules exhibit positive permittivity, showing a capacitive character. In fact, negative permittivity was derived from the collective plasma oscillation of percolative Cu networks, and Cu@SiO2 granules were responsible for diluting effective electron concentration of Cu. For the ternary Cu/Cu@SiO2/PVDF composite, negative permittivity value was suppressed to several orders of magnitude to -178 (measured at 1 MHz) and plasma frequency decreased to radio frequency region. Besides, with the construction of percolative Cu networks, the Ac conduction mechanism was transformed from hopping conduction to metal-like conduction. Based on the equivalent circuit analysis, capacitive and inductive characteristics were related to the ENZ response and demonstrated the permittivity transition for the ternary Cu/Cu@SiO2/PVDF metacomposites.

Key words metacomposites, epsilon-near-zero, negative permittivity, copper, percolative materials

Session: Meta-Composites

Presenting Type: Oral−Virtual Platform

Polarization Insensitive Hierarchical Metamaterial for Broadband Microwave Absorption with Multi-scale Optimization and Integrated Design

Tuo Zhang、Yuping Duan*
Dalian university of technology

The structural destructive resonance caused by the single resonant thickness of flat microwave absorbers results in narrow absorption, hindering the progress of stealth materials. Multi-scale optimization and metastructure design are effective in the improvement of multiple resonance thickness as well as wavefront transmission, allowing for greater freedom in the realization of broadband. Herein, hierarchical metamaterials constructed from pyramid metastructure composites and Huygens' metasurface on the basis of Fibonacci spiral element are reported here, with effective absorption bandwidth (reflection loss ≤ −10 dB) ranging from 4.8 to 18 GHz in terms of subwavelength thickness. The hybrid absorber also exhibits robustness with incident angle across 0°–50° for transverse magnetic polarization. The gradient impedance model based on pyramid composites comprising spherical carbonyl iron particles and graphene sheets will serve as a driver for the enhancement of the electromagnetic wave transmission and the booster of impedance matching. Huygens' resonance induces the magnetic field convergence effect due to the simultaneous balance of effective surface current and magnetic current, which facilitates the absorption of lossy composites for further broadening absorption bandwidth. This integrated design could be widely applied to other absorbent materials of choice.

Key words Hierarchical metamaterials; Huygens' metasurface; Broadband microwave absorption; Magnetic-dielectric lossy composites; Gradient impedance; Polarization insensitive

Session: Meta-Composites

Presenting Type：Oral-Virtual Platform

Defect-induced insulator-metal transition and negative permittivity in La1-xBaxCoO3 perovskite structure

Zaixin Wei、Yao Liu*
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The development of negative permittivity materials in multifunctional applications requests expansion of their operating frequency and improvement of stability of negative permittivity. Low electron density is beneficial to reduce plasma frequency so that negative permittivity is achieved in kHz region. Negative permittivity achieved by percolating composites is restricted in practicality due to its instability nature at high temperatures. To achieve temperature-stable negative permittivity in kHz region, monophase La1-xBaxCoO3 ceramics were prepared, and the transition from dielectric to metal was elaborated in the perspective of electrical conductivity and negative permittivity. The plasma-like negative permittivity is attained in kHz region, which is interpreted by the collective oscillation of low electron density. The temperature-stable negative permittivity is based on the fact that the plasmonic state will not be undermined at high temperatures. In addition, zero-crossing behavior of real permittivity is observed in La0.9Ba0.1CoO3 sample, which provides a promising alternative to designing epsilon-near-zero materials. This work makes the La1-xBaxCoO3 system a source material for achieving effective negative permittivity.

Key words Negative permittivity, insulator-metal transition

Session: Meta-Composites

Presenting Type: Oral−Virtual Platform

Highly efficient broadband achromatic microlens design based on low dispersion materials with single-step fabrication

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Metalens with achromatic performance offers a new opportunity for high-quality imaging with ultra-compact configuration, however, it suffered from complex fabrication processes and low focusing efficiency. Here, we propose an efficient design method for achromatic microlenses with wavelength scale by using materials with low dispersion, an adequately designed convex surface and the overall size. By considering the absolute chromatic aberration |df|, the relative amount of focal length shift and the numerical aperture NA, a microlens with a certain focal length can be realized through the map we outlined regarding the geometry features. Accordingly, the as-designed achromatic microlenses adopting low-dispersion fused silica were simply fabricated through single-step manufacturing of focused ion beam and the precise surface profiles were obtained. The fabricated microlenses manifest a high average focusing efficiency of 65% at visible wavelengths of 410 ~ 680 nm and exhibit excellent achromatic capability via the experiment of white light imaging. Moreover, it exhibits advantages of polarization-independent and near-diffraction limited. It demonstrates the effectiveness of our proposed achromatic microlens design approach, which expands the prospects of miniaturized optical such as virtual and augmented reality, ultra-compact microscopes, and biological endoscopy.

Key words metamaterials, low dispersion materials, broadband achromatic microlenses

Session: Meta-Composites

Presenting Type: Oral-Virtual Platform

Electromagnetic wave-absorbing metamaterials with Multicomponent coupled in Penrose tiling

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The powerful absorber is highly demanded in “5G wireless system” that can prevent electromagnetic radiation and interferences. Therefore, we designed the absorber with Penrose tiling as a quasiperiodic structure owning higher point group symmetry, which has advantages in enhancing expansion of beam propagates through the medium. Penrose tiling consisted of fat and thin rhombus with an area ratio of golden mean (τ=0.618), which is a marvelous proportion in mathematics, biological settings, and painting. It inspired us to explore the mechanism of electromagnetic response and impedance matching by combining binary components in Penrose absorber. When flake carbonyl iron in fat rhombus and spherical carbonyl iron in thin rhombus, the effective absorption bandwidth (Reflection loss ≤-10 dB) of which realize 9.32 GHz from 15.78 GHz to 6.46 GHz in 2mm thickness. The electromagnetic parameter can respond alternately with changing frequency at large scales based on the quarter wavelength cancellation model and mutually coupling in local unit cells from inhomogeneous absorber. The unique, aperiodic and anisotropic arrangement of Penrose tiling makes the vertices surround different environments, resulting in nonlinear response. The structure and component can synergistically improve impedance matching and broadband absorption as much as possible.

Key words Microwave absorber; Penrose tiling; Carbonyl iron; Localized coupling;

Session: Meta-Composites

Presenting Type: Oral-Virtual Platform

FeCoNiCrCu multi-principal element alloy powders with multi-temperature adaptability and broadband megahertz electromagnetic wave absorption

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The development of megahertz (MHz) electromagnetic wave absorbers with broadband absorption, multi-temperature adaptability, and facile fabrication methods remains a challenge. Due to compositional, microstructure, and manufacturability constraints, conventional soft magnetic materials are generally not able to simultaneously possess excellent and temperature-stable permeability for efficient and temperature-stable MHz electromagnetic wave absorption. The synergistic effect among the multiple components of multi-principal element alloy (MPEA) makes it a suitable candidate to satisfy the above conditions. In this study, nanocrystalline FeCoNiCrCu high-entropy alloy powders with large aspect ratio and thin intercrystalline amorphous layer were prepared by designing the preparation process and adjusting the chemical composition, maintaining temperature-stable permeability and electromagnetic wave absorption in a wide temperature range. The effective electromagnetic wave absorption bandwidth of the MPEA/SiO2 composites can be maintained at 523-600 MHz in the range of −50-150 °C. At the same time, according to the microstructure changes caused by composition adjustment, the temperature dependence of permeability was deeply studied. The phase transformation mechanism in the multi-stage mechanical alloying process was studied, and the microstructure of the MPEA was finally controlled. In addition, relying on the cocktail effect, FeCoNiCrCu MPEA powders also have high Curie temperature, excellent corrosion resistance and oxidation resistance. This work provides a simple and tunable strategy to design MHz electromagnetic absorbers with temperature stability, broadband and resistance to harsh environments.

Key words Electromagnetic wave absorption; Mechanical alloying; High-entropy alloys; Temperature-stable; Megahertz frequency range

Session: Meta-Composites

Presenting Type：Oral−Virtual Platform

Plasma oscillation of meta-composites at radio frequency

Zongxiang Wang、Runhua Fan*
Shanghai Maritime University

In this work, ternary copper/silica coated copper/polyvinylidene fluoride ($Cu/Cu@SiO_2/PVDF$) composites were prepared to investigate the ENZ response at the radio frequency. With increasing the content of Cu granules, a transition from positive to negative permittivity was observed in the binary Cu/PVDF composites, in which negative permittivity was related to an inductive character. On the contrary, the binary $Cu@SiO_2/PVDF$ composites without any uncoated Cu granules exhibit positive permittivity, showing a capacitive character. In fact, negative permittivity was derived from the collective plasma oscillation of percolative Cu networks, and $Cu@SiO_2$ granules were responsible for diluting effective electron concentration of Cu. For the ternary $Cu/Cu@SiO_2/PVDF$ composites, values of negative permittivity were suppressed to several orders of magnitude to -178 (measured at 1 MHz) and plasma frequency decreased to radio frequency about 10^6 rad/s. Besides, with the construction of percolative Cu networks, the Ac conduction mechanism was transformed from hopping conduction to metal-like conduction. Based on the equivalent circuit analysis, it showed that a permittivity transition was responsible for the capacitive to inductive character.

Key words Plasma oscillation；meta-composites；dielectric properties

Session: Meta-Composites

Presenting Type: Oral-Virtual Platform

Dielectric Enhancement Effect on Polyimide-Based Composites with Layered Structures

Qifa He、Runhua Fan*
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Epsilon-negative materials show fascinating prospects in electronic components, such as coil-free inductors, stacked capacitors, and resonators, while extremely high negative permittivity at radio frequency blocks their further applications in electronic devices. In order to realize weakly negative permittivity and explore its applications in the field of capacitance enhancements, we introduce silica (SiO_2) into multiwalled carbon nanotubes and polyimide (MWCNTs/PI) composites to acquire a negative permittivity layer (SiO_2/MWCNTs/PI), and design a trilayer structure (PI-SiO_2/MWCNTs/PI-PI) consisting of a negative permittivity layer sandwiched by two positive permittivity PI layers. It is demonstrated that the permittivity of the MWCNTs/PI composites transforms from positive to negative at the MWCNTs content of 4.0 wt% owing to low-frequency plasma oscillation. Meanwhile, a capacitance enhancement effect (5-fold higher than PI) and concurrently low loss tangent of ~0.018@10 kHz is observed in sandwich composites, which benefits from epsilon-negative materials are connected to epsilon-positive materials in series. The sandwich-structured composites containing an epsilon-negative middle layer in this work provide a promising method in the design of huge-capacity capacitors.

Key words metacompsites, negative permittivity, dielectric, sandwich composites

Session: Meta-Composites

Presenting Type: Oral-Virtual Platform

Inhomogeneous Dielectric Composites for Capacitive Energy Storage

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With the rapid miniaturization and high integration of electronic devices, increasing attention has been paid to the exploration of novel high dielectric constant (high-*k*) materials with further improved dielectric constants. Targeting at the long-standing dilemma in the field of dielectric materials that enhanced dielectric constant is always accompanied by suppressed breakdown strength, we herein suggest the construction of a novel class of high-*k* composites via designing macroscopic layered structures and microscopic fillers networks in traditional ferroelectric ceramic/polymer composites. Our recent researches demonstrated that, constructing layer-structured materials is an effective way to achieve substantially enhanced breakdown strength, while constructing fillers networks is capable of obtaining significantly improved dielectric constants.

Key words Inhomogeneous composites; Dielectric; Capacitive energy storage; Metacomposite

Session: Meta-Composites

Presenting Type: Poster

Sound insulation performance of membrane-type metamaterials combined with pyramidal truss core sandwich structure

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Recently, sandwich structures have been widely used in different field because of their good mechanical properties but these structures are weak in acoustic performance. In this paper, by combining the pyramidal truss core sandwich structure with membrane-type metamaterials, a new structure is proposed with both good mechanical properties and excellent acoustic performance at low frequency. An analytical model of the membrane-type metamaterials combined with the pyramidal truss core sandwich structure is developed to investigate the sound transmission loss (STL) performance of the structure. Finite element method (FEM) is also used to investigate the STL performance at low frequency. The effects of the additional block on the membrane, the tension of the membrane, the incident wave angle and the geometrical size of the structure to the STL of the structure are discussed.

Key words membrane-type metamaterials; sound transmission loss; pyramidal truss core

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Invited

Functional fillers for forming photodegradable plastics with self-indicating stable stage

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Adding photocatalytic functional fillers to the plastics can convert the traditional non-degradable plastics to photodegradable plastics, which can alleviate the plastic pollution problems. Nevertheless, the performance of the photocatalyst cannot be delayed resulting in unstable performance of the plastics during plastics' shelf life, and there is no color changing to indicate whether the photocatalytic performance starts or not. These problems hinder the industrial application of photodegradable plastics. In this study, a new type of photocatalyst as a functional filler has been proposed. The functional filler possesses delayed onset of performance under irradiation. The periods before and after the onset of the performance are named as stable stage and active stage, respectively. The color of the photocatalyst changes from blue/brown to white when the photocatalyst changes from stable stage to active stage. The functional filler is prepared via surface modification of TiO_2 with polyiodide complex. The functional filler is added to low density polyethylene (LDPE) forming photodegradable LDPE (P-LDPE). When the mass ratio of the functional filler to LDEP is 0.02:1, the P-LDPE possesses stable stage and color changing point of 32 h, which corresonds to ~30 d of irradiation in the environment at 20 °C. The length of the stable stage is tunable. Characterizations are conducted to analyse the mechanism of simultaneous control for photocatalytically generated electron-hole pair and color. The structure and chemical state of iodine element plays an important role in tuning the recombination and separation of photogenerated electrons and holes. The structure evolution of the polyiodide complex during irradiation is a prerequisite to make the color changing happen simutaneously with active stage initiation. This study proposes a new photocatalyst as functional filler to increase the degradability of plastic in a self-indicating and delayed-onset way for the first time.

Key words photodegradable plastics; functional filler; photocatalyst; self-indicating; stable stage

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Invited

2D Nanomaterial Nanocomposites for Electromagnetic Interference Shielding

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Lightweight polymer nanocomposites with excellent processability and chemical resistance are considered as promising electromagnetic interference (EMI) shielding materials. The EMI shielding performance of polymer nanocomposites greatly depends on electrical conductivity and the distribution of conductive nanomaterials in the matrices. Yet, it still remains a great challenge to finely construct electrically conducting networks formed with MXene and other conductive fillers in the polymer matrices, and we addressed the relevant key scientific issues from three aspects: i) Several approaches for modulating the filler dispersion and matrix-MXene interfaces are developed for high-performance electrically conductive polymer nanocomposites; ii) Proposed some routes for constructing three-dimensional conductive MXene architectures for efficient EMI shielding and other multifunctionalities; iii) Multi-interface structures are designed for the integration of high EMI shielding performance and lightweight feature for various MXene films/fabrics. We will summarize the recent research advances, and forecasts the future challenges and opportunities of polymer nanocomposites for electromagnetic shielding.

Key words 2D Nanomaterials; Polymer nanocomposites; Graphene; Two-dimensional transition metal carbon/nitride (MXenes); Electromagnetic interference shielding;

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Session: Multi-Functional Smart Composites

Presenting Type: Oral−Invited

Ice-templated assembly of polymeric porous and composite materials with bioinspired architecture and functionality

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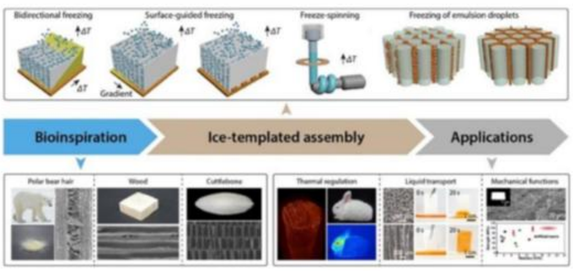
Biological materials, such as polar bear hair, wood, and cuttlebone, exhibit outstanding thermal and mechanical properties due to their hierarchical architectures. Specifically, polar bears can retain thermal homeostasis in the extremely cold Arctic due to outstanding thermal insulation property of their porous hairs; wood exhibits mechanical strength and low density due to its hierarchically aligned porous architecture; cuttlebone can resist large hydrostatic pressure in the deep-sea environment due to its mechanically efficient porous structure with lamellar septa connected by asymmetrically S-shaped walls. Obviously, the hierarchical architecture is crucial for the excellent performance of biological materials. Inspired by these natural design motifs, bioinspired materials with hierarchical architectures have been widely explored for various applications. As a controllable, versatile, scalable, and environmental-friendly process, ice-templating represents an effective approach to fabricating bioinspired structural materials. In recent years, we have conducted comprehensive studies on the mechanism of ice-templating approach and provided a rich toolbox based on this technique to meet various manufacturing demands. First, bidirectional freezing guided by dual temperature gradients was developed to generate long-range nacre-mimetic lamellar architectures. Next, complex hierarchical lamellar architectures were constructed through freezing on engineered cold surfaces with either wettability gradient or grooved pattern. Additionally, "freeze-spinning" technique was developed to realize continuous and large-scale fabrication of fibers with aligned porous architecture mimicking polar bear hair. Finally, the applicability of unidirectional ice-templating technique was broadened from soluble to insoluble polymeric materials. These techniques have been widely used to fabricate a series of polymer porous and composite materials with bioinspired architectures, which hold great potential in thermal regulation, liquid transport, and mechanical functions for wide applications in various fields.

Key words ice-templating; biological materials; porous and composite materials; hierarchical architecture; multifunctionality



Session: Multi-Functional Smart Composites

Presenting Type：Oral−Invited

Simulation and Electro-mechanical Performance of Cylindrical Composite Structural Batteries with Multifunctional Solid-state Electrolytes

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A structural lithium-ion battery is a material that can carry load and simultaneously be used to store electrical energy. We propose for the first time the fabrication of cylindrical structural batteries based on solid polymer electrolyte membrane. With the successful fabrication of solid polymer electrolyte membrane of high ionic conductivity, metal sheets supported solid state battery core can be integrated with fiber reinforced polymer composites by layer stacking and subsequent co-curing to produce lightweight composite structural batteries, which has achieved unprecedented compression strength and can still operate a LED when subjected to compressive stress of ~51 MPa.
Experimental and simulation research both demonstrate the effect of the solid state battery core number on the ultimate compression strength. Meanwhile, the interfacial bonding between the metal sheets supported solid state battery core and fiber reinforced polymer composites plays an important role in the achievable co5mpression strength of cylindrical structural batteries. It is interesting to notice in the experiment that the two LEDs lit by cylindrical structural batteries distinguished in a sequence, which indicates the inhomogeneous stress distribution at compression, which has also been confirmed by simulation. There exists a critical compressive strength beyond which the stress distribution in the solid state battery core transforms from a homogeneous state to an inhomogeneous state. Meanwhile, we infer from the inhomogeneous state that there may exist hotspots at which the failure of cylindrical structural batteries is triggered.
The successful operation of a ducted fan by the as-obtained cylindrical structural batteries not only represents the first report on the one-step fabrication of non-planar structural batteries, but reflects the application potential of the strategy in developing structural batteries for aviation and aerospace. This study shows that composites technology combined with solid state battery represent a promising path to mechanically strong structural batteries.

Key words Fiber reinforced polymer composites; Structural batteries; Solid polymer electrolyte; Compression strength; Stress.

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Functional Nanofibrous Aerogels: Progress in Materials, Properties, and Applications

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Electrospun nanofibers, as the forefront of advanced fibrous materials, hold extraordinary potential applications ranging from environmental, energy to biology owing to their integrated advantages of fine diameter, extremely high aspect ratio, and ease of scalable synthesis from various materials. Despite their outstanding potential, the major problem associated with electrospun nanofibers is their anisotropic lamellar deposition character, which leads to the bottlenecks in further improving the thickness and porosity of current electrospun nanofibrous materials. Alternatively, three-dimensional nanofibrous aerogels (NFAs) with both high porosity and excellent compressive resilient might open up the possibility of solving the above problem and expand the applications of electrospun nanofibers; however, creating such NFAs has proven extremely difficult. Herein, we demonstrate a novel strategy to create fibrous, isotropically-bonded elastic reconstructed (FIBER) NFAs with a hierarchical cellular structure and superelasticity by combining electrospun nanofibers and the fibrous freeze-shaping technique. Our approach causes the intrinsically lamellar deposited electrospun nanofibers to assemble into elastic bulk aerogels with tunable densities and desirable shapes. We have carried out a systematic study towards the controllable fabrication, hierarchical structure regulation, structure-activity relationships to achieve the enhancement of performance in terms of various applications. 3D multifunctional electrospun ceramic and polymeric nanofibrous aerogels with high porosity, tunable densities and desirable shapes were successfully fabricated, the resulting FIBER NFAs exhibit densities of > 0.12 mg cm^{-3}, rapid recovery from deformation, slight plastic deformation with 14.5% after 1000th cyclic compression at a large ε of 60%, efficient energy absorption and multifunctionality in terms of the combination of thermal insulation, sound absorption, warmth retention, emulsion separation and elasticity-responsive electric conduction. Additionally, the newly developed ceramic nanofibrous aerogels possess low thermal conductivity (~0.025W m^{-1} K^{-1}) and intriguing temperature-invariant superelasticity to 1100^{o}C. The successfully synthesis of such fascinating FIBER NFAs provide a new insight into the design and development of multifunctional NFAs for various applications.

Key words aerogels, nanofibers, electrospinning, superelastic, multifunctionality

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Ultrarobust functional composites enabled by noncovalent assembly-mediated solid-state drawing for energy harvesting

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Developing clean and sustainable energy technology is imperative to alleviate the impending energy crisis. Nowadays, polymer-based energy composites have attracted increasing attention owing to their superiority in lightweight, corrosion resistance, ease of processing, and mechanical flexibility. However, due to the limited morphological/structural regulation within narrow length scale, most existing energy materials suffer from a long-standing challenge to achieve the balance between energy harvesting performance and mechanical robustness. Here, we propose a noncovalent assembly-mediated solid-state drawing strategy for the fabrication of high-performance polymeric energy composites. Through introducing dynamic interfacial interactions between tannic acid-functionalized liquid metals (LMs) and oxidized polyethylene wax-modified ultrahigh molecular weight polyethylene (UHMWPE) matrix, the deformable LMs nanoparticles can be uniformly programmed in the rigid UHMWPE nanofiber skeleton during solid-state drawing. The resultant composite exhibits an unprecedented combination of strong broad-band light absorption (96.9–99.3%), excellent photothermal conversion ability (η_{pt} = 77.3 %), remarkable mechanical property (tensile strength of 283.7 MPa, which can lift 200 000 times its own weight), and long-term structural reliability (bearing 100 000 bending cycles), which can realize powerful and durable solar-heat-electricity conversion when integrated with a thermoelectric generator. Furthermore, through introducing noncovalent assembly network between glycine modified-MoS_2 nanosheets and polyvinylidene fluoride (PVDF), the strong intermolecular interactions and confinement between 2D nanosheets and PVDF dipoles can aggressively induce the self-polarized β-phase transition of PVDF in a favorable direction. The resulted nanocomposite without extra electrical treatment exhibits remarkable piezoelectric performance (d_{33} =24.9 pC N^{-1}) and extraordinary mechanical performance (tensile strength of 213.3 MPa, toughness of 85.8 MJ m^{-3}), which can realize efficient mechanical energy harvesting from human motions and self-powered sensing applications. This strategy opens an avenue toward the large-area compliant and low-energy manufacturing of diverse high-performance energy materials and devices.

Key words nanocomposites; energy harvesting; noncovalent assembly; solid-state drawing

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Super-wettable and electrically conductive nanofiber composites for smart sensing

Jiefeng Gao*
Yangzhou University

Electrically conductive nanofiber composites (CNCs) have potential applications in wearable sensing and hence attracted great attention from both academia and industry, due to their flexibility, breathability, easy processing and tunable conductive network. It remains great challenge to develop multi-functional, durable and wearable CNC sensors that can work reliably in some harsh environment (e.g., moisture and even corrosive conditions). In our work, we prepared a series of superhydrophobic CNCs with hierarchical micro/nano structures by assembling conductive nanofillers such as carbon nanotubes, reduced graphene oxide and MXene nanosheets on nanofiber surface. The unique core-shell structure can maintain the flexibility and stretchability while improve the tensile strength of the elastomer nanofibrous membranes. The strong interfacial interaction and hence excellent durability can be achieved by rational interface design. The obtained CNCs usually possess outstanding photo-thermal and Joule heating effect, which can extend the applications of the materials. When the CNCs are used for strain sensing, the influence of the nanofiller dimension on the strain sensing performance are investigated. Some strategies are also proposed to improve the electrical conductivity and sensitivity of the strain sensor. The strain sensing mechanism is revealed based on the conductive network evolution. The multi-functional CNCs can be used to detect different body motions and environment temperature, and can work in some corrosive conditions. We have also done some primary work about the CNCs with unidirectional water transportation behavior.

Key words Nanofiber composites ; Strain sensing; Temperature sensing; Conductive network; Superhydrophobicity;

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Left-handed behaviour of ferromagnetic microwire composites

Hua-Xin Peng*
Zhejiang University

Ferromagnetic microwires are feasible building blocks to constructfor the construction ofelectromagnetic composites with tunable left-handed response towards external stimulus. In this work, a typical left-handed signature of the transmission window was revealed in Co-rich microwires ranging from 9.3 to 10.4 GHz, which arised from the ferromagnetic resonance under a constant DC magnetic field of 8 Oe.

Key words Ferromagnetic microwire

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Polyvinylidene fluoride piezoelectric yarn for real-time damage monitoring of advanced 3D textile composites

Jingyu KANG、Tao Liu、Wei Fan*
Xi'an Polytechnic University

Real-time online damage monitoring is essential and critical to the safe service of advanced fibers reinforced composites. This paper firstly reports a piezoelectric yarn sensor based on electrospinning and 2D braiding technology, to monitor advanced 3D textile composites, which can generate a voltage of about 1 V and sustain long-term cycles at a high frequency of 4 Hz. The polyvinylidene fluoride (PVDF) piezoelectric yarn is embedded into 3D orthogonal composites to realize the online health monitoring of advanced 3D textile composites through the three-point bending test. Following the bending fatigue and modal tests, the PVDF piezoelectric yarn sensor proposed in this work enables long-term, low-frequency, high-frequency, and stable monitoring, thus showing good potential and wide application in damage monitoring as a piezoelectric sensor in composites.

Key words A. Carbon fibre; Textiles; Smart materials B. Fatigue; D. Mechanical testing; Process monitoring

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Biomimetic Multifunctional E-Skins Based on Hierarchically Structured Rubber Nanocomposites

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With the vigorous development of new technologies and new fields such as the Internet of Everything and 5G communication, the demand for flexible sensing devices is increasing. Due to their stretchability and conductivity, the application of conductive rubber nanocomposites in stretchable electronic devices has received a lot of attention from academia as well as industry. However, due to the lack of interaction between the conductive fillers and the matrix, the prepared rubber nanocomposites have poor mechanical stretchability, electrical properties and easy to damage. Here, a new method for large-scale preparation of multifunctional self-healing sensing rubber nanocomposites is established. A self-healing rubber matrix with high self-healing efficiency (93.98%) and short healing time (about 10 s) is fabricated by constructing multiple dynamic networks of ionic and hydrogen bonds between brominated natural rubber and histidine. And by constructing a three-dimensional isolated conductive network of graphene between the substrates, a self-healing sensing material with high sensitivity (GF=127) and wide monitoring range (maximum strain of 300%) is prepared. Furthermore, endowing biological skin with multiple functions, the biomimetic microcrack structure of phosphoric acid-doped polyaniline@cellulose nanocrystals conductive layer and the mechanoluminescent particle ZnS:Cu are introduced into a single material system. The fabricated sensing material can not only respond to stress multimodal, but also has an ultrafast (1.5 s), highly sensitive (ammonia concentration as low as 5 wt%) ammonia detection capability, achieving skin-like versatility. The bio-inspired multifunctional self-healing sensor demonstrates great potential for applications in E-skins, environmental monitoring robotic systems and other electronic devices.

Key words Rubber Nanocomposites, E-Skins, Sensor, Multifunction, Hierarchical structure

Session: Multi-Functional Smart Composites

Presenting Type：Oral−Onsite

Soft Composites under HyperGravity

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With the energetic development of aerospace and aviation industries of our country, it is a critical and onerous mission to protect the life and health of astronauts and aviators. It is already demonstrated in the real flight or centrifuge test that several living organisms would suffer large deformations, instability or even damages under extreme hypergravity environment. To overcome the shortcomings from those direct experimental measurements in the literature, the present project will establish a theoretical framework to investigate the deformation and surface instability phenomenon of composite soft materials or structures systems under hypergravity effect. In the meantime, a centrifuge platform is built to create hypergravity environment to conduct instability experiments on soft materials or multiphase flows. In addition, theoretical and numerical models is established for the movement of multiphase flow and large deformation of soft materials with hypergravity effect. Finally, the concept of soft composites is employed by inserting fibers or particulates into soft substrate, whose microscale parameters, such as dimension, geometrical layout and surface tension, etc., are tailored to study the effect on the deformation of soft composite materials with hypergravity effect. We hope the present project will provide new insights on the research and development of biomaterials for aerospace and aviation industries.

Key words Soft Composites; Multiphase Media; HyperGravity Effect

Session: Multi-Functional Smart Composites

Presenting Type：Oral-Onsite

Tissue Engineering Applications of Multifunctional Micro/Nano-Polymer Materials*

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Fuzhou University

The multifunctional micro/nano-polymer materials in this paper are mainly classified into multi stimuli-responsive materials, functional nanoparticles, and construction of their composite platforms. Among them, by introducing micro/nano probes with good conductivity, photothermal transformation ability, and sensitive biological components into the polymer substrate, multi stimuli-responsive materials can be widely used in the fields of smart sensors, tissue engineering, multi-component detection wearable device, and anti-tumor therapy. For example, modifications of pH, GSH and H_2O_2-responsive groups can be used to realize an on-demand release of antitumor drugs. Group modification of iridium complexes can be used as fluorescent probe to monitor hypochlorite and ferrous ions in vivo. Nanomaterials containing manganese, iron, and platinum can also realize integration of diagnosis and treatment based on imaging function. On the whole, multifunctional micro/nano-composite materials formed by compounding the multi stimuli-responsive polymer substrate with the nanomaterials can not only design the patterned bionic microstructure to regulate biological properties, but also organically combine functionalities of diagnosis, therapy, and repair through a minimally-invasive method, laying a solid foundation for extending applications of such novel polymer materials in the field of tissue engineering.

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Self-Healing Functional Elastomers for Flexible Devices

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Sichuan University

Intelligent materials and flexible devices are highly desired in the future Internet-of-Things applications. During their long service life, the irregularity in external stimuli and repetitive motions always result in unavoidable permanent damages, where the self-healing ability inspired by skin is indispensable and highly attractive. However, the introduction of supramolecular networks to achieve self-healing ability based on reversible dynamic noncovalent bonds usually leads to relatively low strength, while the conflict between high mechanical properties and high self-healing efficiency is still a great challenge. Herein, we propose interfacial supramolecular crosslinking strategy to improve the mechanical properties of self-healing materials while maintaining desired self-healing performance. For the construction of interfacial supramolecular crosslinking, fillers and polymer matrixes are usually modified separately and corresponding groups are introduced; then the desired supramolecular interactions are mainly concentrated at the interface during the assemble process. The collective effect of noncovalent interactions at the interface of fillers and polymer matrix produces a strong adhesive force, endowing the obtained self-healing materials with a series of advantages such as enhanced mechanical properties and excellent functional stability. This work may open up new opportunities for the design and fabrication of high-performance self-healable functional materials for various flexible devices.

Key words Self-Healing, Functional Elastomers, Interfacial Supramolecular Crosslinking

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

PVDF-based Polymer with High Dielectric Constant and High Polarization for Highly Ionic Conductive Solid-State Polymer Electrolytes

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The extremely low room-temperature ionic conductivity of solid-state polymer electrolytes (SPEs) ranging from 10^{-7} to 10^{-5} S/cm seriously restricts their practical application in solid-state lithium metal batteries (LMBs). Herein, a unique relaxor ferroelectric (RFE) polymer of poly(vinylidene fluoride-co-trifluoroethylene-co-chlorotrifluoroethylene) [P(VDF-TrFE-CTFE)] and a random P(VDF-TrFE) copolymer are first investigated as matrixs of SPEs. We find that the P(VDF-TrFE-CTFE) with an ultrahigh dielectric constant (ε_r) of 44 presents a stronger solvation ability towards lithium ions, which promotes the dissociation of $LiN(SO_2CF_3)_2$ (LiTFSI) to form more free charge carriers and enhance their mobility compared to the conventional PVDF with a low ε_r of 9. The P(VDF-TrFE-CTFE)-based SPEs show a much higher ionic conductivity of 3.10×10^{-4} S/cm at 25 °C and lower activation energy (0.26 eV) than PVDF electrolytes (1.77×10^{-5} S/cm and 0.49 eV). P(VDF-TrFE) that always shows a high polarity all-trans (TTTT) conformation also promotes the dissociation of LiTFSI, and endows P(VDF-TrFE) SPEs with remarkably enhanced ionic conductivity of 4.48×10^{-4} S/cm at 25 °C. The $LiNi_{0.8}Co_{0.1}Mn_{0.1}O_2$ (NCM811)/P(VDF-TrFE) SPEs/Li batteries present stable cycling at 1C and 2C at 25 °C while the controlled NCM811/PVDF SPEs/Li batteries exhibit a dramatical capacity decay. The Li/P(VDF-TrFE) SPEs/Li batteries stably cycles for nearly 2000 h without a short circuit. This work proposes a new strategy and opens a new research area to construct SPEs with high ionic conductivity by greatly increasing the dielectric constant and polarization of polymers.

Key words Solid-state polymer electrolytes, PVDF, dielectric constant, polarization, ionic conductivity

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Conductive polymer composites with segregated structure for improved electromagnetic interference shielding performance

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Conductive polymer composites (CPCs) with various electrical conductivity can be used in many vital areas such as anti-static, electromagnetic interference shielding, and lightning protection. Still, the content of conductive particles required by CPCs to establish a flawless conductive network is considerably high, which will lead to higher costs, increased density, and deterioration of mechanical and processing properties. Constructing a segregated structure endows CPCs with a perfect conductive network at extremely low conductive particle content. Based on the segregated structure, we have obtained high-performance antistatic and electromagnetic interference shielding composites through the coupling of molding temperature, pressure and flow field: (1) Using semi-solid phase molding method to limit the diffusion of conductive particles into the polymer and enhance the interfacial cohesiveness. The compressive strength and modulus of the segregated polystyrene/graphene composites are increased by 94% and 40% compared with conventional composites, while its electrical conductivity and electromagnetic interference shielding effectiveness (EMI SE) can reach 43.5 S/m and 45.1 dB, respectively. Relatively high electrical conductivity (117.0 S/m) and superior EMI SE (48.3 dB) are obtained in the polypropylene/carbon nanotube composites, while the tensile strength and modulus are increased by 74% and 130% compared with conventional composites. (2) A segregated polyurethane/carbon nanotube composite with continuous matrix is formed by 3D printing. When the conductivity and EMI SE reach 46.7 S/m and 37.8 dB, the tensile strength and elongation at break are increased by 389% and 1238% compared to conventional composites; (3) By adjusting the distribution of conductive particles in polypropylene with different melting points, the segregated polypropylene/carbon nanotube composite is prepared by injection molding. EMI SE shows the same level as the compression molded composites with segregated structure. The tensile strength, elastic modulus and elongation at break of our composite have been greatly improved (especially the elongation at break increased by 17 times compared with compression molded composites). Our work provides new ideas for the molding and processing of segregated

CPCs, and has guiding significance for the realization of large-scale industrial applications of segregated CPCs.

Key words Conductive polymer composites; segregated structure; electromagnetic interference shielding

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Analysis of electrochemical properties of Structure-Integrated Energy Storage System

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KAIST

As the emission problem of harmful substances from the use of fossil fuels becomes serious, researches on energy storage devices are becoming more and more important. With the development of energy storage technology, the scale of applications and the level of required performance are also increasing. The structural battery research aims to increase the energy density per weight or volume of the overall application by integrating the load bearing and energy storage functions in the form of multifunctional composites. In this concept, the current collector and separator among the components of the battery are effective elements that can support the mechanical load by keeping the load path continuous to the surrounding structure beyond the battery part. In this study, carbon fabrics and glass fabrics were used as current collectors and separators, respectively, to secure the versatility of the battery. In addition, in order to prevent leakage of commercial liquid electrolyte and penetration of moisture, the battery part and the structural part were separated with a thermoplastic tape in the continuous fabric. For the experiment, a coin cell of the same constituents of the structural battery was used as a reference, and then a structural battery was manufactured and tested. The electrochemical characteristics evaluations were performed, and the structural battery capacity was measured under a mechanical load. As a result of the experiment, the fabricated structural battery showed about 88% of the battery capacity compared to that of the coin cell, which was 110 mAh/g upto 50 cycles at 0.2C. Also, when a mechanical load of 1% strain was applied, the battery capacity was about 72% compared to the case without a mechanical load. Comparisons were also made with the results of other experiments.

Key words Structural battery, Carbon current collector, Glass separator, Load bearing

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Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

A radiative cooling paper based on ceramic fiber for thermal management of human head

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The intensification of global warming has resulted in extremely hot weather in many parts of the world, posing a severe challenge to the health and safety of outdoor workers. Passive daytime radiative cooling (PDRC) textiles with no energy input requirements can effectively achieve temperature management. However, few wearable radiative cooling devices have been successfully prepared. This study demonstrates a radiative cooling paper (RCP) with tunable stiffness for the thermal management of human head by using SiO2 fibers and fumed SiO2 as emitters. The as-prepared RCP exhibits high sunlight reflectivity of 0.97, and high emissivity of 0.91 in the at_x0002_mospheric window. The results demonstrate that the RCP hat can prevent hair from overheating by reducing the temperature by an average of 12.9 ◦C compared with a white cotton hat under peak daylight conditions. Besides, the RCP exhibits outstanding integrated properties of high mechanical properties, waterproofness, and air permeability. Therefore, it is more suitable than other textiles for the manufacture of radiative cooling hats, and offers a promising solution to solve the problem of head thermal management in outdoor conditions.

Key words Passive daytime radiative cooling;Mechanical properties; Thermal management

Session: Multi-Functional Smart Composites

Presenting Type：Oral-Onsite

Parametric design of a porous auxetic metamaterial based on neural network

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Auxetic metamaterials are widely designed and applied in several fields recently thanks to their counter-intuitive deformation and superior mechanical characterization. Although the metamaterials can be designed by adjusting microstructure to achieve expected target performance, a challenge is often encountered due to the nonlinear responses and non-convexity of optimization problems. This paper provides a framework for the inverse design of a porous auxetic metamaterial. First, a neural network is introduced to fit the mapping between the microstructure and properties, which generates a nearly real-time predicted database. Then, based on the database, we conduct parametric analysis and inverse design, seeking optimized architecture for multiple mechanical properties. The framework has good performance in property prediction and inverse design of the porous metamaterial. It can be easily extended to more structural materials to provide design guideline.

Key words auxetic metamaterials, neural network, inverse design

Session: Multi-Functional Smart Composites

Presenting Type：Oral-Onsite

Epitaxial Crystallization Constructs Biomimetic Topology to Promote Osteoblast Differentiation and Osteogenesis

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The natural extracellular matrix has a rich topology. Mimicking the extracellular matrix to construct biomimetic topologies is a significant method to modulate cellular behavior. The continuous precipitation of polycaprolactone molecules from the acetic acid/aqueous solution was realized by the homogeneous epigenetic crystallization method and the nanosheet structure was formed by orientation crystallization on the substrate. Its structural characteristics can be controlled by the concentration of polycaprolactone growth solution. The biomimetic topology constructed by epitaxial crystallization could significantly promote the osteogenic differentiation and mineralization deposition in vitro cell experiments. This was due to biomimetic topology can activate transcriptional co-stimulator/ (runt-related transcription factor 2， Runx2) pathway in the PDZ-binding domain. In order to further simulate the orientation topology of natural bone, after the polycaprolactone substrate was uniaxially stretched, the biomimetic topology which plumbed stretching direction was obtained by epiphytic crystallization. Compared with the isotropic topology, the oriented topology can better induce cells to grow oriented along the nanosheet orientation through contact induction in vitro cell experiments. This promoted the proliferation and osteogenic differentiation of stem cells. Furthermore, repair of skull defect models can be promoted by the biomimetic topology in vivo animal experiments. The biomimetic topology constructed by epitaxial crystallization provided an innovative approach for the design of bone tissue engineering scaffolds.

Key words epitaxial crystallization; topology; osteogenic differentiation

Session: Multi-Functional Smart Composites

Presenting Type：Oral-Onsite

Achieving Efficient Radiative Cooling and Electrophysiological Monitoring Capabilities on a Superelastic and Microporous Metafabric

Yunpeng Huang*、Jiancheng Dong、Tianxi Liu
Jiangnan University

Wearable health monitoring electronics with superb passive-cooling capabilities are of great value for both daytime outdoor dressing comfort and low-carbon economy. Herein, a multifunctional and skin-attachable electronic was rationally developed on a porous all-elastomer metafabric for efficient passive daytime radiative cooling (PDRC) and human electrophysiological monitoring. Such remarkable performance is ascribed to the homogeneously impregnated polytetrafluoroethylene (PTFE) microparticles in the styrene-ethylene-butylene-styrene (SEBS) fibers, and the thermal-induced micropores with tailored pore size in SEBS/PTFE metafabrics, which synergistically backscatter ultraviolet-visible–near-infrared (UV-visible-NIR) light (maximum reflectance over 98.0%) to minimize heat absorption while efficiently emit human-body midinfrared radiation to the sky. Thus, developed PDRC metafabric achieves approximately 17 °C cooling effects in outdoor daytime environment, and completely retains its passive cooling performance even under 50% stretching. Further, breathable and skin-conformal bioelectrode for electrophysiological monitoring is also realized through liquid metal (LM) printing on the PDRC metafabric, enabling the high fidelity acquiring of electrocardiograph (ECG), surface electromyogram (sEMG), and electroencephalograph (EEG) signals. Hence, the fabricated PDRC metafabric open a new avenue for the development of body-comfortable electronics and low-carbon wearing technologies.

Key words Radiative Cooling fabrics; Liquid metal; Electrophysiological monitoring

Session: Multi-Functional Smart Composites

Presenting Type：Oral−Onsite

Ionic Liquid-Modulated PEDOT:PSS-based Thermoelectric Composites

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In the recent decade, polymer thermoelectric (TE) composite has achieved significant progress in harvesting low-quality/waste heat. Intrinsically conducting polymers, such as poly(3,4-ethylenedioxythiophene) (PEDOT), polypyrrole and polyaniline are usually selected as the organic polymer components of composites, in which PEDOT is perhaps the most successful one with the high TE performance and the commercial availability in the form of PEDOT:polystyrenesulfonate (PSS) solution. Herein, the synergistically boosting TE properties of PEDOT:PSS/single-walled CNT (SWCNT) composites by the ionic liquid (IL) are reported. The IL additive has two major functions, i.e. inducing the phase separation of PEDOT:PSS and a linear quinoid conformation of PEDOT and promoting the SWCNT dispersion. The maximum power factor reaches 182.7 ± 9.2 μW m-1 K-2 for the flexible PEDOT:PSS/SWCNT film with the IL at room temperature. Besides, polyvinyl alcohol (PVA) is added to the PEDOT:PSS/SWCNT system with IL to modulate the mechanical performance. The resultant PEDOT:PSS/PVA/SWCNT composite shows a high TE performance with a power factor of 106.1 ± 8.2 μW m-1 K-2 at room temperature, and strong mechanical robustness with a tensile modulus of 4.2 ± 0.5 GPa and fracture strength of 136.5 ± 10.6 MPa. The present study provides a promising way to enhance TE performance and help address the inferior mechanical performance of TE composites without significantly compromising TE performance for PEDOT:PSS-based TE composite.

Key words Thermoelectrics; PEDOT; ionic liquid; mechanical performance

Session: Multi-Functional Smart Composites

Presenting Type：Oral-Onsite

Stretchable and flexible strain sensor with high sensitivity, large workable range and excellent breathability for wearable electronic skins

Wei ZHAI、Wei Zhai*、Kun Dai、Chuntai Liu
Zhengzhou University

Flexible strain sensors with integrated attributes of stretchability and robustness are urgently needed owing to their potential applications in healthcare detecting and environment monitoring. Herein, we fabricated a stretchable thermoplastic polyurethane (TPU) film (PUF) through electrospinning technology, then decorated with polyaniline (PANI) bridged by reduced graphene oxide (rGO) nanosheets by in-situ polymerization and ultrasonication. The rGO/PANI/TPU film (GPTF) was then assembled as strain sensors (GPTSS), achieving broad sensitive range of 0.1% to 300% strain, high gauge factor (GF) of 3000.2, good response stability, short response time (90 ms) and excellent durability (undergoing 10000 stretching/releasing cycles), which endows the strain sensor with high discernibility for detecting intricate human motions. The GPTSS shows capacity to precisely monitor ammonia gas (as low as 5 ppm), which can be used to detect harmful gases. The integrated capabilities of strain sensing and environmental monitoring promote the progress of high performance electronic.

Key words Strain sensor; flexibility; human motion detection; environmental monitoring

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Force Response Color-changing Resin Matrix Composites that can be used for Material Health Monitoring

ling BAI、Rongguo Wang*
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Usually, when the polymer material yields or the composite material undergoes interfacial separation or the second phase in the composite material ruptures, materials will produce mechanical discoloration. Therefore, whether the mechanochromic polymer material is discolored can determine whether the material is damaged or not. Applying force-responsive color-changing intelligent materials in resin matrix composites can realize the health monitoring of material components. In this study, mechanochromic polyurethane (PU-SP) was prepared by chemically linking the mechanochromic group bishydroxyspiropyran in the molecular chain of polyurethane. Blends E-51 resin with the mechanochromic polyurethane to obtain a mechanochromic mixture (PU-SP/E-51), compares PU-SP and PU-SP/E-51 force-responsive discoloration efficiency. The force-responsive discoloration strain threshold decreased from 399.10% to 326.38%. Combining the UV absorption spectra of the two under the same tensile strain also verifies that the force response efficiency of PU-SP/E-51 is better than that of PU-SP. That is to say, a certain proportion of PU-SP/E-51 is better than PU-SP in force-response discoloration performance. Based on this, more sensitive force-responsive color change performance will provide more possibilities for minor monitoring stress or slight damage occurring in the material system.

Key words chanochromic, polyurethane, epoxy resin

Session: Multi-Functional Smart Composites

Presenting Type：Oral-Onsite

Carbon fiber structural battery composites based on structural electrolytes with vertical ion channels towards high multifunctional performance

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1. Beijing Jiaotong University
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3. Shandong Institutes of Industrial Technology

Structural batteries (SBs) based on carbon fibers (CFs) are promising multifunctional composite materials to simultaneously realize load-bearing and electrical energy storage. Conventional structural battery electrolytes(SBEs) have bicontinuous phase microstructure characteristics, which makes a further considerable improvement in both mechanical and electrochemical performance of structural batteries rather challenging. Herein, a novel SBE with vertical ion channels in the form of patterned macropores was developed by photolithography based on the UV-initiated cation polymerization, which was subsequently used in the fabrication of the CF half-cell lamina. The mechanical and electrochemical properties were characterized for both SBE and SB half-cells. The Young's modulus and ionic conductivity of the porous epoxy post-filled with liquid electrolyte were 1.2 GPa and 3.6 mS/cm, respectively, which exceeded the state-of-art multifunctional performances of bicontinuous SBEs. The specific capacity of the SE half-cell could reach 222±10 mAh/g (2nd) at 0.17 C, while the tensile modulus of the CF half-cell lamina was 66±4 GPa (Vf=22%). This work could provide new insights into a microstructural design for structural batteries towards high multifunctional performances. Meanwhile, as the macroporous epoxy structure can be considered as a mechanical scaffold, the performance of structural batteries can be designed at an extensive range by changing the parameters of macroporous membranes and post-filling the ion channels with different electrolytes. In summary, the CF UD lamina electrode based on the vertical ion channels is promising in enhancing the multifunctional performance of structural batteries. The MPSBE developed can provide new insights into high-performance SBs, which enables a free and more controllable design of the energy storage and load bearing functions.

Key words Carbon fibers; Structural battery composites; Structural battery electrolytes; Electrochemical performances; Mechanical properties

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Performance optimization and application design of nanogenerators based on PVDF matrix composite

Binbin Zhao、Tao Yu*
Tongji University

With the surge in demand for green energy, nanocomposites show great prospects in the preparation of piezoelectric nanogenerators (PENGs), triboelectric nanogenerators (TENGs) and hybrid nanogenerators (HNGs). However, their application is severely limited by their poor performance due to the lack of design of raw materials and structures. In this work, the output performance of PENGs and HNGs was optimized through materials modification and structural design. For PENGs, a core-double shell structure was prepared by PMMA coated hyperbranched BaTiO3 nanowires (BTO@HBP@PMMA), which were mixed with PVDF for electrospinning to improve their properties. The high dielectric constant of the hyperbranched structure makes the nanofiber film fully polarized and obtain high β phase content in the electrospinning process. PMMA coating improves the dispersion of the nanowires and the stress transfer between the matrix/nanowires. These effects increase the open circuit voltage and short circuit current from 1.9V and 0.12μA to 3.4V and 0.31μA (78.9% and 166.7%). In addition, we have prepared a hybrid nanogenerators (HNGs) with excellent performance and simple structure by electrospinning through mixing BTO and carbon nanotubes (CNT) into PVDF and PDMS. The micro-capacitors formed by BTO and CNT as well as the polarization degree of piezoelectric dipoles enhanced by the charges generated by triboelectricity improve the performance of HNGs. The optimized HNG exhibits the highest open circuit voltage and short circuit current of 117V and 4.7μA, respectively, which is better than most literature reports and can power small electronic devices such as calculators and timers continuously. The two nanogenerators have proved to be of great potential in monitoring human movement. In addition, the intelligent monitoring system is designed for self-powered monitoring in remote areas. In conclusion, this study provides a new direction for the performance improvement and application scenarios of different nanogenerators.

Key words nanogenerators, modification, structure, performance, application

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Highly Efficient Electronic Chip Thermal management

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Nowadays, as the integration of electronic chips continues to increase, the total power consumption of integrated circuits has risen exponentially, and the problem of chip failure will become more and more prominent. Among all the failure phenomena of electronic devices, the thermal failure rate accounts for about 55%. It can be seen that chip heat dissipation technology has been an important restrictive factor affecting the development of the electronics industry. On the basis of existing heat dissipation technology, the development of cooling technology for chips is an important guarantee for the effective operation of electronic devices. Here, we reported a cooling device with a high intrinsic thermodynamic efficiency using a flexible electrocaloric (EC) polymer film and an electrostatic actuation mechanism. The use of reversible electrostatic forces reduces parasitic power consumption and allows efficient heat transfer through instantaneous formation of good thermal contacts with the heat source or sink. The thin-film EC cooling device is flexible and can conform to curvilinear surfaces. To further improve the EC performance of cooling device, a double-unit EC polymer-based refrigeration device with high intrinsic thermodynamic efficiency was demonstrated using a flexible EC polymer film with improved performance by doping plasticizer and an electrostatic actuation mechanism. The highly efficient and compact EC cooling device demonstrated here not only leapfrogs the performance of existing solid-state cooling technologies, but also brings solid state cooling closer to reality for a variety of practical applications that require compact or mechanically flexible refrigeration.

Key words Thermal management; Chip cooling; Electrocaloric effect; Thermoelectric; Radiative cooling

Session: Multi-Functional Smart Composites

Presenting Type：Oral-Onsite

Tissue Engineering Applications of Multifunctional Micro/Nano-Polymer Materials

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The multifunctional micro/nano-polymer materials in this paper are mainly classified into multi stimuli-responsive materials, functional nanoparticles, and construction of their composite platforms. Among them, by introducing micro/nano probes with good conductivity, photothermal transformation ability, and sensitive biological components into the polymer substrate, multi stimuli-responsive materials can be widely used in the fields of smart sensors, tissue engineering, multi-component detection wearable device, and anti-tumor therapy. For example, modifications of pH, GSH and H_2O_2-responsive groups can be used to realize an on-demand release of antitumor drugs. Group modification of iridium complexes can be used as fluorescent probe to monitor hypochlorite and ferrous ions in vivo. Nanomaterials containing manganese, iron, and platinum can also realize integration of diagnosis and treatment based on imaging function. On the whole, multifunctional micro/nano-composite materials formed by compounding the multi stimuli-responsive polymer substrate with the nanomaterials can not only design the patterned bionic microstructure to regulate biological properties, but also organically combine functionalities of diagnosis, therapy, and repair through a minimally-invasive method, laying a solid foundation for extending applications of such novel polymer materials in the field of tissue engineering.

Key words multifunctional micro/nano-polymer, stimuli-responsive, functional nanoparticles, tissue engineering, anti-tumor therapy

Session: Multi-Functional Smart Composites

Presenting Type：Oral-Onsite

Modelling of electrical properties of microscale self-enclosed ionic liquid enhanced soft composites

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The incorporation of room temperature ionic liquid (IL) as inclusions for dielectric elastomer composites currently generate great interest due to their potential applications in soft actuator and optical-related devices. Experiments have shown that the electrical properties of IL enhanced soft composites (ILESCs) are dependent on AC (alternating current) frequency of the electrical loading. This current work develops a mixed micromechanical model with incorporation of electrical double layer (EDL) to predict the electrical properties of the ILESCs while revealing the physical mechanisms (including crowding and overscreening structure, percolation threshold, interfacial tunneling, MWS polarization) that underpin the phenomena. Particularly, the Bazant-Storey-Kornyshev (BSK) phenomenological theory is integrated into EDL surface diffusion model for the first time to evaluate the influence of crowding and overscreening effects. The results show excellent agreement with experimental data of IL enhanced PDMS composites over the frequency range from 1 Hz to 10 GHz. Parametric analysis from the perspective of designing is conducted to explore the optimization of ILESCs with high dielectric constant and frequency-dependent stability. It is found that IL with smaller size and aspect ratio significantly increases the dielectric constant of the ILESCs before the critical dipole relaxation frequency. Increasing the surface charge density of the matrix and replacing of diluted electrolyte with IL delays the frequency-facilitated dielectric response, which is beneficial to maintain the dielectric stability of the ILESCs in the low-frequency band.

Key words Smart composites,Electrical properties, Micro-mechanics, Ionic liquid

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Two-dimensional sensing materials and devices

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fudan university

Two-dimensional (2D) materials and 2D field-effect transistor (2D-FET) sensors are one of the frontier research fields of advanced sensing technologies. 2D materials have large surface area and ultra-thin thickness approaching the physical limit, which give rise to remarkably enhanced sensitivities. On the other hand, all of the electron processes take place at the material surface or interfaces. The interfaces will largely influence the performances. Thus, the interfacial modulation is an important scientific question. This research is focused on the interfacial modulation of the 2D-FET sensors. Main results include: a new methods are developed to controllably produce high quality 2D sensing materials and the interfaces of the 2D-FET sensors; a new approach is demonstrated to improve the interface between the semiconductor and the dielectric substrate by using conformal h-BN; new mechanisms such as giant photoelectrical-gating effect, photoelectrical enhancement effect of molecular crystals at 2D limit, controllable charge doping at the sensing interface, etc. are developed to modulate the electron processes at the sensing interface, which improves photoelectrical or chemical sensing performances of 2D-FET sensors.

Key words Two dimensional materials, sensors, field-effect transistor

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Novel sensitive materials and flexible sensors

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Shanghai Institute of Ceramics, Chinese Academy of Sciences

As the foundation of information collection, sensors are the core devices of wearable systems, and show broad application prospects in national key deployment areas such as health care, artificial intelligence, and advanced combat. Rigid sensors do not match the mechanical properties of human skin or internal organs, resulting in problems such as undetectable physiological signals, inaccurate measurements, or limited test information. In contrast, flexible sensors have higher conformability and biocompatiblity, and have more advantages in the field of wearable health monitoring and disease diagnosis and treatment, which has become an international academic research frontier in recent years. The development of novel flexible sensitive materials is the key to achieve the intrinsic flexibility of sensor. This report will focus on the preparation of novel sensitive materials, the design of high performance, multifunctional and self-powering flexible sensors, the exploration of their applications and the discovering of new sensing mechanisms by the reporter team.

Key words flexible sensors, wearable sensors, electronic skin

Session: Multi-Functional Smart Composites

Presenting Type：Oral-Onsite

A novel shock absorber based on shear thickening fluid for marine gearbox

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2. School of Mechanical Engineering, Tongji University
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This study developed a novel shock absorber based on shear thickening fluid (STF) and the mechanical behavior and application of marine gearbox with the shock absorber were analyzed. First, the microstructure of the silica particles and rheological properties of the STFs were measured. Besides, the dynamic compressive of STF was investigated by a split Hopkinson pressure bar (SHPB). The results showed that modulus and the impact toughness of the STF increased with the peak strain rate. Finally, the compressive and impact behavior of the shock absorber based on STF were tested, and the free drop experiments of gearboxes with shock absorber were carried out under different dropping height. The result showed that the acceleration attenuation of the gearboxes can reach a maximum of 76%. This work provided a novel idea to improve the shock absorber performance for the marine gearbox.

Key words Shear thickening fluid；Shock absorber；Compressive behavior；Marine gearbox

Hangzhou, PR China 25-28 April, 2023

Session: Multi-Functional Smart Composites

Presenting Type：Oral-Onsite

Lightweight, High-Performance Polymeric Nanocomposite for Electromagnetic Interference Shielding

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Lightweight polymer nanocomposites embedded with various conductive nanomaterials such as carbon nanotube, graphene, metal nanowires, and transmission metal carbides/nitrides (MXenes) have attracted increasing attention for addressing emergency electromagnetic radiation or interference. Here, we employed efficient polymers for assisting in building lightweight, robust, and highly flexible EMI shielding composites. Typically, we employed low-dimension cellulose nanofibrils for assisting in building ultralow-density, robust, and highly flexible aerogels with orientated biomimetic hybrid cell walls. High conductivity and introduced interfaces lead to high intrinsic shielding ability of cell walls, which can be amplified by the cellular structures in the aerogels. Taking completely advantage of the biomimetic cell walls and cellular structure, the normalized surface specific shielding effectiveness is up to 189400 dB·cm2/g, significantly exceeds that of other EMI shielding materials reported so far. We have suggested some convenient, facile preparation approaches for constructing high-performance polymer nanocomposite-based EMI shields.

Key words lightweight, nanocomposites, porous architectures, polymer, EMI shielding

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Multifunctional self-healing poly(oxime urethane) composites for diverse applications

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Donghua University

Self-healing polymer have shown great promising in many fields. Recently, we have developed a series of multifunctional self-healing polymers and composites based on emerging dynamic oxime-urethane bond. We reveal multiple chemical transformations of oxime-urethane group, which distinct it from most other dynamic bonds and enable novel properties. We construct a Cu(II)–dimethylglyoxime–urethane-complex-based poly(oxime-urethane) elastomer (Cu–DOU-CPU) with synergetic hydrogen bonds/coordination bonds/dynamic covalent bonds to reconcile the typical contradictory high healing efficiency and mechanical strength based on the two functions of copper ions including forming metal coordination bonds for strengthening and catalyzing the reversible dissociation of dynamic covalent bonds. The resultant elastomers exhibit a world-record mechanical strength and toughness of room temperature self-healing materials. Taking poly(oxime-urethane) Cu-DOU-CPU as an example, we demonstrate a "Print-Healing" strategy to solve several bottlenecks in fused deposition modeling printing. Inspired by Lego bricks, we rationally split the complex three-dimensional structure into simple modules for printing. Then, the complete complex architectures were assembled from these modules and spliced by self-healing. This strategy enabling constructing complex structures and large objects from compact printer. The triple dynamic bonds induce strong binding between layers to avoid typical poor layer-to-layer adhesion. We explore diverse applications of poly(oxime-urethane)s. Poly(oxime-urethane)s with tunable mechanical properties are assembled at the lesions via self-healing in vivo to construct repair devices in situ for efficient treatment of aortic aneurysm, nerve coaptation and bone immobilization in rat models. A macroscopically discretionary healing-assembly strategy to fabricate reconfigurable soft robots based on tunable self-healing poly(oxime-urethane) elastomers is developed. Poly(oxime-urethane)s have also been used to fabricate multifunctional protective films with superior resistance to mechanical damage, rapid room temperature self-healing, and anti-counterfeiting features, stretchable self-healing conductors, detachable and self-healing hot melt adhesives. We expect versatile oxime–urethane will create more functional smart materials and enable more novel applications in future.

Key words self-healing, dynamic covalent bonds, polyurethane, metal coordination, 3D printing

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Low-hysteresis and Flexible Pressure/Strain Sensitive Composites for Robust Responsive Wearables and Machine Intelligence

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2. Institute of High Performance Computing (IHPC), A*STAR, Singapore.
3. Department of Materials Science and Engineering, National University of Singapore, Singapore.

Electronic skins are essential for real-time health monitoring and tactile perception in robots. Pressure/strain sensitive composites have advanced rapidly and many applications require high repeatability and robustness under various mechanical deformations. However, the intrinsic viscoelasticity of soft polymeric materials remains a long-standing challenge resulting in cyclic hysteresis. This causes sensor data variations between contact events that negatively impact the accuracy and reliability. Here, we introduce the interface mechanics-guided optimal design of sensitive composite microstructures to address the inherent trade-off between sensitivity and hysteresis in tactile sensors when using soft materials. We demonstrate that the pressure sensors can accurately detect and measure the pulse wave velocity (PWV) when skin mounted. Moreover, we show that these tactile sensors when arrayed enabled fast reliable one-touch surface texture classification with neuromorphic encoding and deep learning algorithms. Additionally, integrations of the stretchable composite conductors with fabrics showed wearable displays that can survive machine-washes and hundreds of mechanical loading cycles. Furthermore, stretchable conductors are used to connect flexible printed circuit boards and piezoresistive sensors on a tactile sensing glove for the emerging sensorized prosthetics.

Key words sensitive composite, electromechanical hysteresis, electronic skin, machine learning, robotics, wearable

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Fabrication and multi-stimuli response performance of twisted two-way shape memory EVA/RGO composite fibers

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Zhejiang Sci-Tech University

Two-way shape memory effect (2W-SME) and multi-stimuli response properties have become a research hotspot in the field of shape memory polymers (SMPs). In this paper, two-way shape memory EVA/RGO composite fibers with thermal-, electro- and near-infrared- (NIR) responsive properties were successfully prepared by melt spinning, UV cross-linking, swelling ultrasonic and one-step twisting method. The two-way shape memory, electrical conductivity, electrothermal and photothermal conversion properties of EVA/RGO composite fibers were studied. The results show that the gel mass fraction is a key factor in determining the two-way shape memory property of EVA fibers, and crosslinked EVA fibers exhibit thermal-activated 2W-SME under constant stress, i.e. melting-induced contraction (MIC) and crystallization-induced elongation (CIE). In addition, RGO nanosheets rooted on the EVA fiber surfaces form a continuous conductive network, and then are conformed into a consistent helical structure as yarns twisted, enabling the network with great stretchability and abundant piezoresistive contacts between nanosheets. The EVA/RGO composite fibers display high conductivity (up to 31.23 S/m), and the resistance of the twisted composite yarn decreased from 3.06 kΩ/cm to 0.52 kΩ/cm with increasing the number of composite fibers. Based on the excellent electrothermal, photothermal conversion and strain sensing properties of EVA/RGO composite fibers, the integration of remote precise control reversible actuation and strain sensing of EVA/RGO composite fibers is realized. This work provides a simple strategy for developing RGO/EVA composite fibers with excellent two-way shape memory effect and multi-stimuli response performance for various applications, including in soft actuators and artificial muscle.

Key words shape memory polymer fiber; two-way shape memory effect; multi-stimuli response

Hangzhou, PR China 25-28 April, 2023

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Smart flexible sensor based on carbon materials and its applications

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In recent years, the applications of flexible sensors in wearable electronic devices, human health monitoring, and intelligent robots have received extensive attention and research. Two-dimensional material has become a potential sensitive material for the fabrication of flexible sensors due to its unique physical and chemical properties. A flexible, non-contact, and multi-functional humidity sensor based on two-dimensional cobalt-metal-organic framework nanosheets is proposed to realize multi-functional applications such as human respiration monitoring, skin humidity sensing, and fruit freshness monitoring. A self-actuated flexible sensor based on GO-doped polyacrylamide hydrogel was prepared to realize human gait recognition. A flexible three-dimensional aerogel pressure sensor based on cellulose and graphene was prepared to realize real-time wireless monitoring of human breathing and sleep status at different frequencies. The results show that the flexible sensor proposed in this paper has broad application prospects in human-computer interaction (HMI) devices.

Keywords Paper-based sensor, Polyacrylic acid, Silver nanoparticles, Ammonia sensor, Inkjet printing

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

LC Resonant Wireless Strain Sensing Using MWCNT/EP Composite Film

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Carbon nanotubes in polymer matrix form a complex network which consists of resistors, inductors, and capacitors. The present research focuses on wireless strain sensing using multi-walled carbon nanotube (MWCNT)/epoxy resin (EP) films. Following a specific process, the nanocomposite strain gauges with different MWCNT concentrations were fabricated. The test on these prototypes shows that the MWCNT/EP films can respond to wireless electromagnetic excitation by means of generating induced voltage. Experimental measurement also proves that mechanical strain affects the resonant frequencies of the MWCNT/EP strain gauges. Therefore, the nanocomposite films can be used to detect mechanical strain wirelessly by calculating the shift of the resonant frequency. Aiming to reveal the working mechanism of the wireless sensing, this study hypothesizes that the nanocomposite strain gauges can be modeled by an equivalent RLC circuit. The subsequent theoretical analysis, and the comparison between the analytical predictions and the experimental results both indicate that the hypothesis is reasonable, since the RLC model can successfully explain the phenomenon of the strain-induced shift of the resonant frequency. The current work provides a promising method to make tag-type wireless strain sensors.

Keywords Wireless sensing, MWCNT, EP, strain gauge, frequency shift

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Onsite

Self-reinforced Tough and Multifunctional PVA based Anisotropic Composite Hydrogels

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It is particularly challenging to prepare hydrogels with excellent mechanical properties that are comparable to those of strong biological tissues such as ligaments and tendons. Here, inspired by the anisotropic structure of tissues, we present a facile strategy to fabricate anisotropic fiber-based multifunctional hydrogels utilizing oriented wet spinning, soaking and cyclic freezing treatments. The fabricated polyvinyl alcohol (PVA) hydrogels are highly anisotropic and exhibit excellent properties, such as extremely high fracture stress (12.8±0.7 MPa) and fracture strain (1719±77%), excellent modulus (4.51±0.76 MPa) and high toughness (134.47±9.29 MJ m-3) compared with other strong hydrogels and even natural tendons. In addition, based on the soaking technology, fabric composite hydrogels with woven structure were developed and their mechanical and electrical properties were studied. The resultant composite hydrogels exhibit simultaneously high tensile strength (18.5 MPa), toughness (53312 J/m2), tearing resistance (35 N/mm), flexibility and excellent environment adaptability without compromising transparency. In addition, these hydrogels have good ionic conductivity, which can be applied to strain sensors and touch screens, and with proper design, it is successfully applied in flexible actuators. These results indicate the hydrogels have great potential for applications in different fields such as smart wearable devices and bionic actuators. The preparation method proposed in this paper is simple and controllable, and the material properties can be customized to meet specific needs, opening up possibilities for large-scale production of composite hydrogels.

Keywords Tough hydrogel, Self-reinforced, Fabric composite, Smart wearable devices

Session: Multi-Functional Smart Composites

Presenting Type: Oral−Virtual Platform

A rubber-based shape memory alloy composite plate with two-way bending/twisting deformation

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Hebei University of Engineering

A simple fabricating method of rubber-based shape memory alloy (SMA) composite plate with bending or twisting deforming was introduced in the work by two-step curing technology, in which the rubber-based SMA strips were formed firstly and heat-treated above the austenitic finish temperature to obtain the pre-bending shapes. Then, the pre-bending strips were placed the second mold to fabricate the initial shape of SMA plate with bending or twisting deforming. The results showed that the SMA plate could arrive the bending deforming when the pre-bending strips towards the same direction, however, the SMA plate would realize the twisting deforming when the pre-bending strips towards the opposite direction. Moreover, the two-way bending or twisting angle was measured.

Key words Shape memory alloy; bending ot twisting deforming; application

Session: Multi-Functional Smart Composites

Presenting Type: Oral−Virtual Platform

Development of minute strain optical fiber sensors for low thermal expansion CFRP

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2. Adtec engineering, Inc.

Low thermal expansion CFRP laminates have been applied to a base structure which needs high dimensional stability. In the present study we tried to develop high accurate and embeddable strain sensors using EFPI (Extrinsic Fabry-Perot Interferometer) to measure minute thermal strain of CFRP.

Two optical fibers were fixed in a glass capillary with a gap length d as shown in Fig.1. Two reflected lights from the edges of fibers construct an interference signal in the spectrum as illustrated in the figure. The gap length was calculated from the output spectrum by FFT.

Firstly, accuracy of the sensors with gap lengths of 0.05, 0.2, 0.1 and 0.3 mm was evaluated from fluctuation at room temperature. Secondly, thermal strain of unidirectional CFRP laminates as illustrated in Fig.2 was measured by the built-in EFPI sensor during a thermal test.

Figure 3 shows accuracy calculated from fluctuation of the measured strain. It was found that the minimum value was ±0.0182 me when the gap was 0.1 mm. It also appeared that long gap length and small measuring points per period decrease strain accuracy. In addition, it appeared that the adequate measuring points per period improved the measurement accuracy.

Figure 4 shows fluctuation of strain of CFRP laminates during thermal test. From the results, it was found that the accuracy of the minimum value after the sensor embedded was ±0.0206 me, and the accuracy was almost the same as before embedded. Therefore, it was considered that embedment of the sensor into CFRP laminates did not affect the sensing accuracy.

Key words Strain measurement, EFPI sensor, CFRP, Thermal strain, high precision

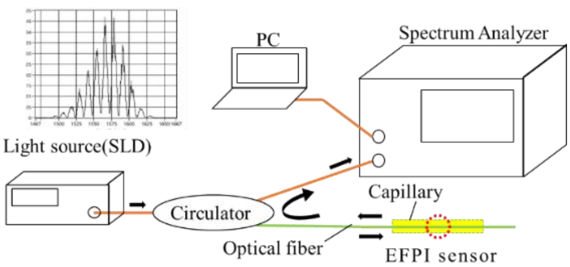

Fig.1. EFPI sensor and measurement system

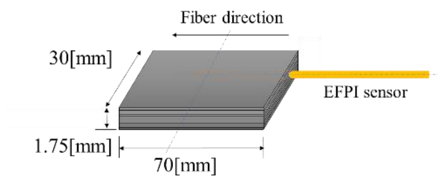

Fig.2. CFRP specimen with built-in EFPI sensor

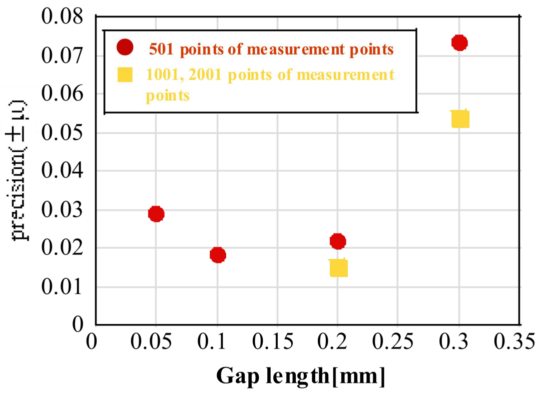

Fig.3. accuracy calculated from fluctuation of the measured strain.

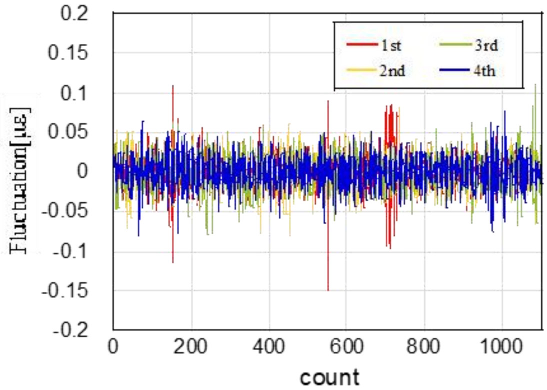

Fig.4. Fluctuation of strain of CFRP laminates during thermal test.

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Virtual Platform

Ameliorated Properties in Multifunctional Composites via Segregated Graphene Nanosheets/Boron Nitride Nanosheets Dual Network Structure under High Pressure

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3. Northwestern Polytechnical University

The practical application of polymer composites in electronic and communication industry often requires multi-properties, such as high thermal conductivity (TC), efficient EMI shielding ability with low electrical conductivity, superior tribological performance, reliable thermal stability and excellent mechanical properties. However， the integration of these mutually exclusive properties is still a challenge, ascribed to their different requirement on the incorporated nanofillers, composite microstructure as well as processing process. Herein, a well-designed boron nitride nanosheets (BN)/graphene nanosheets (GNP)/polyphenylene sulfide (PPS) composite is fabricated via high-pressure molding. Distinctively separated arranged GNP and BN in segregated structure is realized by mechanically wrapping PPS particles with GNP and BN separately and in sequence before hot-pressing, which can not only give rise to high thermal conductivities ascribed to reduced phonon scattering at the interfaces between two identical fillers, but also effectively reduce the electrical conductivity. Synergetic enhancement effect of BN and GNP on thermal conductive performance is stimulated by high pressure. Consequently, PPS composites with 30 wt% GNP and 10 wt% BN hot-pressed under 600 MPa present superior comprehensive properties with a high TC of 6.4 W/m/K, outstanding EMI SE as high as 70 dB, marvelous tribological performance, reliable thermal stability and satisfactory mechanical properties, which make it promising for application in miniaturized electronic devices in complex environments.

Key words EMI shielding, thermal conductive, wear resisting, segregated dual network structure

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Virtual Platform

Bioinspired chromotropic composite skin for discriminable strain/temperature/pressure multimodal sensing

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3. University of New South Wales

Highly flexible multimodal sensors are essential to both detecting and differentiating complex stimuli from surrounding environments for emerging wearable sensing applications. Enabling simultaneous detection and discrimination of physical stimuli using an all-in-one sensing system is highly desired. However, current multimodal sensors suffer from inescapable mutual interference among different sensing components. Most of the sensors with a stimuli-decoupling capability are bimodal, such as temperature and pressure, strain and pressure, and so on. Developing a multimodal sensor capable of concurrently discriminating strain/temperature/pressure stimuli remains a daunting challenge. This work reports a rational design of a bioinspired chromotropic composite sensor which can concurrently monitor in-plane strain/temperature/pressure stimuli by integrating mechanochromic, thermoresistive and triboelectric sensing principles, as shown in Fig. 1. The wavelength signal obtained from the mechanochromic photonic crystals of magnetic nanoparticles exhibit color-switching responses to strain stimulus. The temperature measurement of resistance signal is enabled by the ultrasensitive thermoresistive effect of ionic hydrogel with aligned polymer chains. Pressure sensing of voltage signal with strain- and temperature-insensitive capabilities is implemented by constructing a triboelectric multilayer structure consisting of a chromotropic hydrogel film (electrode), a wrinkle-patterned PDMS (frictional layer) and a CNT/PDMS elastic electrode. Ultrahigh stimuli discriminability is achieved by tailoring the material properties and multilayer design with gradient modulus to deliver an extremely sensitive response to a selective external stimulus while highly insensitive to unwanted ones. The integrated single sensor facilitates mutually-discriminating trimodal sensing with accurate measurements and quantitative mapping, and thus offers new insights into the design of emerging interactive e-skin systems.

Key words ionic skin, multimodal sensing, chromotropic iontronics, hybrid mechanism, stimuli discriminability

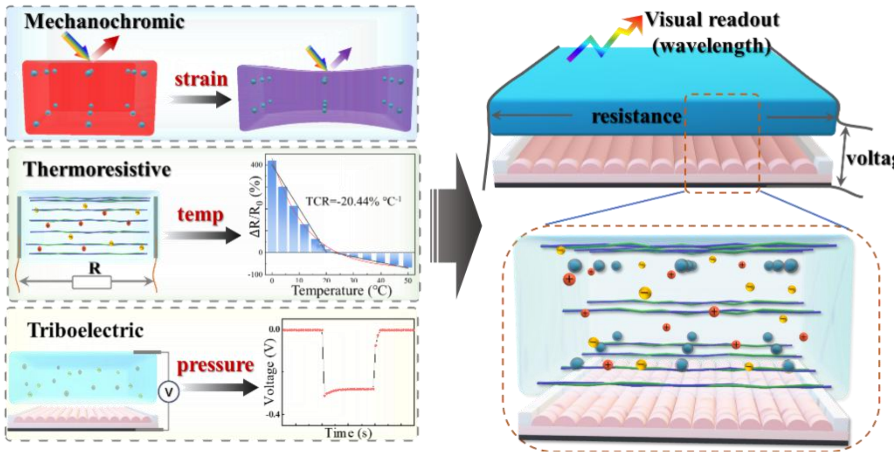

Fig. 1. Illustration of chromotropic composite sensor with integrated mechanochromic, thermoresistive and triboelectric sensing mechanisms by means of the strain-sensitive wavelength, temperature-sensitive resistance and pressure-sensitive voltage signal, respectively.

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Virtual Platform

Molecular motions in polymer matrix for microenvironment sensing

Yanhua CHENG*
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The chain structure, condensed matter structure and hybrid structure of polymers are the keys to link molecular information and macroscopic properties. Therefore, how to track the structural evolution in the material processing process, and improve the material production efficiency are the key issues in the material design and preparation process. Although many advanced equipment and methods have successfully achieved the characterization of polymer structures, most of these techniques are limited to a fixed state, and it is difficult to track the dynamic evolution process. In order to address above problems, aggregation-induced emission (AIE) organic molecules are used as intelligent building units, and they are heterogeneously assembled with polymer networks through physical or chemical bonds. The macroscopic optical signal is used to reversely perceive the changes of the polymer microenvironment, realize the online visualization of the polymer chain structure, condensed matter structure and its hybrid structure, establish the structure-activity relationship between the polymer material structure and the macroscopic optical signal. The intelligent application of optically responsive materials provides theoretical guidance and data support for the processing and preparation of polymers and their composites.

Key words aggregation-induced emission, smart sensing, fibers, polymer structure

Session: Multi-Functional Smart Composites

Presenting Type: Oral−Virtual Platform

INFLENCE OF SENSOR EMBEDDING STATE ON CURING MEASUREMENT OF COMPLEX SHAPED FRP

Tomoki OHNISHI*、Tatsuro Kosaka、Genko Fujioka
Kochi University of Technology

We have been developed a measurement method of degree of curing (DOC) of FRP products using a Fresnel type optical fiber sensor. Although this sensor has good accuracy of DOC measurement, it appeared that optical loss by local bending when embedded in a complex preform degraded accuracy. Our previous study showed that the release of elastic deformation during impregnation of VaRTM affected measurement stability. The purpose of this study was to clarify the effect of the embedding state on measurement accuracy quantitatively.

Optical bending loss of an embedded optical fiber in three-dimensional shaped preform was monitored during VARTM as illustrated Fig. 1. In this experiment, several states of embedding loss were prepared. Then, in order to improve measurement stability, an optical fiber sewn into preform was used for curing measurement.

Figure 2 shows the relationship between the initial light loss during vacuuming and the light intensity change rate during resin impregnation. Note that the error bars in the figure indicate maximum and minimum values. From the figure, it was found that the larger the initial loss, the larger the change in light intensity during impregnation. The figure shows that the measurement error became very large when the initial loss was more than 3 dB.

In order to improve the measurement accuracy, the optical fiber was sewn in a preform. Figure 3 shows the time series changes of the light intensity measured by the sewn fiber during the impregnation process. From the figure, it appeared that although the light power changed during impregnation process, the final change was 5.07%, which was much smaller than 50% of the non-sewn fiber as shown in Fig. 2. It was considered that this was because optical fiber was constrained by sewed in a preform.

Key words Fresnel type，optical fiber，VaRTM，FRP，Degree of cure，DOC，optical loss

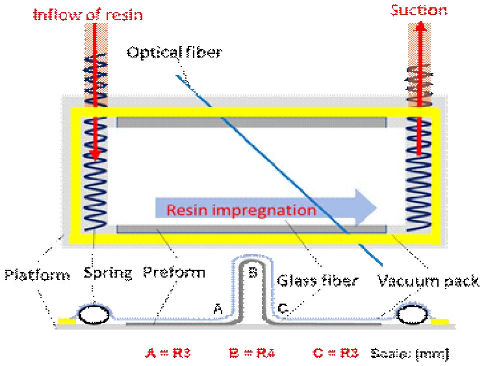

Fig. 1. Schematic view of experimental set-up of VaRTM for measuring optical bending loss during resin impregnation process.

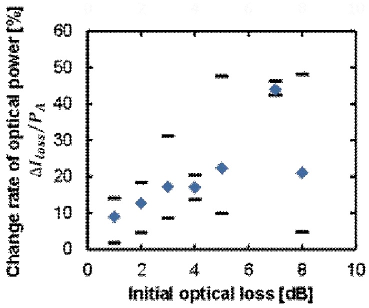

Fig. 2. Relationship between the change rate of optical power during resin impregnation process and the initial optical loss.

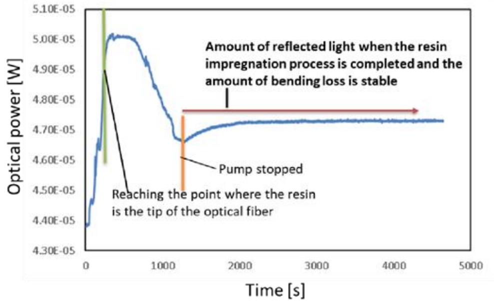

Fig. 3. Changes in optical power during the resin impregnation process in VaRTM(fiber optics sewn into preform).

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Virtual Platform

Challenges and opportunities of polymer nanodielectrics for electric energy storage

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To further develop higher energy density film capacitors, polymer nanocomposite dielectrics (or nanodielectrics) have attracted intense attention due to the "hope" of combining the high dielectric constant of inorganic nanofillers and the high breakdown strength/low loss of the polymer matrix at the same time. Although impressively high energy density has been achieved in laboratories, we are still far away from the eventual goal of polymer nanodielectric capacitors. In this presentation, we focus on essential materials issues for various polymer/nanoparticle composites. Different parameters, including dielectric constant, dielectric loss, breakdown strength, high temperature tolerance, and discharge energy density will be discussed from both point of views of fundamental science and capacitor applications. The goal is to identify advantages and disadvantages of the polymer nanodielectric approach against other approaches utilizing neat dielectric polymers and ceramics.

Key words Polymer nanodielectrics, film capacitors, high energy density, high temperature rating, low dielectric loss

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Hangzhou, PR China 25-28 April, 2023

Session: Multi-Functional Smart Composites

Presenting Type: Oral−Virtual Platform

EFFECT OF MECHANICAL PROPERTY AND SURFACE TREATMENT OF CARBON FIBERS ON FIBER-BREAK AE OF SINGLE FIBER COMPOSITE

Koichi ISHIHARA*
Kochi university of technology

It's known that the AE characteristic is different according to damage modes. In recent years, time-frequency analysis by wavelet analysis has been applied to damage analysis of composites. In this paper, fiber-break AE of single fiber composites (SFC) was focused. Several types of fibers and surface treatment were used to discuss the effect of mechanical properties and surface treatment on AE characteristics.

We prepared six kinds of SFC (PAN and pitch based carbon fibers, surface treatment of ethanol and acetone), and detected AE signals by fragmentation tests as illustrated in Fig. 1. Two AE sensors and strain gage were adhered on the specimen. The condition of fiber breakage was observed by microscope using a polarized light. Time-frequency distribution of AE was calculated by wavelet analysis where the Morlet (Gabor) was used as a mother wavelet.

Figure 2 shows typical wave forms of AE in carbon SFC. It appeared that the AE frequency was in a range of 800-1000kHz, 250-400kHz and 100-150kHz except low frequency AE less than 100kHz by matrix crack.

Figure 3 shows the relationship between frequency of high-frequency component over 250 kHz of AE signal and strain. AE between 300 kHz and 400 kHz was fiber-breaking, high-frequency AE due to pull-out around 800 kHz was frequently observed. It appeared that it was difficult to see difference in frequency of fiber-break AE of PAN and pitch specimens.

Comparing the acetone and ethanol treatments, the frequency of fiber-break AE tends to be slightly lower. This is expected that the length of fiber -matrix interfacial debonding is longer with the removal of sizing, and the resonance characteristics of the resin part near the fiber break are slightly different.

Key words Acoustic emission, fiber breakage, single fiber composite, wavelet transform

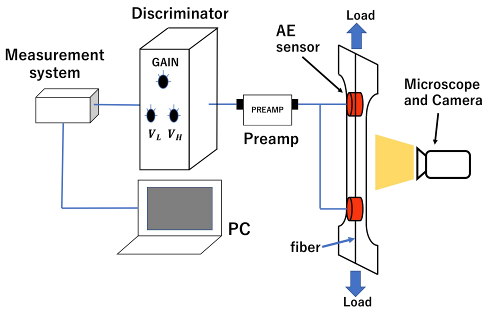
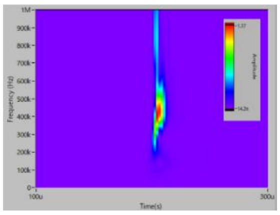
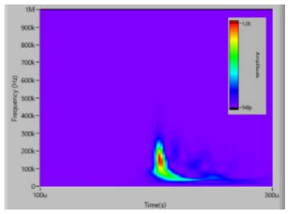


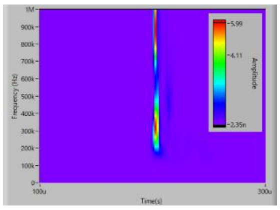
Fig. 1. Experimental system of fragmentation test



(a) High frequency pulse

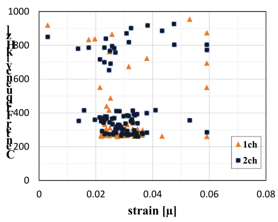


(b) Low frequency

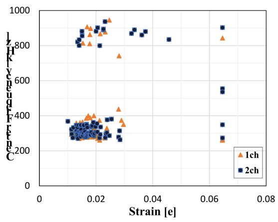


(c) two High frequency pulse

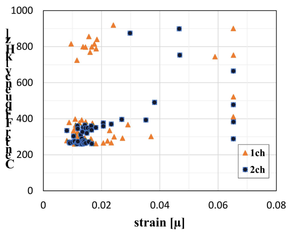
Fig. 2. Wavelet daigram of AE signals in carbon SFC



(a) T700SC



(b) YSH-50A-20S



(c) XN-60-A2S

Fig. 3. Relationship between strain and AE frequency in SFC (ethanol treatment)

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Virtual Platform

Atomic edge guided polyethylene crystallization on monolayer two dimensional materials

Bo LI*
Villanova University

We combine an advance synthesis of two-dimensional (2D) materials (MoSe2) having well-defined atomic edge configurations and with ab-initio and atomistic molecular dynamics (MD) simulations to elucidate how atomic edges interact with polyethylene (HDPE) chains in a dilute solution assembly process. Our results reveal that Mo-terminated zigzag (Mo-ZZ) edges act as preferred nucleation sites and strongly interact with HDPE chains. The HDPE chains align in parallel with the Mo-ZZ edges and form arrays of lamellae that are perpendicular to the edges. Interestingly, atomic edge configurations are observed to dramatically change such interactions. The ab-initio calculation suggests that Se-terminated edges have lower binding energy with HDPE chains in comparison to other edges and that they are not expected to be preferred nucleation and lamellae growth sites. The polymer assembly process was simulated through molecular dynamics simulations, which demonstrate the nucleation and propagation of HDPE crystallization on the monolayer of MoSe2 with crystalline polymeric chains aligned with the Mo-ZZ edge. The crystallization discrepancy at different edges was demonstrated on the same piece of MoSe2 with different types of edges. Following the Mo-ZZ edge preferred nucleation principle, controlled long-range alignment of HDPE lamellae can be realized by creating multilayer MoSe2 with parallel atomic steps. This research opens a pathway toward an atomic level understanding of polymer- 2D nanomaterial interactions. It also bridges the gap between atomic-level and long-range mesoscopic structures and introduces a novel strategy for long-range structural control of composite.

Key words interface, atomic structure, polymer, nanomaterials, composite

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Multi-Functional Smart Composites

Presenting Type: Oral-Virtual Platform

GROWTH MONITORING OF MODE II DELAMINATION BY RAYLEIGH SCATTERING-BASED SENSORS

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1. Kochi University of Technology
2. Sinfonia Technology Co., Ltd

1 Introduction

Rayleigh scattering-based optical fiber distribution sensor, which has a high spatial resolution of 1 mm and a wide measurement range, has been developed in recent years. In this paper, in order to construct an identifying method of FRP delamination, ENF tests were conducted. The acquired strain distribution were compared to delamination shape obtained by visual inspection and FEM analysis.

2 Experiment

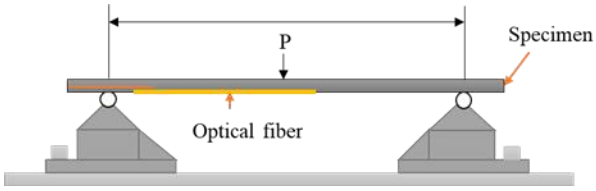
The strain distribution was measured using a Rayleigh scattering based distribution sensor (ODiSI A-50, LUNA Technologies). The minimum gauge length and spatial resolution of the system used in this paper is 1 mm, and the strain resolution is 1 με.

Figure 1 illustrates set-up of ENF test for mode II delamination growth monitoring. GFRP laminates were used for observation delamination shape from surface. The initial delamination tip has some angles against width direction and single optical fiber sensor area attached to two different positions as illustrated Fig. 1(b).

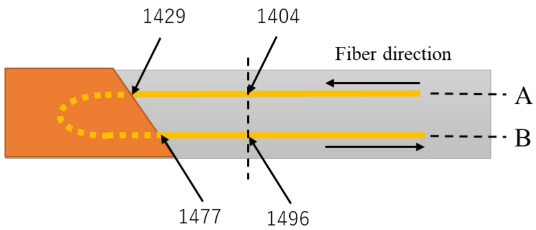
3 Result and discussion

The figure 2 shows Surface strain distribution measured by an optical fiber sensor and FEM during ENF test of GFRP laminates. The orange and blue lines indicate distribution when the crack lengths by the visual inspection were [25 and 31 mm] and [33 and 36mm], respectively. From the figure, it appeared that measured strain distribution shape (solid line) was agreed with FEM results (dotted line). It was found that the peak position of strain distribution moved when the delamination grew. Table 1 shows peak position measured by an optical fiber sensor and a FEM. It appeared that the peak position by the sensor agreed well with that by FEM analysis. Therefore, it can be considered that the peak of surface strain distribution is useful for identifying a mode II delamination edge of GFRP laminates.

Key words Delamination identification, Mode II delamination growth, optical fiber, Rayleigh scattering, strain distribution



(a) Side view



(b) Bottom View

Fig.1. set-up of ENF test for mode II delamination growth monitoring

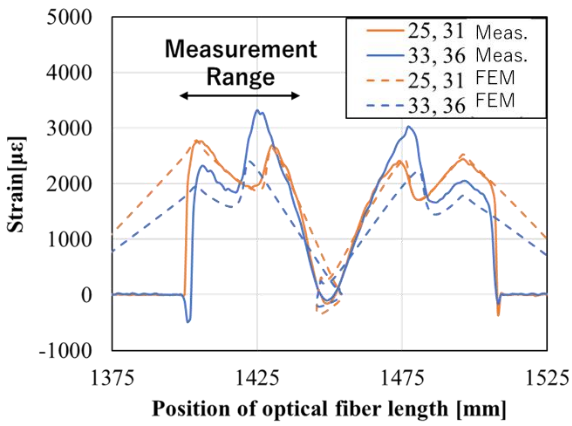


Fig.2. Surface strain distribution measured by an optical fiber sensor and a FEM during ENF test of GFRP laminates.

Table 1 Peak position measured by an optical fiber sensor and a FEM

	A	B	A	B
Delamination length [mm]	25	31	33	36
Peak position by sensor [mm]	1430	1474	1425	1477
Peak position by FEM [mm]	1430	1476	1422	1480
Error [mm]	0	2	3	3

Session: Multi-Functional Smart Composites

Presenting Type: Poster

The mechanical characterization of shape memory composite reinforced with carbon fiber cloth and shape memory alloy wire

Yichuan Shao*、Faxiang Luo、Shibin Song、Xin Xue
Fuzhou University

The low recovery force of shape memory polymer (SMP) makes it difficult to satisfy the practical requirement of engineering applications. To cope with this issue, a novel shape memory composite (SMC) with relative low density of 2.0x10^3 kg/m^3 and high recovery force was manufactured by reinforcing epoxy-based SMP with carbon fiber cloth and SMA wires via the vacuum assisted resin infusion (VARI) method. The effect of wire diameter and its arrangement density on the energy storage modules, shape recovery speed, and shape recovery moment of the SMC was investigated by DMA and bending shape recovery test. With only a 10% increase on the density, the SMC reinforced with SMA wires is enabled to achieve a maximum energy storage module of 1.67Gpa which is 3 times higher than that of the SMC without SMA. On the other hand, the increased wire diameter and density of the embedded SMA leads to uncoordinated deformaion between the carbon fiber reinforced SMP and SMA, which decreases the shape recovery speed to some extend. However, the shape recovery moment of the SMCs reinforced with SMA wires is found to reach a maximum value of 285.2N.cm, which is 3 times higher than that of the SMCs without SMA. The results show that SMC with high energy density can be manufactured without sacrificing its light weight by reinforcing the CFRP with SMA wires, which make it suitable for the aerospace applications such as morphing wings and space foldable mechanisms.

Key words shape memeory composite, shape memory alloy, shape recovery moment, light weight, aerospace application

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Liquid metal/TPU mat with aligned wavelike structure for wearable electronic skin and self-powered sensing

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Zhengzhou University

School of Material Science and Engineering, Key Laboratory of Materials Processing and Mold (Zhengzhou University), Ministry of Education, Zhengzhou University, Zhengzhou, Henan 450001, China

For smart and flexible electronics, wearable mat sensors with excellent sensing performance and durable property are urgently desired. Nevertheless, it remains a challenge to fabricate portable, multi-functional and easy to large-scale manufacturing flexible electronics. Herein, the aligned nano-liquid metal (LM)/polyurethane (TPU) fibrous membrane (ALTFM) was fabricated through the method of electrospinning, coating and pre-stretching. Further, the sensing performances of ALTFM based strain sensor in vertical and parallel directions are investigated detailly. More importantly, ALTFM can be employed for triboelectric nanogenerators (TENGs) as portable and self-powered electronic device. Meanwhile, single-electrode TENG based on ALTFM (4 × 4 cm2) exhibits an open-circuit voltage of 255 V and a large instantaneous power density of 27.6 mW/m2. Hence, stimulus-response electronics have potential in diverse applications of human movement detection, human-machine interaction, artificial muscle and prosthetics.

Key words liquid metal (LM), aligned fibrous mat, electrospinning, triboelectric nanogenerators (TENGs)

Session: Multi-Functional Smart Composites

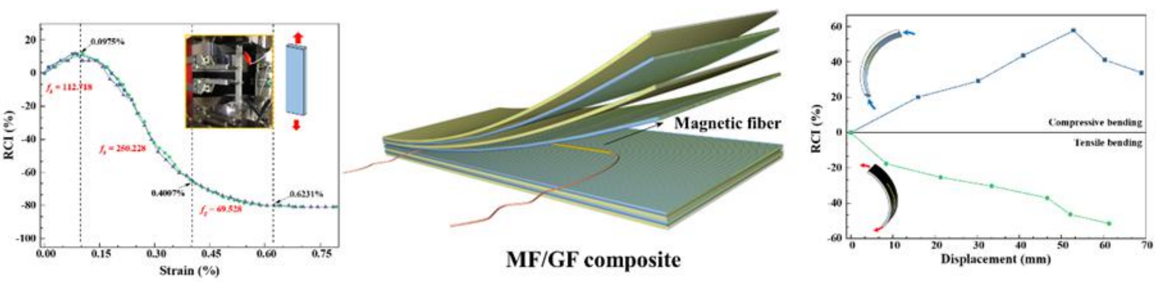
Presenting Type: Poster

Ultra-sensitive in-situ monitoring and smart bending recognizing of fiber-reinforced polymer composites with embedded magnetic fiber

Tangfeng Feng、Faxiang Qin*
Zhejiang University

Multifunctional composites realized by embedded sensing materials draw much attention to structural health monitoring applications. However, much composites are not able to recognize their strain behavior, meanwhile, the embedding sensing elements lack compatibility with host structures and cause the degradation of the properties. In this work, flexible and tiny magnetic fibers (MFs) as embedded sensing units enable conventional composites to possess intelligent monitoring ability. Combining impedance measurement with mechanical test, the sensing mechanism of MF is elucidated that the stress-sensitivity of MF derives from the natural ferromagnetic resonance induced by its intrinsic magnetic anisotropy. The uniaxial tensile and cyclic loading are executed to investigate the electromechanical response ability and monitoring stability of MF monofilament as a sensing element. Then, MFs are embedded into glass fiber (GF) reinforcement composite to realize multi-functional MF/GF composites with self-sensing capability, which also does not deteriorate its original mechanical properties. The MF/GF composites inherit high strain sensitivity with a maximum gauge factor of 376, and simultaneously exhibit the ability of bending orientation recognition and damage detection. Therefore, the MF as a low invasive and embedded functional fiber have great potential to realize self-sensing ability of fiber-reinforced composites, which find particular priority application in pressure vessels and pipes.

Key words Multifunctional composites; Magnetic fibers; Stress-impedance effect; Structural health monitoring.



Session: Multi-Functional Smart Composites

Presenting Type: Poster

Flexible capacitive sensor based on ionic liquid microcapsules for wearable tactile sensing

Yanlin Chen、Faxiang Qin*
Institute for Composites Science Innovation (InCSI), School of Materials Science and Engineering, Zhejiang University

Conventional tactile sensors are typically rigid restricting various natural body movements and subjected to plastic deformation and failure under pressure which compromise their conformability and durability. As an alternative, here we exploit the fluidity of ionic liquid (IL) which was tactically encapsulated within a polyurea (PU) shell before being directly incorporated into flexible water-borne polyurethane (WPU) matrix. This approach not only ensured IL stability in the composite by preventing leakage but also enabled low dielectric losses beneficial for low-power consumption. Such design yielded high sensitivity (0.083 kPa-1), fast response (40 ms), wide operation range (0-40 kPa) and excellent stability under cyclic pressure (3000 cycles). The sensor also demonstrated application potential on robot gripping, e-skin and real time motion detection as experimentally validated by accurately detecting pressure distribution and perceiving real time signals and hand motion. In addition to these salient features, our flexible sensor exhibited long-term sensing stability under complex environments, particularly addressing the issue of poor washability of liquid-based sensors upon repeated washing. As such, IL@PU/WPU capacitive sensors not only meet the low-power but washability requirements of wearable devices.

Key words ionic liquids; microcapsule structure; wearable devices; low-power capacitive sensors

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Triboelectric Nanogenerator Based on Template-assisted Electrospinning of Microhump Structures for Energy Harvesting and Tactile Sensing

Meijie CUI*、Wei ZHAI、Kun DAI、Guoqiang ZHENG、Chuntai LIU
Zhengzhou University

Triboelectric nanogenerators have emerged as the perfect choice for energy harvesters and tactile sensors owing to their ability to harvest energy during daily activities and to convert external tactile stimulation into electrical signals in real-time without the need for a power source. The introduction of micro-/nano-textures on the active layer in the triboelectric nanogenerator to increase the effective contact area is an effective strategy to improve its output performance. However, it is huge challenge to fabricated triboelectric nanogenerator in mass due to high equipment costs and complex processes, which limit its practical and industrial applications. Here, a facile, low-cost, and scalable method is employed to prepare triboelectric nanogenerator with surface microhump array structures for energy harvesting and tactile sensing. Besides, the open-circuit voltage, short-circuit current, and instantaneous output power density of triboelectric nanogenerator are 123 V, 1.7 μA, and 122 mW/m^2, respectively. Meanwhile, the triboelectric nanogenerator possesses a high sensitivity of 15.94 mV/Pa and a fast response/recovery time of 76 ms and 58 ms, respectively. Conclusively, it has proven to have a wide range of application prospects in writing recognition, material recognition, intelligent information transmission, and pulse monitoring.

Key words Triboelectric nanogenerator; Template-assisted electrospinning; Microhump; Energy harvesting; Tactile sensing

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Study on Chemical Flow of Mineral Polyurethane Grouting Reinforcement Material

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wll06077@163.com

Polyurethane grouting reinforcement material, which has excellent performance of rapid curing, high strength, strong adhesion, and good flexibility, has been widely used in the fields of pre-reinforcement of large mining height working face, fracture and crush belt in the coal mine and etc. However, the lack of related system research on the microstructure evolution mechanism in the process of "dynamic" in high-pressure grouting, especially under the interaction of shear field and coal rock heat conduction, leading that such material still is in a“black box”state in the application process and hindering the technical optimization and further expansion of the application scope.

In this study, Rotational Rheology-Fourier Infrared combined equipment is utilized for the flow simulation of slit grouting. The synchronous variation of functional groups and dynamic rheological behaviors of polyurethane grouting reinforcement materials were preliminarily explored, as shown in Fig. 1. In addition, the experimental results showed the curing time of the material was shortened with more PMDETA addition at 10°C.The curing time is 120 min without PMDETA and 30min with 5‰PMDETA. This study has positive significance for expanding the research of reactive polymer grouting materials from“static” to“dynamic” and opening the application of the “black box”.

Key words Polyurethane grouting reinforcement material; Shear field; Chemo-rheological behavior

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Preparation and performance of thermal insulation load bearing integrated thermoplastic composite corrugated sandwich panel

Jingwen Li*、Yiliang Sun、Yixuan Song、Yinghui Ding
Beihang University

Lightweight design, which could improve structural efficiency and reduce carbon emissions, is a hot research area. Fiber-reinforced polymer composites have the advantages of light and high strength, and have been widely applied in aerospace, military machinery and other fields. Thermoplastic composites have excellent toughness and impact resistance and have a bright application prospect in the military and civil fields. The corrugated sandwich structure has excellent weight reduction property, bending resistance and designability, also could be functional by making fully use of the corrugated cavity space. In this paper, based on the original excellent mechanical bearing and weight reduction performance of the corrugated sandwich panel, the design of thermal insulation function is carried out. Corrugated sandwich panels with different filling materials were prepared by the molding method. The thermal insulation and flat compression properties of corrugated sandwich panels were tested by experiments. After filling, the flat compressive strength of the corrugated sandwich plate can reach 1.82 MPa, and the thermal conductivity can be as low as 0.04 W/mK.

Key words Thermoplastic Composite; Corrugated Sandwich Panel; Thermal Insulation; Mechanical property

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Thermally conductive polymer composites with oriented anisotropic filler: Heat conduction mechanism study using multiscale simulation

Dongliang Ding*、Yanhui Chen
Northwestern Polytechnical University

In the present 5G era, heat accumulation in devices has become a serious problem, which highly shortens the service life of modern high-performance devices, and even causes fire hazards. Thermally conductive polymer composites with high in- and through- plane thermal conductivity (λ) have been successfully used as thermal management materials (TMMs) to dissipate that excess heat. To endow the TMMs with outstanding through- or in- plane *λ*, constructing vertically or horizontally oriented anisotropic fillers networks as directed thermal paths are necessary.

Polydisperse h-BN (ae-BN) /PI composites with superior in-plane *λ* (30 vol% ~ 6.57 W/(m·K)) were fabricated via vacuum-filtration and hot-pressing methods. Our iterative EMT model based on the first principles investigation of the intrinsic *λ* of ae-BN demonstrated that ae-PN/PI composites possessed reduced thermal boundary resistance due to the more thermal paths at higher filler loading.

In addition, silicone rubber composites with vertically oriented magnetic carbon fibers (o-MCF/SR) were successfully prepared via the filler orientation upon uniform magnetic field. To reveal its underlying through-plane heat conduction mechanism, finite-element simulation combined with classical effective medium theory was used. A new parameter, *i.e.*, shape factor, indirectly reflecting the assembly of matrix and anisotropic fillers, was introduced here. Finally, at a 9 vol% MCF loading, the o-MCF/SR composite exhibited a maximum through-plane *λ* of 4.72 W/(m·K) and minimum shape factor (0.0077).

However, the isolated and discontinuous thermal paths are the bottleneck for its high efficiency heat conduction. Take the prepared vertically aligned SiC fibers (SiCFs) entangled by SiC nanowires (SiCNWs) networks /SR (VA-SiCFs/SR) composites as an example. The relevant heat conduction mechanism was studied by finite-element simulation based on the first principles investigation of SiC. A cooperative enhancement mechanism, of "through-plane long-range continuous thermal path" and its concomitant "in-plane thermal spreader" on the thermal conductivity of polymer composites, was put forward.

Key words Polymer composites; Thermal conductivity; Heat conduction mechanism; First principles; Finite-element simulation.

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Fiber-based strain sensor with multiple microstructures and ultrawide sensing range for strain visualization and wind monitoring

Xinxin Zhao*、Wei Zhai、Guoqiang Zheng、Kun Dai、ChunTai Liu
ZhengZhou university

Flexible strain sensors show great application prospects in the medical treatment, electronic skin, environmental monitoring and other fields due to its great flexibility, ductility, skin-mountability and other characteristics. However, the inherent contradictions between the high sensitivity and wide sensing range limit the further development of flexible strain sensors, thus there is an urgent need for a way to solve this challenge. Herein, an easy-to-operate twice pre-stretching strategy was proposed, in addition the wrinkle and crack structures were successfully integrated into one fiber-based strain sensor. Benefiting from the synergistic structure of the conductive layer, the strain sensor simultaneously possesses ultrawide sensing range (up to 530% strain), high sensitivity (up to 158), low detection limit (0.5% strain) and satisfactory sensing stability and durability (more than 1000 stretching/releasing cycles). Moreover, strain visualization of the strain sensor under UV light was also realized because of the excellent UV-shielding property of the CNTs conductive layer and the exposure of FA in matrix fiber during the crack propagation process. Finally, the fiber-based strain sensors can be used for human bio-signals acquirement as well as the monitoring of wind direction and wind force, showing its broad application prospects.

Key words Flexible strain sensor; Crack; Wrinkle; Strain visualization; Wind monitoring

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Preparation and properties of high dielectric polyimide composites

Zhiqiang Wu*、Yanhui Chen
Northwestern Polytechnical University

In the work of this project, we explore the influence of nano-filler modification and multilayer composite process on the dielectric properties (dielectric constant, dielectric breakdown strength, energy storage density, etc.) of polyimide (PI) matrix composites, and study the thermal stability and mechanical properties of PI composites. Firstly, dopamine-coated barium titanate nanoparticles (PDA@BT) are modified and compounded with PI. The core-shell structure of PDA@BT is used to improve their dispersion uniformity in PI, which can alleviate local electric field distortion inside the material, enhance the interface polarization strength and improve the dielectric constant and breakdown strength of PI composite film. Secondly, the amino modified MOF particle (UiO-66-NH_2) is compounded with PI. PI composite films has high dielectric constant and low dielectric loss due to the high charge density of the coordination molecule, polarization between the central zirconium atom and the oxygen atom ligand, and good dispersion of UiO-66-NH_2 between the polymer matrix. Meanwhile, ZrO_2 is formed by thermal decomposition of UiO-66-NH_2 in the process of thermal imination. The PI composite film has high dielectric constant and breakdown field strength due to the introduction of UiO-66-NH_2 into PI as the carrier of ZrO_2. Finally, the sandwich structure PI-BNNS-PVDF composite film is prepared by stepwise flow-casting method. With the increase of BNNS content in the intermediate layer, the dielectric constant of the composite film gradually increases, and the breakdown strength shows a trend of first increasing and then decreasing. The above PI composites maintain good thermal stability and mechanical properties.

Key words Polyimide; Composite materials; Filler modification; Multilayer structure; Dielectric properties

Session: Multi-Functional Smart Composites

Presenting Type：Poster

Graphene/Mxene Inks for Embedded High-Performance Piezoresistive Sensors in FRP Composites

Anchalee Duongthipthewa、Limin Zhou*
Southern University of Science and Technology

Fiber-reinforced polymer (FRP) composites have been applied in different fields such as building, automobiles, robots, and aircraft due to their high strength and weight ratio. Sensors with high sensitivity and reliability are in high demand for monitoring the condition of composite structures and detecting the motion of the devices. There are two types of sensor installation in the composites, which are surface mounting and internal embedding. Surfaced-mounted sensors are easy to install and maintain, while internal sensors embedment could offer better signal acquisition accuracy. However, it is still a great challenge to develop the embedded high-performance sensor in FRP without sacrificing mechanical properties due to the high stress concentration at the end of the resin pocket of the thick sensor and poor interface interaction between sensor and fiber prepreg. In this work, an embedded ultra-thin piezoresistive sensor based on water-based Graphene/MXene (GMX) ink is fabricated in the FRP composites with a simple and reproducible large-scale fabrication process. The morphological characteristics of the GMX ink and embedded sensor are observed by SEM, XRD, XPS, and RAMAN. Highly sensitive and integrable sensors are obtained using the porous structure and the synergistic effect of 2D graphene and MXene nanomaterials. The incorporation of GMX sensors does not affect the structural geometry and mechanical properties, demonstrated by tensile strength and inter-laminar shear strength. FRP composites with sensor integration are then tested over 10,000 and 1,000 cycles in tension and bending providing excellent cycling stability. The embedded sensors also successfully detect low frequency of mechanical vibration (100-3,000 Hz). These embedded high-performance sensors in FRP composites with a simple and scalable fabrication have shown great potential application for monitoring the composite structural conditions and in real-time motion detection such as machine tools.

Key words Graphene, MXene, piezoresistive sensor, FRP composites

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Functionalized Nonwoven Sensing Composites and Their Multifunctional Applications

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1. Zhejiang Sci-Tech University
2. University of Delaware

Carbon Nanotubes (CNTs) are one of the most popular carbonaceous materials and have been extensively studied in the past two decades due to their extraordinary physical, electrical and chemical properties. In addition, apart from the conventional usage of CNTs as composite nanofillers for structural reinforcement, recent advances in CNT-based composites have demonstrated broad potential of utilizing them as multifunctional sensors because of their unique electrical properties, which have been becoming the emerging center of interest in academic research and proven to possess great potential for industrial applications. Here, we introduce a series of CNT-functionalized nonwoven sensing composites that possess excellent application scalability, customizability, and conformability. In specific, a thin, porous nonwoven fabric was selectively utilized as the CNT carrier and then hybridized with CNTs following an economic, facile water-based impregnation method. Particularly, the locally integrated CNT coating establishes a broad piezoresistive network that is highly sensitive to both physical and chemical stimuli, simply enabling a large-area versatile sensor. In this presentation, we highlight and demonstrate the multifunctional applications of the CNT-functionalized nonwoven sensing composites as *in situ*, real-time sensors for strain monitoring, spatial damage detection, large-scale structural health monitoring, pressure sensing and mapping, process monitoring of manufacturing fiber composite, and temperature sensing. Both one- and two-dimensional sensing applications are demonstrated.

Key words Carbon Nanotube, Nonwoven Sensing Composite, Multifunctional Applications

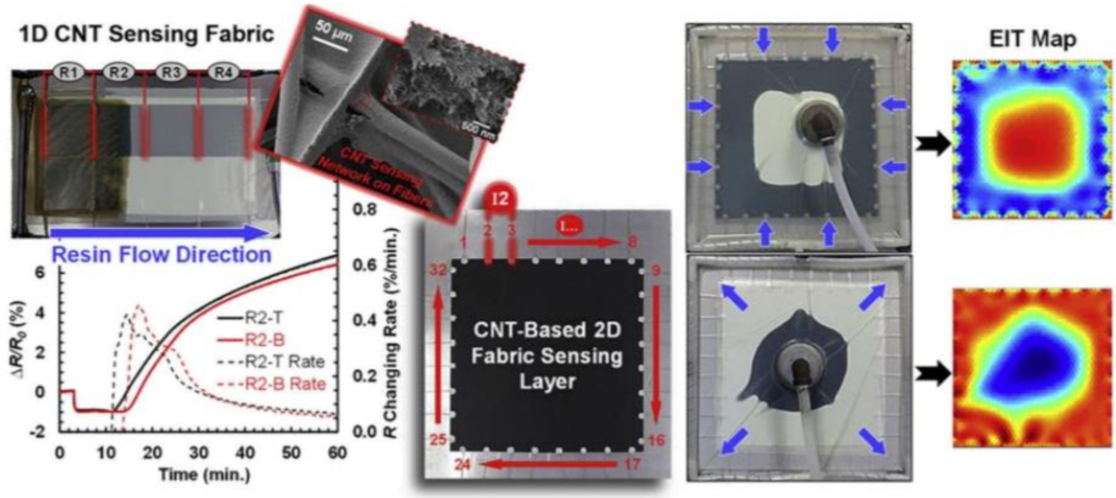

Fig. 1. The distributed CNT-functionalized nonwoven composite sensors for monitoring the VARTM process of manufacturing GFRP composite panels.

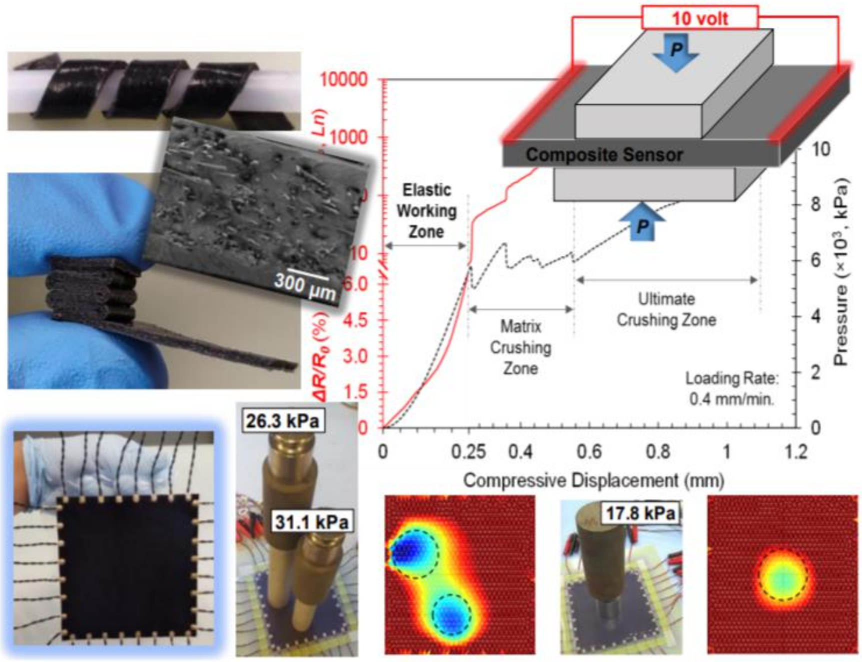

Fig. 2. The CNT-functionalized nonwoven flexible composite sensors for pressure sensing and mapping.

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Facile manufacturing of Ni/MnO nanoparticle embedded carbon nanocomposite fibers for electromagnetic wave absorption

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A type of nickel/manganese oxide (Ni/MnO) /carbon nanocomposite fibers were prepared via a facile and scalable electrospinning and carbonization approach. In comparison to the pure carbon showing a severe agglomeration, the uniformly embedded MnO and Ni nanoparticles promoted the formation of the fibrous carbon-based nanocomposites with an average diameter of 250 nm and a rough surface. The synergistic coactions of the MnO nanoparticles acting as impedance modulating mediator, the magnetic Ni nanoparticles, and the conductive, fibrous carbon with large aspect ratio and rough surface contributed to the excellent electromagnetic wave (EMW) absorbing performance of the nanocomposites. The nanocomposites with a MnO/Ni ratio of 1:1 exhibited an effective absorption bandwidth of 6.5 GHz at a thickness of 2.9 mm and a minimum reflection loss of −53.23 dB at a thickness of 2.3 mm. The EMW absorption mechanisms of the nanocomposite fibers were discussed at length, which showed the importance of the multi-component building units and microstructure for achieving high EMW absorbing performance. This work thus suggested a convenient, facile, and scalable manufacturing approach for constructing high-performance multi-component nanocomposite fiber based EMW absorbing materials.

Key words nanocomposite; microwave absorption; electrospinning; carbon, metal nanoparticles

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Preparation of Highly Stretchable Conductive Polyacrylamide-Gelatin Hydrogels for Wireless Wearable Devices

Minghua TIAN*、Wei Zhai、Kun Dai、Guoqiang Zheng、Chuntai Liu
Zhengzhou University

Conductive hydrogels have shown great potential applications in a wide variety of fields, including artificial intelligence devices and biomedical engineering. Herein, we synergistically constructed a double-network hydrogel as a flexible polymer matrix by using acrylamide as a monomer to synthesize a chemically cross-linked network and a gelatin-based physical cross-linked network. By using high aspect ratio AgNWs as conductive fillers, the PGA hydrogel exhibits a wide strain sensing range (0-1649%) and high sensitivity (gauge factor, GF=1.36). Furthermore, during the cycling response, the PGA hydrogel exhibited good cycling durability (800 cyclic stretch-recovery tests). With the elastic and conductive virtues, the PGA hydrogel is an optimal candidate for fabricating a wearable and real-time human-motion monitor, meanwhile, wireless monitoring could also be realized with a smartphone through Bluetooth transmission. This study provides a new idea for fabricating flexible wearable strain sensors with a wide sensing range and high sensitivity. Furthermore, the biocompatibility and easy to form property of the PGA hydrogel would be expected to be applied to human organs.

Key words conductive hydrogel, Ag nanomaterials, Flexible strain sensor, Polyacrylamide, Gelatin

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Application of ferroelectric composite in energy storage devices

Fan Ye*、Xin-Gui Tang
Guangdong University of Technology

With the development of large-scale integrated systems, silicon-based devices that meet the miniaturization requirements have attracted wide attention in the field of thin-film capacitor research. The ferroelectric polarization can be optimized because of lattice distortion and structural transformation induced by A-site or B-site doping of ferroelectric materials. Therefore, ferroelectric composites have a great advantage in building superior energy storage and high efficiency thin film capacitor devices. We designed thin film capacitor dielectric layers by doping barium titanate Ba(1-x)CexTiO3 composites. The MFM (Metal- Ferroelectric- Metal) structured film capacitors are directly integrated on silicon substrates, thus exhibiting ultra-high storage density (Wrec) and efficiency (η). In this work, we significantly improve the electric breakdown strength by tuning the Ba0.95Ce0.05TiO3 film thickness, which leads to excellent energy storage performance at super high voltage. The results expand the application of ferroelectric composites in the field of energy storage devices.

Key words Ferroelectric composites; Ce-doped BaTiO3; Thin film capacitors; Energy storage performance

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Constructing Stretchable Tribopositive Yarn Through Electrospinning for Energy Harvesting and Underwater Sensing

Suya Hu*、Wei Zhai、Kun Dai、Guoqiang Zheng、Chuntai Liu
Zhengzhou University

Triboelectric nanogenerators based on fiber/yarn have aroused tremendous attentions owing to their merits of good shape-adaptability and weavability. However, it is still a challenge to simultaneously achieve wearing comfort, stretchability, and high output performance. Here, a stretchable triboelectric positive fiber （TPF） with coaxial structure was designed by electrospinning technology; TPU fibrous film in the skin layer and the conductive helical silver yarn in the core layer of TPF were employed as friction material and the electrode, respectively. Meanwhile, they endow the triboelectric yarn with good charge transfer/accumulation ability, breathability and stretchability. As a result, the yarn TENG works in the single-electrode mode can achieve an open circuit voltage of 16 V and a maximum power density 11.8 μW/m and the output performance showed weak change after undergoing various deformations. In additional, the fiber mats woven by yarn could be used to drive electronic devices. The pressure sensors based on the TPF have potential prospects in motion monitoring and human-machine interactions under water.

Key words Electrospinning; Fiber triboelectric nanogenerator; Stretchable; Underwater sensing

Session: Multi-Functional Smart Composites

Presenting Type: Poster

Synaptic devices based on memristors :new chance and challenge

Jiaying CHEN*
School of Physics and Optoelectric Engineering, Guangdong University of Technology

The traditional von Neumann computing system is facing great challenges. With the data explosion in the intelligent era,the traditional computing system has high consumption and slow speed and the feature size of the chip is limit due to the end of Moore's Law. It is a problem to be solve in storage and computing. Compared to the von Neumann computing system, the neural computing system has superior performance in consumption and speed,which caused a huge attention in artificial intelligence area. Synaptic devices based on memristors are basic components in the neural computing system. The functional realization of neural computing depends properties of synaptic devices similar to biological neuron. It is possible for synaptic devices based on memristors to simulate various neuronal activities, such as long-term and short-term plasticity. However, instability of memristors also influence the development of the neural computing system.

Key words synaptic devices， neural computing system， memristors

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Dense and intense Cu^{2+}-doped char to protect flammable polymers

Mingjun CHEN*、Lei He、Jia-Lin He、Ting Wang
Xihua University

Obtaining intumescent char with continuous porous structure and mechanical strength is the key point to enhance the flame retardance and smoke suppression for flammable polymers. Herein, a novel Cu^{2+}-doped intumescent flame retardant (IFRs) is designed to realize the synchronization between carbonization and gas release for obtaining an intumescent char foam with continuous porous structure and extremely high mechanical strength. This char can hold up to 2,000 times its own weight. Additionally, the Cu^{2+} doped IFR also improve the compactness and mechanical strength of epoxy resin, resulting in the peak heat release rate, total smoke production, and fire growth rate are reduced by 70%, 53%, and 75% compared with pure EP, respectively. Interestingly, Cu^{2+}-doped polyelectrolyte complex coating can endow highly flammable nylon-cotton blends fabrics with excellent flame retardancy. It is also due to that a compact intumescent char layer is formed. Our work provides a new strategy for designing intumescent flame retardants to enhance the flame retardancy and smoke suppression of polymers by formation of dense and intense metal-doped char.

Key words intumescence, compactness, flame retardancy, smoke suppression, polymers

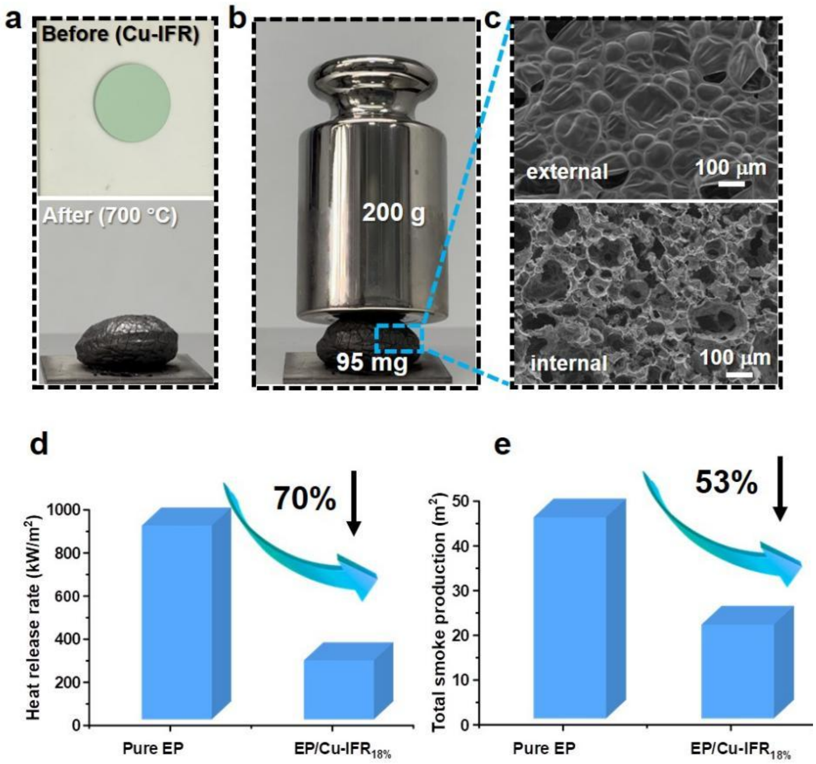

Fig. 1. Cu^{2+}-doped intumescent flame retardant epoxy resin.

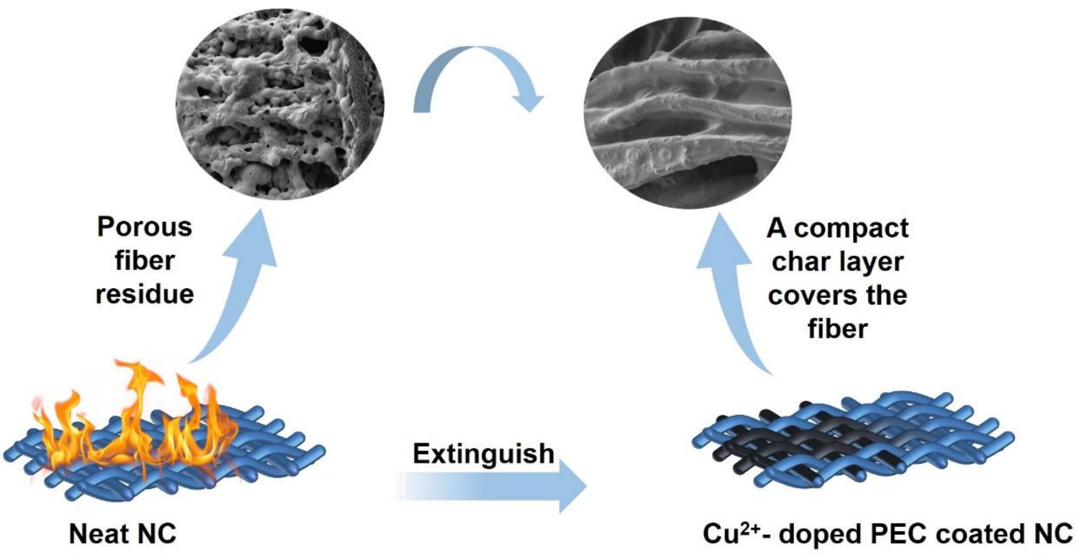

Fig. 2. Cu^{2+}-doped intumescent flame retardant nylon-cotton fabric.

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Fire-Safety Thermal Energy-Storage Materials And Their Applications

Cong DENG*、Pan-Pan Zhao、Yu-Zhong Wang
Sichuan University

Organic phase change material (PCM), as a latent heat storage medium that can realize the storage and release of thermal energy through the transformation of solid-liquid phase state, can alleviate the low efficient energy utilization faced by building materials. However, when organic PCM is used in building materials, its flammability will further worsen the fire risk of building materials. At present, the main way to improve the fire safety of organic PCM is to add flame retardants. However, the addition of flame retardants has a serious negative impact on the energy-storage density and long-term fire safety of organic PCM. Preparing intrinsically flame-retarded PCMs or encapsulated PCMs with flame retardants should be effective methods to overcome above problems. So far, no commercial building material which simultaneously takes into account fire safety and phase change energy storage has been developed. In our work, starting from the molecular structural design, we incorporated phosphorus/nitrogen flame retardant elements into molecular chains of PCM or the supporting framework of PCM, and prepared a series of fire-safety thermal energy storage materials, including Schiff Base-containing PCM, ionic liquid PCM, composite layered double hydroxides-based PCM, etc. Different measurements were used to illustrate the physical and chemical structures of these PCMs. Then, these PCMs were applied to fabricate flame-retarded thermal energy-storage wood plastic composites (WPCs). Further, flame retardancy, temperature-regulating ability, mechanical properties, thermal stability, etc., were investigated deeply for these WPCs. Finally, corresponding mechanisms concerning flame retardancy, leak proof and high thermal energy storage were discussed in detail. The work presented here may provide some insightful thoughts into fire-safety thermal energy-storage materials.

Key words Flame retard, Wood plastic composite, Thermal energy storage, Phase change material

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Flame-retardant and Superamphiphobic Multifunctional coatings with Environmental Adaptability

Fang WANG*、Fei Song、Yu-Zhong Wang
Sichuan University

To meet the growing demands of multifunctional coatings in complex service surroundings that require fire safety, developing flame-retardant coatings with integrated environmental adaptability is urgently needed. Here, a flame-retardant and superamphiphobic multi-functional coating, consisting of functionalized nanoparticles and micro-sized ammonium polyphosphate particles is constructed, which can be universally applied for a wide range of substrates. By virtue of a simple and cost-effective spaying approach, a unique randomly overhanging re-entrant and hierarchical structure can be constructed, showing superhydrophobic/superoleophobic, self-cleaning, flame-retardant properties and environmental adaptability. The created surface demonstrates extremely high stability under exposure to strong corrosive chemicals, namely aqua regia, concentrated sulfuric acid and sodium hydroxide, cyclic mechanical abrasions, and heat treatment. More importantly, such coating offers high flame retardancy and self-extinguishing property to flammable substrates. Featuring with easy processability, multi-functions and high endurance, the coating is promising for applications in advanced functional textiles, architecture, infrastructure and transportation facility, etc.

Key words Flame-retardant; Superamphiphobic; Multifunctions; Environmental adaptive

Session: Thermal Fire Retardant Composites

Presenting Type：Oral−Invited

Strong Yet Tough Epoxy with Superior Fire Suppression Enabled by in-situ formed DOPO-Based Diels-Alder Network

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1. China-Spain Collaborative Research Center for Advanced Materials (CSCRC), School of Materials Science and Engineering, Chongqing Jiaotong University, China
2. IMDEA Materials Institute

The synchronized improvement of strength, toughness and fire suppression poses to be a critical trade-off issue towards high-performance epoxy resin. Aiming to impart epoxy with balanced multifunctional improvement, the Sciff-derived bio-based phosphaphenanthrene small-molecule reinforcer towards in-situ constructed Diels-Alder nodes within existing 3D network was proposed. The incorporation of 3.5wt% reinforcer (CQ-DOPO) concurrently enhanced the tensile strength and unnotched impact strength of epoxy by 26.6% and 48.4% to 70.9±13 MPa and 13.8±0.6kJ/m2 without notable deterioration of transparency. The accompanied increment of glass transition temperature by 14oC via dynamic mechanical analysis was observed. The underpinning experimental and simulation investigation verified the proof of concept of in-situ formed Diels-Alder sacrificing nodes towards higher crosslinking density and strong-weak dual network. In parallel, the 3.5wt% CQ-DOPO with an ultralow phosphorous loading of 0.245wt% enabled to impart epoxy matrix with UL-94 V-0 rating as well as limiting oxygen index of 32.0%. The multi-scale dual-phase analysis unveiled the synchronized suppression of fire reactions in vapor phase via PO· quenching as well as in condensed phase via char microstructure optimization. Following this rule, the borate-containing DOPO-based small-molecule reinforcers were prepared with highly efficient flame retardancy (2wt% V-0), mechanical robustness and toughness. In perspective, the rational strategy via in-situ construction of phosphaphenanthrene sacrificing bond toward dual network exploits a novel roadmap for balancing fire suppression, strength and toughness of polymers.

Key words Epoxy; Fire Suppression; Strength; Toughness; Diels-Alder

Session: Thermal Fire Retardant Composites

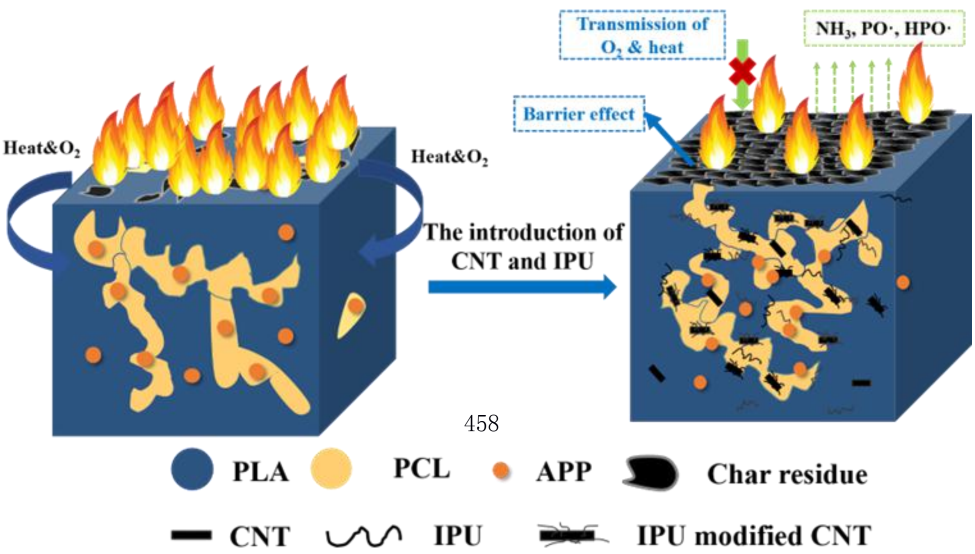
Presenting Type: Oral-Invited

Improving flame retardant and EMI shielding properties of PLA/PCL composites using catalytic imidazolium modified CNTs and ammonium polyphosphate

Pei XU*、Zhengfeng Wang
Hefei University of Technology

The flame retardants and electromagnetic interference (EMI) shielding performance were enhanced by using imidazolium-functionalized polyurethane (IPU) modified multi-walled carbon nanotubes (CNTs) and ammonium polyphosphate (APP) for polylactic acid (PLA)/polycaprolactone (PCL) composites. The PLA/PCL/10APP/8CNT/1.6IPU composite containing 10 wt% APP and 8 wt% imidazolium modified CNTs reached the limiting oxygen index (LOI) value of 30.3 % and passed the V-0 rating in UL-94 tests. Moreover, the peak of the heat release rate (pHRR) and total heat release (THR) for this composite reached around 302 kW/m2 and 64 kJ/m2, which were decreased by 39.1 % and 15.8 % compared with that of PLA/PCL/10APP composite. The improved flame retardancy was attributed to the interplay of catalytic, barrier, and condensed char forming of imidazolium-modified CNTs and APP. IPU expanded to the phase interface between PLA and PCL as an interfacial compatibilizer and regulated the migration of more CNTs to disperse at the two-phase interface. The dispersion of imidazolium-modified CNTs and co-continuous phase structure of the composites can establish continuous conductive pathways. The PLA/PCL/APP/CNT/IPU composite obtained a higher conductivity than that of the PLA/PCL/APP/CNT composite and whose EMI SE reached 33.9 dB. This work offered a novel methodology for fabricating composites with excellent EMI SE and flame-retardant properties, which were promising candidates for next-generation sustainable and protective plastics.

Key words Polylactic acid; Polymer-matrix composites; Electromagnetic interference shielding; Interface/interphase; Flame retardant



Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Transition-Metal-Based Layered Double Hydroxides (LDHs) toward High-Efficiency Flame Retardancy and Smoke Suppression for Silicone Foam

Bin Zhao*、Lin-Lin Zhou
Qingdao University

Flexible silicone foam (SiF) is a polymeric elastomer with abundant porosity and relatively low density, shows excellent properties of both silicone rubbers and traditional polymeric foams. SiF has a high specific surface area and abundant flammable organic groups on its side chain, resulting to smolder and release smoke during combustion. In this work, two kinds of transition-metal-based layered double hydroxides (LDHs) were designed by adjusting transition-metal-cations (Co2+, Ni2+, Ti4+) with SO42- of interlayer anions (NiCo-LDH-SO42-and NiTi-LDH-SO42-) and successfully fabricated by the chemical coprecipitation methods. The crystal structure, chemical composition and microscopic morphology of the two LDHs were systematically characterized by X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), Inductively coupled plasma optical emission spectrometry (ICP-OES), X-ray photoelectron spectroscopy (XPS) and scanning electron microscopy (SEM). Then, the two LDHs were introduced into SiF by the in-situ foaming process. With only 1 phr loadings, both NiCo-LDH-SO42-and NiTi-LDH-SO42- can endow SiF with higher limiting oxygen index (LOI) values beyond 30% and FV-0 rating for vertical flame testing, demonstrating high-efficiency flame retardancy. Cone calorimeter test and smoke density test were utilized to evaluate the fire behavior and smoke release for SiF/LDHs composites, the results of which showed that the two LDHs can effectively increase the fire safety and smoke suppression of SiF. Finally, the flame retardant and smoke suppression mechanisms of the two transition-metal-based LDHs have been proposed by deep analyses in both condensed and gaseous phases.

Key words Silicone foam; Flame-retardant; Smoke suppression; layered double hydroxides

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Preparation of environmental-friendly and low-smoke flame retardant for rigid polyurethane foams by P-hybrid silica aerogel

Wenhui RAO*、Jie Tao、Tao Wu
Guilin University of Technology

The application of rigid polyurethane foam (RPUF) in the field of building thermal insulation materials is limited because of its high flammability. To overcome this shortcoming, in this study, a phosphorus-containing silane coupling agent (APD) was synthesized firstly by using 3-aminopropylmethyldiethoxysilane (KH-902) and diphenylphosphinoxid (DPO). Then the P-hybrid silica aerogel (m-SA) was prepared via the sol-gel method by combining APD with tetraethoxysilane (TEOS). Afterward, m-SA was functionalized by polydopamine and PPOA to obtain DA@(m-SA). The thermal stability (TG) test showed that the T-5% and T-50% of 15 wt% DA@(m-SA)/RPUF composites were higher than that of neat RPUF, and the char residue rate of 15 wt% DA@(m-SA)/RPUF composites reached 30.3 wt% at 700 °C. Cone calorimetry (CC) test showed that the addition of 15 wt% DA@(m-SA) significantly reduced the peak heat release rate (PHRR) and total heat release (THR) of RPUF composites by 25.0 % and 35.6 % respectively, while the total smoke release (TSP) decreased by 45.9 %, presenting excellent smoke suppression effect. The mechanism analysis confirmed that the existence of organophosphate and Fe irons in DA@(m-SA) associated with the physical barrier of silicon dioxide promoted the formation of P/Fe/Si-hybrid char layer with highly aromatization, thereby improving the fire safety of epoxy matrix. This research offers an effective method for designing high-performance nanocomposites with high fire safety.

Key words Rigid polyurethane foam; Modified silica aerogel; Dopamine hydrochloride; Transition metal; Smoke suppression

Session: Thermal Fire Retardant Composites

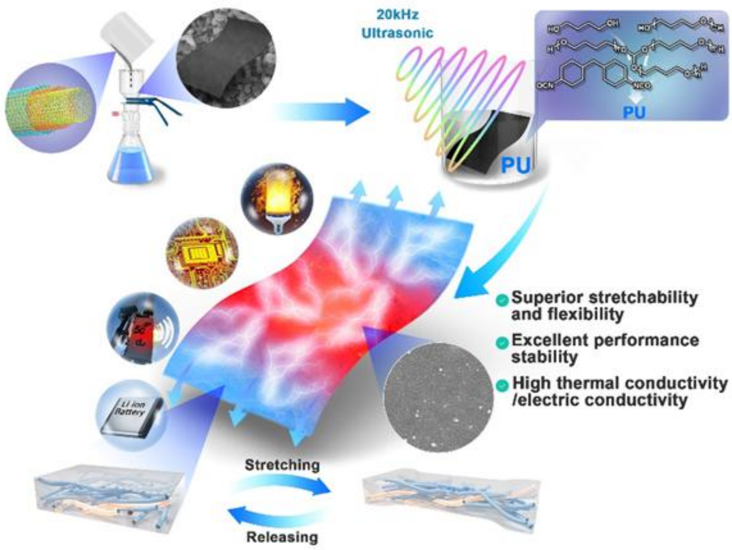
Presenting Type: Oral-Invited

Low Infrared-Emission MXene And Its Application on Radiation Thermal Management

Jingyao SUN*、Daming Wu
Beijing University of Chemical Technology

Due to the rapid development of miniaturization and portability of electronic devices, the demand for polymer composites with high thermal conductivity and mechanical flexibility has increased significantly. The carbon nanotube (CNT)-graphene (Gr)/polydimethylsiloxane (PDMS) composite with excellent thermal conductivity and mechanical flexibility is prepared by ultrasonic-assisted forced infiltration (UAFI). When the mass ratio of CNT and Gr reaches 3:1, the thermal conductivity of CNT-Gr(3:1)/PDMS composite is 4.641 W/(m·K), which is 1619% higher than that of pure PDMS matrix. In addition, CNT-Gr(3:1)/PDMS composite also has excellent mechanical properties. The tensile strength and elongation at break of CNT-Gr(3:1)/PDMS composites could achieve 3.29 MPa and 29.40%, respectively. The CNT-Gr/PDMS composite also shows good performance in terms of electromagnetic shielding and thermal stability. The PDMS composites have great potential in the thermal management of electronic devices.

Key words Ultrasonic-assisted method; Thermal conductivity; EMI shielding; Forced infiltration



Session: Thermal Fire Retardant Composites

Presenting Type：Oral−Invited

Fabrication of high-performance flame-retardant foam-like materials

Hai-Bo Zhao*
Sichuan university

Polymer foam materials are widely used in industry, agriculture, construction, transportation and other fields. However, most polymeric foams are highly flammable in nature, and emit a large amount of deadly smoke and toxic gases in a fire, which poses a serious fire safety hazard. The traditional physical/chemical method of adding flame retardants usually destroys the porous network structure of the foam, resulting in the decline of mechanical and thermal insulation properties. In response to the problem, we developed a series of new technologies for high-efficiency condensed phase flame retardant and smoke suppression and detoxification, which broke through the bottleneck of the traditional gas-phase flame retardant method for deteriorating the release of smoke toxins from materials. These works provided some new ideas and approaches for solving difficult problems in the flame-retardant materials field.

Key words Flame retardant, foam

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Strategic design unsaturated polyester resins composites with excellent flame retardancy and high mechanical properties

Yingming Li*
Chongqing Jiaotong University

Unsaturated polyester resin (UPR) composites with excellent flame retardancy and high mechanical property is a great challenge to its widely application. In present work, a highly efficient flame retardant (MA-DOPO) containing nitrogen, sulfur and phosphorus elements was designed via a nucleophilic substitution reaction of amino and aldehyde groups. For the UPR/MA-DOPO15 composites, its tensile strength was 28.3 MPa, which was 19.9 % higher than that of neat UPR attributing to the formation of hydrogen bonds with UPR. It should be noted that tensile strength of UPR/MA-DOPO20 composites reached the highest 39.6 MPa, showing a growth trend with the enhancement of incorporation amount of MA-DOPO. Meanwhile, the UPR/MA-DOPO15composites passed the UL-94 V-0 rating with a LOI of 27.0%, and the peak heat release rate (PHRR) and total heat release rate (THR) were reduced by 35.1% and 41.6% in cone calorimeter (CC) test comparing to that of neat UPR respectively. Moreover, the detailed flame-retarding mechanism of MA-DOPO was investigated by the thermogravimetric infrared spectroscopy (TG-IR), Raman spectrum, X-ray photoelectron spectroscopy (XPS) and pyrolysis-gas chromatography/mass spectrometry (PY-GC/MS), in which the releasement of inert gas in gas-phase and the catalytic carbonation in condensed phase jointly taking effect.

Key words Unsaturated polyester resin, flame retardancy, mechanical performance, flame-retarding mechanism

Session: Thermal Fire Retardant Composites

Presenting Type: Oral−Invited

High-performance polymer-based thermal management materials

Wei Yang*
Sichuan University

Higher requirements concerning thermal management materials have been put forward in recent years for the employment of a large number of high-power and integrated systems in the important fields of informatization and intelligence, such as high-speed communication, electronic appliances, advanced energy facilities, and new energy vehicles. Generally, thermally conductive fillers are used to improve thermal conductivity of thermal management materials, which inevitably generates heat resistance at filler-matrix and filler-filler interfaces, leading to the phonon scattering and hindering the significant improvement of thermal conductivity. With the innovation of nanomaterials and nanotechnologies, effectively constructing 3D interconnected thermal transfer networks to reduce the interfacial thermal resistance has become a promising strategy for the development of high-performance thermal management materials. Based on the interaction between polymers and thermally conductive fillers, a variety of ordered heat conduction networks were designed and realized using large-scale melt processing technology to minimize interface thermal resistance and phonon scattering, resulting in high-performance thermal interface materials and phase change materials for thermal management applications.

Key words Thermal management materials;

Session: Thermal Fire Retardant Composites

Presenting Type：Oral−Invited

Anisotropic Nanocomposites for Multifunctional Thermal Management

Jianfeng WANG*、Mengke Shi、Lei Li、Yuxuan Zhang
Zhengzhou University

Metals are typical low IR emitters for application in thermal camouflage, infrared stealth, energy-saving heating, but the easy-corrosive, high-density, hard-processability drawbacks seriously hinder their usefulness. Recently, we firstly reported the low infrared (IR) emission characteristic of $Ti_3C_2T_x$ MXene that is comparable to typical metals. MXenes are water/organic solvent soluble with tunable surface chemistry, and can be processed through simple and low-cost approaches, such as spraying, spinning, solution blending, in-situ polymerization, rather than the complex process of metals such as high temperature sputtering. We then demonstrate the application of low infrared-emission MXene and its composites on thermal camouflage, passive radiative heating, efficient photo/electro-thermal conversion. Low IR emitters from MXenes are ideal alternatives to traditional metals, and are highly promising on radiation thermal management.

Key words MXene; low infrared emission; thermal camouflage; infrared heating; photo/electro-conversion

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Molecular-Micron Multiscale Toughening And Flame Retarding for Polyurethane Foams

Furong Zeng、Haibo Zhao、Yuzhong Wang*
Sichuan University

Globally, the frequent fires caused by polyurethane foams (PUF) have raised an urgent demand for fire-safe PUF materials. Existing flame retardants, however, always damage the cross-linking networks of PUF, thus leading to severe deterioration of the dynamic fatigue resistance and toughness of materials. Facing this dilemma, we demonstrate a facile strategy for fabricating phosphorus-based multiscale energy dissipation networks to engineer PUF with superior toughness and fire safety. The designed mono-hydroxyl flame retardant facilitates the in-situ construction of multiscale networks during foaming by employing their polarity/reactivity nature, which consists of molecular scale pendant groups with toughening mechanisms and microscale particles with compatible interphase/reinforcing mechanisms. Notably, the synergistic multiphase networks enable PUF to have an outstanding capability to redistribute/dissipate external stress. Consequently, the resulting flame retardant PUF exhibits greatly improved strength/toughness (+92%) and high deformation recovery ratio (97.3%), avoiding the fragility caused by conventional crosslinked networks or rigid fillers. In addition, the flame-retardant disparity and mechanism of three phosphorus-based molecules with tiny chemical differences were systematically investigated. More phosphorus species with high-energy radical scavenging abilities in gas, given by hydroxymethyl diphenylphosphine oxide (DPM), endow PUF with higher flame-retardant efficiency, which is quite challenging for the other two with P-O bonds. The resulting PUF achieves rapid self-extinguishing with low addition of 1.8 wt% DPM, which is far superior to previous counterparts. This work provides a new enlightening strategy for dramatic improvement in toughness and fire safety of foams, based on synergistic energy dissipation networks spanning molecular and micron scales, showing obvious superiority for practical applications.

Key words Multiscale toughening; Strengthening; Flame retarding; Polyurethane foam

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Ultrasonic-Assisted Method for The Preparation of Polymer Composites with Integrated Thermal Conductivity, Electromagnetic Interference Shielding, And Mechanical Performances

Yongqian SHI*、Kexin Chen、Zixiao Wang
Fuzhou University

Polymers has been widely utilized in the electronic industry, transportation, household and cosmetics. However, polymers are highly flammable and usually generates a great amount of smoke and toxic gaseous species, which are harmful to victims escape from fire. Therefore, developing highly effective flame retardant polymeric materials with the release of low toxic fumes during burning still keep a huge challenge. In response to these challenges, tremendous efforts have been made to improve the flame retardant properties of polymeric materials by adding nanofillers.

Our group successfully synthesized a series of functionalized MXenes to fabricate high performance polymer composites towards fire safety. Firstly, inorganic compounds were used to modify MXene. (1) The as-synthesized Ti3C2Tx/Nano-Cu hybrid exhibited excellent smoke and toxic gaseous products suppression function during combustion of the TPU. (2) The significantly improved mechanical and fire-safe performances of TPU/Ti3C2Tx@MCA-3.0 were superior to those of TPU nanocomposites filled with other nano-additives. Secondly, organically modifiers were used to functionalize MXene. (1) After the incorporation of 1.0 wt% Ti3C2Tx-PPPA, the PHRR, THR, TSR and COTY of the TPU nanocomposite were decreased by 24.5%, 32.6%, 54.4% and 36.8%, respectively. (2) With the incorporation of 2.0 wt% Ti3C2Tx-D-H nanohybrid, the PHRR, TSR and COTY of TPU nanocomposites were decreased by 27.3%, 43.8% and 36.7%, respectively. Besides, TPU/Ti3C2Tx-D-H-2.0 nanocomposite displayed significantly improved strength (+32.8%) and toughness (+56.8%).

Though application of MXene and its derivatives in flame retarding polymeric materials has received increasing interest from the researchers, several key points are urgent to overcome. (1) MXene-based multifunctional integrated polymer composites should be further explored, e.g., electromagnetic shielding, fire alarm, flame retardant properties, and mechanical properties. (2) MXene hybrids with smaller additions and stronger performance improvements need to be further investigated. (3) The interaction mode and high-performance mechanism of MXene-based hybrids with the polymer matrix need an in-depth investigation.

Key words MXene; Interface decoration; Flame retardancy; Smoke suppression

Session: Thermal Fire Retardant Composites

Presenting Type: Oral−Invited

Pyrolysis Modelling of Flame Retarded Polymer Composites with Degradation and Gas Decomposition Kinetics Descriptions via Molecular Dynamics

Anthony Chun Yin Yuen*、Timothy Bo Yuan Chen、Ivan Miguel De Cachinho Cordeiro、Guan Heng Yeoh
University of New South Wales

Lightweight building polymers have been commonly utilized in modern high-rise constructions owing to their flexibility, ease to manufacture, thermal insulative and sound absorption properties. Nevertheless, these materials without the incorporation of fire retardants are generally flammable as they emit combustible volatiles while thermally decomposed at a relatively low temperature. To realise the elevation of chemical compounds from a fundamental physiochemistry standpoint, it is vital to study the molecule breakdown process from an atomic level. In this study, an in-house fire field model has been developed to provide a better understanding of the flame propagation, toxic gases and smoke generations of selected flame-retardant polymer foam structures. The effectiveness of the fire retardant coating on foam samples was investigated experimentally and numerically via Cone Calorimetry and Thermogravimetric analysis. To generate quality pyrolysis kinetics to enhance the accuracy of the fire model, a systematic framework to extract TGA data is proposed involving the Kissinger–Akahira–Sunose method followed by the Genetic Algorithm, with less than 5% of RMS error against experimental data. Furthermore, a framework was proposed to validate the foam samples' kinetics through fundamental modelling using Molecular Dynamics (MD) technique (Fig.1). With the application of MD modelling of the fundamental breakdown of foam samples system, the detailed concentrations of gas volatiles involved in the solid decomposition process were comprehensively described and can be used as inputs to the numerical fire predictive model. Prediction demonstrated that this approach is viable with reasonable agreements with experimental heat release rate, gas concentration and smoke data.

Key words computational fluid dynamics, fire modelling, machine learning, molecular dynamics, reaxff

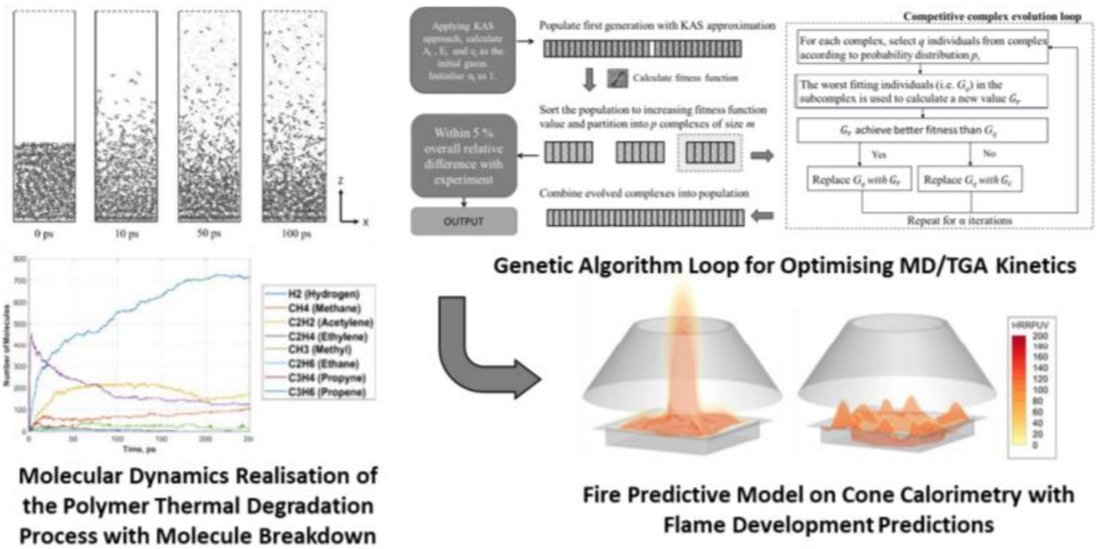


Fig. 1. Framework of utilising the atomistic polymer breakdown model to establish kinetics for fire predictive model for the reconstruction of fire development.

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Properties and ceramic mechanism of ceramifiable flame retardant room temperature vulcanized silicone rubber foam

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2. Tianjin University of Technology

The ceramifiable flame retardant room temperature vulcanized (RTV) silicone rubber foam was prepared using glass powder (GP) as fluxing agent, mica power (MP) as refractory filler and aluminium hydroxide (ATH) as flame retardant agent. The effects of these inorganic fillers on the flame retardancy and combustion behavior of RTV silicone rubber foam were investigated by limiting oxygen index (LOI), vertical combustion (UL-94) and cone calorimetry (CC) test. The results show that the introduction of MP and ATH can markedly improve the flame retardancy of the RTV silicone rubber foam. LOI value of the sample with an inorganic filler loading of 30 wt% can reach above 35, and it can pass UL-94 V-0 rating. Meanwhile, the RTV silicone rubber foam show excellent fire safety in the cone calorimetry test, in which the heat release and smoke release of the material decrease significantly. However, the introduction of GP has a serious negative impact on the flame retardancy and combustion behavior of the RTV silicone rubber foam. The RTV silicone rubber foams were pyrolyzed under two different pyrolysis conditions: 1) the samples were pyrolyzed from room temperature to 600 °C, 800 °C, and 1000 °C, respectively; 2) samples were pyrolyzed at 600 °C, 800 °C, and 1000 °C for 1h, respectively, so as to analyze the ceramic mechanism. The results show that the mass loss rate of the samples pyrolyzed with the second pyrolysis condition obviously lower than the samples pyrolyzed with the first pyrolysis condition. The SEM images show that the samples pyrolyzed with the second pyrolysis condition have a denser micromorphology than the samples pyrolyzed with the first pyrolysis condition, and the micromorphology of the samples is smoother and denser with increase of the pyrolysis temperature.

Key words silicone rubber foam; flame retardancy; combustion behavior; ceramic mechanism

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

The phosphorus-bridged amitrole sheet toward high fire safety epoxy resin

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Fujian Normal University

In an attempt to reduce the fire hazards of epoxy resin in the practical application, amitrole was converted to a novel P/N type flame retardant (PBA) through organophosphorus modification, and then utilized to fabricate fire safe epoxy thermosets (EP) with the help of physical blending. Interestingly, PBA exhibited a lamellar morphology, and it served as an additive-type flame retardant for EP. The results showed that EP containing 7.5 wt% PBA underwent quick self-extinguishment upon ignition in the UL-94 test, and this blend displayed a high limiting oxygen index (LOI) value which was up to 34%, much higher than that of unmodified EP. More importantly, hazardous products (heat, smoke, toxic gases including CO/ CO2) released during combustion of EP based on the results of cone calorimeter test (CCT), were strongly suppressed in the presence of PBA, indicating PBA was effective to enhance the fire safety of EP. Additionally, the mechanical properties of EP-PBA blends are comparable to those of virgin EP despite the physical dispersion of PBA in EP. The tensile strength of EP containing PBA was 90% of that of unmodified EP, and the flexural strength was somewhat greater. Moreover, the flame retardant activities of PBA were found related to the radical scavenging and the dilution effect of fuels and oxygen in the gas phase, as well as the formation of high-quality char derived by the dehydration and carbonization of epoxy resin catalyzed by phosphoric acids in the condensed phase. Generally, this work provides a feasible method to prepare a high fire safety epoxy resins.

Key words Epoxy resin; phosphorus-bridged amitrole; Flame retardancy; Mechanical properties

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Composite phase change materials with enhanced comprehensive performance for energy conversion

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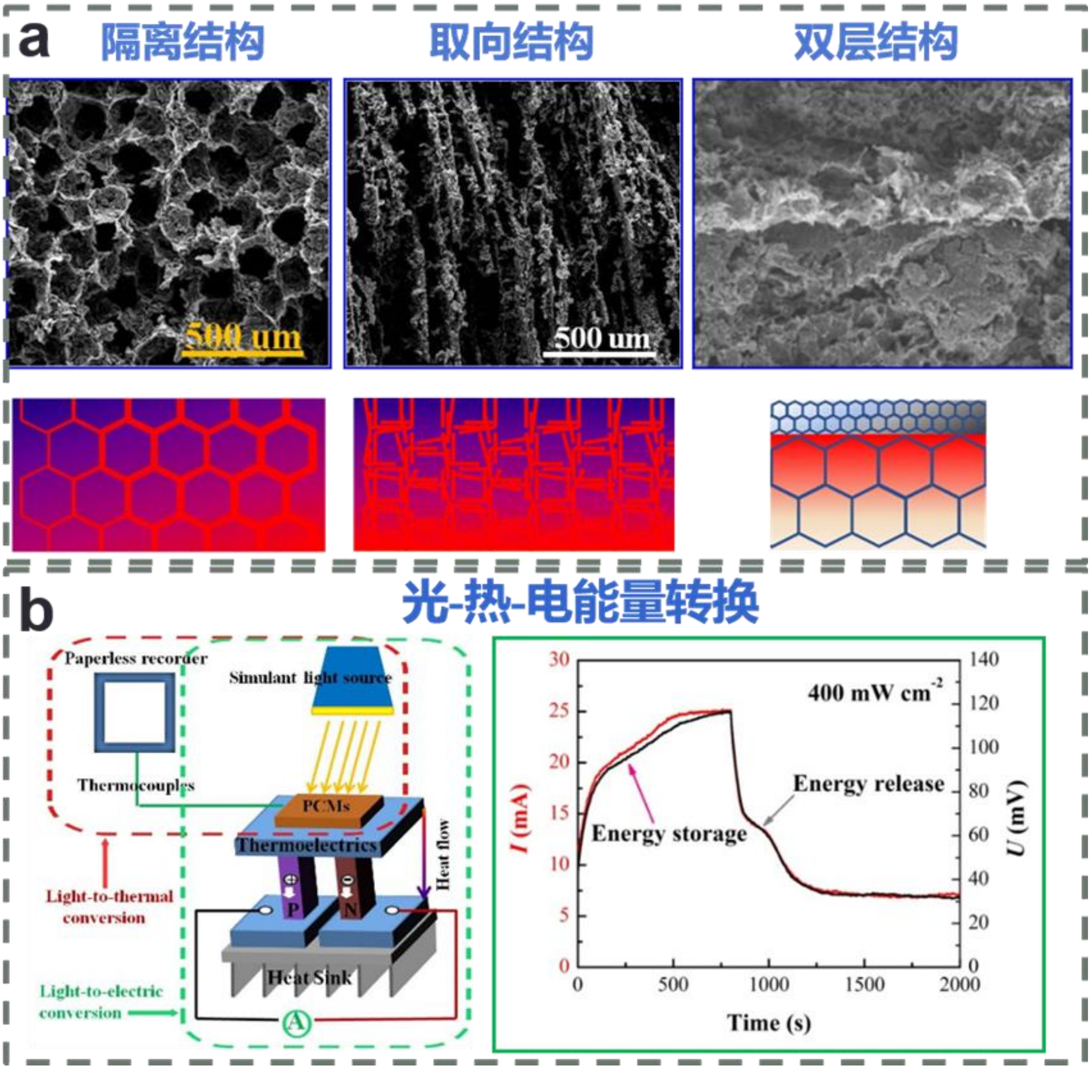
Sichuan University

Phase change materials (PCMs), as a state-of-the-art latent heat storage technique, have garnered tremendous attention to overcome the intermittency of thermal energy in time and space and narrow the mismatch between supply and demand. However, organic PCMs suffer from melt leakage in the period of phase transition and inherently low thermal conductivity, greatly impeding their popularization and practical applications. To tackle these two fatal shortcomings, myriad supporting materials and thermally conductive fillers have been incorporated to yield leakage-proof and thermally conductive composite PCMs. Notably, three-dimensional (3D) structural materials with tailorable properties are ideal alternatives for the simultaneous improvement of shape stability and thermal conductivity, obtaining composite PCMs with enhanced comprehensive performance. Common processing methods to construct 3D structural materials for the fabrication of thermally conductive composites include sacrificial templating, foam-templating, ice-templating, and template-directed chemical vapor deposition (CVD). Among them, the ice-templating strategy has been adopted to customize 3D network structures, including isotropic segregated, anisotropic cellular and double-layered structures, to develop high-performance composite PCMs. Specifically, the resulting leakage-proof composite PCMs exhibit a high thermal conductivity (> 3 W m^{-1} K^{-1}) at a relatively low BN loading (< 30 wt%), maintaining high package capacity (> 70 wt%). Simultaneously, the composite PCMs also present salient thermal reliability and photoabsorption ability, realizing a considerable solar energy conversion. Furthermore, an enticing light-to-heat-to-electric energy conversion can be attained after integrating the composite PCMs with a commercial thermoelectrical module. These works provide an effective solution to improve the utilization efficiency of thermal energy and achieve high-efficiency energy conversion and generation.

Key words Phase change materials, Thermal conductivity, Shape stability, 3D structural materials, Energy conversion and generation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Simulant light source
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PCMs
Thermoelectrics
Heat flow
Light-to-thermal conversion
Light-to-electric conversion
Heat Sink
P
N
A
400 mW cm-2
Energy storage
Energy release
I (mA)
U (mV)
Time (s)

Hangzhou, PR China 25-28 April, 2023

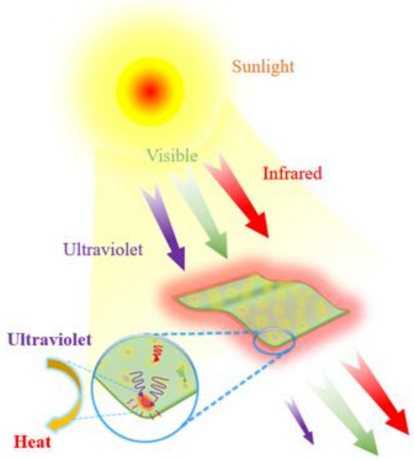
Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Highly Transparent Polymer Composite Films for Energy Savings

Xianhu Liu*
Zhengzhou University

Windows are the energy-efficient components, accounting for nearly 51% of the total solar energy, which seriously aggravates interior energy consumption. Thus, it is desirable to develop a transparent film that can enhance light conversion in order to avoid the heat exchange and heighten windows' energy-saving capability. Herein, we successfully developed a series of visible-light-transparent and UV-absorbing polymer composite films by using a combination of MXene filler and dispersant. The transparent composite film (TCF) could be quickly heated to 65 °C under light irradiation of 400 mW cm-2 and maintained over 85% visible light transmittance as well as low haze (<12%). Because of the efficient UV absorption, the temperature inside a container completely covered with the optimal TCF was reduced by 6–7 °C compared to that inside a container covered with bare glass, demonstrating the potential for these films to be used in energy-saving applications. Additionally, it was predicted to provide cooling energy savings ranging from 31 to 61 MJ m-2 year-1 (approximately 3%-12%) for a typical building in various conditions corresponding to the climate conditions of 12 cities worldwide. These results imply that these TCFs have wide potential for use as transparent devices in new



energy-related applications.

Fig. 1 Schematic diagram of the photothermal conversion for the TCF.

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Construction of Intelligent Coatings for Fire Warning and Protection

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Surface coating strategy is an effective approach for reducing fire hazards of combustible materials. However, there still remain many issues associated current most flame-retardant coating systems, e.g., poor water-resistance, weak mechanical strength, low flame-retardant efficiency as well as single fire shielding function. Thus, it is meaningful to design and construct advanced flame-retardant coatings with excellent comprehensive performance. Herein, we successfully created a series of high-performance nano-coatings with double functions of fire shielding and warning by combining graphene oxide (GO) nanosheets with functionalized fillers or molecules based on bionic design strategies. The resultant GO-based hybrid networks exhibit excellent structural stability even under acid/alkaline solution immersion and water bath ultrasonication conditions. Due to the exceptional high-temperature resistance and fire-shielding performance, they can apply in various combustible substrates such as PU foam as effective fire retardant coating (e.g., ~48% decrease in peak heat release rate at only 10 wt.% content). Furthermore, based on the thermal-induced electrical resistance transition mechanism of GO network, the hybrid networks also possess sensitive and reliable early fire alarm performance e.g., ultrafast fire alarm response (<1 s) and ultralong alarming time (>1200 s). These results indicate that the achieved advanced GO-based hybrid coatings have promising potential for use as fire alarm sensor and shielding material in fire safety-related applications.

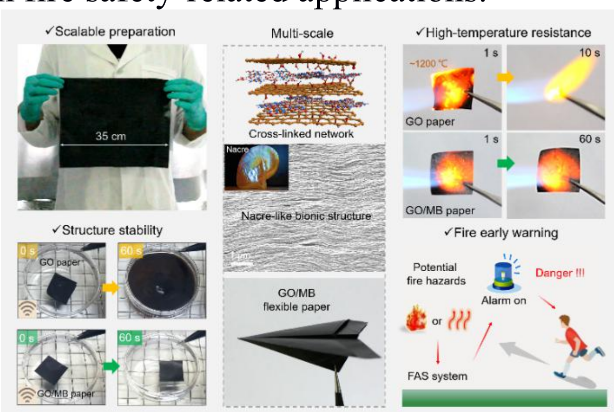

Fig. 1. Schematic diagram of GO-based hybrid networks for fire safety and protection

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Anisotropic Nanocomposites for Multifunctional Thermal Management

Xi SHEN*[1]、Xi SHEN*、Hongming ZHANG[2]、Kit-Ying Chan[1]
1. The Hong Kong Polytechnic university
2. The Hong Kong University of Science and Technology

Thermal managements play a key role in many emerging technologies, requiring materials with directional thermal conductivities ranging from ultralow to extremely high values to precisely control the heat flow depending on the applications. Polymer nanocomposites containing two-dimensional (2D) fillers such as graphene, boron nitride nanosheets (BNNS), and MXene are ideal for anisotropic thermal conduction by exploiting the intrinsic anisotropy of the fillers. The key is to rational assembling these fillers into three-dimensional (3D) structures with preferred alignment based on the applications.[1] Here, we present the rational design of two anisotropic nanocomposites for thermal managements in dielectrics and interfacial solar vapor generation. First, BNNS-polyimide (PI) and reduced GO (rGO)-PI layers are alternatingly stacked to form aligned laminates using a novel sequential freeze-casting technique followed by compaction.[2] The alternating, distinctively separated rGO and BNNS layers give rise to a high in-plane thermal conductivity of 1.49 Wm-1K-1 and excellent electrical insulation in the thickness direction, contributing to high-energy-density dielectric energy storage. Then, we report the development of 3D MXene/polyvinyl alcohol (PVA) composite aerogels with hierarchical pore channels for highly efficient solar vapor generation. An MXene/PVA aerogel with hierarchical porous channels consisting of long horizontal tubular pores and short vertical microchannels are developed for highly efficient solar vapor generation. Its unique pore structure gives rise to both excellent sunlight absorption rate and an ultralow thermal conductivity, contributing to a high evaporation rate of 1.89 kg m-2 h-1 with an over 90% energy efficiency.[3] The anisotropic composites can enable efficient dissipation and utilization of thermal energy for sustainable applications.

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Key words 2D filler; nanocomposite; thermal conductivity; rational assembly

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Invited

Testing and Modeling of Progressive Bearing Damage and Failure for Composite Interference-fit Joints under Thermal Effects

Junshan Hu*、Shiqing Mi、Shengping Zhang、Wei Tian
Nanjing University of Aeronautics and Astronautics

This research reports the testing and modeling methods and outcomes of mechanical performance and damage evolution of single-lap bolted composite interference-fit joints under extreme temperatures. The anisotropic progressive damage model involving thermal effects is established on continuum damage mechanics which integrates the shear nonlinearity constitutive relations characterized by Romberg-Osgood equation. The temperature-induced modification of thermal strains and material properties is incorporated in stress-strain analysis, extended 3D failure criteria and exponential damage evolution rules. The proposed model is calibrated and employed to simulate behavior of composite joints in interference fitting, bolt preloading, thermal and bearing loading processes, during which the influence of interference-fit sizes, preload levels, laminate layups and service temperatures is thoroughly investigated. The predicated interfacial behavior, bearing response and failure modes are in good agreement with experiments. The numerical model is even capable of reflecting some non-intuitive experimental findings such as residual stress relaxation and matrix softening at elevated temperatures.

Key words composite joint, interference-fit, thermal effects, damage evolution

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Onsite

Sago Starch Based Intumescent Material: Effect of Composition and Thickness

Fethma M Nor[1]、Vun Bin Wong[2]、Denni Kurniawan*[1]
1. Universiti Teknologi Brunei
2. Curtin University Malaysia

Intumescent material has potential as passive fire protection layer by expanding into low density, heat resistant carbon foam when in contact with heat. Carbon source is a key constituent in intumescent materials to generate the carbon foam. This study uses sago starch as the carbon source and measures the effect of varying composition of the sago starch and the thickness of the intumescent material in term of temperature at its surface during heating using a propane torch. The intumescent material was made of combination of sago starch, sodium bicarbonate, and polyvinyl alcohol adhesive. The compositions of the sago starch, sodium bicarbonate, and polyvinyl alcohol in the mixture were respectively 4:1:1, 3:2:1, 2:3:1, 3:1:2, and 2:2:2. Using the compositions, the intumescent materials were made into three thicknesses of 10 mm, 20 mm, and 300 mm. Results showed that intumescent effect was exhibited by all samples, with charring occurs and temperature of the material opposite to the fire was maximum at 257 ^{o}C. The temperature lowers with less starch content and more sodium bicarbonate. But the lowest temperature is when polyvinyl alcohol content was made higher but keeping the starch content high as well. The thinnest intumescent material samples showed lower temperature; increasing the thickness beyond 10 mm also increases the temperature.

Key words intumescent material, sago starch, composition, temperature

Session: Thermal Fire Retardant Composites

Presenting Type：Oral-Onsite

Flame Retardancy And Impact Resistance of Polyurea Composites Reinforced by Modified Ammonium Polyphosphate And Two-Dimensional Nano-Fillers

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Beijing Institute of Technology

Polyurea (PUA) is an elastomer with excellent static and dynamic mechanical properties. Since the birth of spray polyurea (SPUA)technology, it has been widely used in anti-explosion and anti-impact of protective structures. PUA is limited in the protection of fuel tanks and lithium-ion batteries due to its inherent flammability and dripping during combustion. In this paper, two-dimensional nano-fillers of graphene oxide (GO) and Layered double hydroxides (LDH) with different proportions were introduced into polyurea matrix together with modified ammonium polyphosphate. Thermal stability and combustion behavior of polyurea and its composites were studied by thermogravimetric analyzer and cone calorimeter. The quasi-static and dynamic compression properties of PUA and its composites were investigated using a universal testing machine and a split Hopkinson pressure bar (SHPB). The composites have exhibited balanced improved flame retardancy and mechanical properties.

Key words Polyurea, graphene oxide,flame retardancy,mechanical properties

Session: Thermal Fire Retardant Composites

Presenting Type: Oral−Onsite

Fast char formation induced by POSS-confined Co-MOF hollow prisms in epoxy composites with mitigated heat and smoke hazards

Zhengde Han、Wenyuan Zhang、Ye-Tang Pan*、Wenchao Zhang、Rongjie Yang
Beijing Institute of Technology

Epoxy resin is widely used in many fields because of its excellent mechanical properties, electrical insulation, and corrosion resistance. However, it is highly flammable and releases a large amount of smoke when burning, which can cause serious harm to people's lives. Metal-organic frameworks (MOFs) are newly emerged flame retardants for epoxy resin, but the flame retardant efficiency is not satisfactory when used singly. After compounding MOFs with silica-based flame retardant polyhedral oligomeric silsesquioxane (POSS), a carbon physical barrier layer can be formed rapidly on the surface of the substrate under the synergistic effect of silica as solid acid and transition metals contained in MOFs, which can improve flame retardancy while enhancing its smoke suppression effect. Recently, our group prepared a novel metal-POSS organic framework by compositing octacarboxyl POSS with ZIF-67 as flame retardant for epoxy resin with high efficacy (ACS Appl. Mater. Interfaces 2022, 14, 49326-49337). Herein, we used a sacrificial template method to grow Co-MOF on a water-soluble sacrificial template first, followed by simultaneous etching and loading with water-soluble POSS to obtain a MOF-POSS nanocomposite (HP-Co-POSS) with a unique hollow prism structure. The obtained HP-Co-POSS with 2 wt % loading in epoxy resin could increase the limiting oxygen index value of the composites from 23.2% to 27.2%. Meanwhile, the peak of the heat release rate and total smoke production decreased by 31.3% and 23.8%, respectively. The total heat release also was reduced by 12.4%. On the other hand, the HP-Co-POSS structure contains many free amino groups that can participate in the curing reaction, increasing the crosslink density of the cured epoxy network. As a result, the mechanical properties of the composites were improved compared with pure epoxy, especially the impact strength, which was improved by 2.1 times.

Key words MOF, POSS, fire safety, epoxy nanocomposites

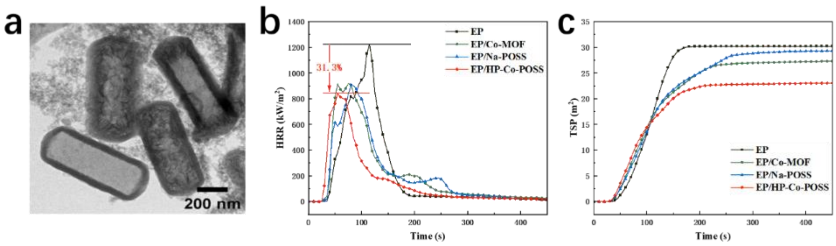

Fig. 1. (a) TEM image of the HP-Co-POSS, (b) HRR, (c) TSP curves for epoxy and its nanocomposites containing 2 wt% fillers.

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Onsite

Improved flame retardancy and mechanical properties of epoxy resin/glass fabric composites modified with ETPTA-microencapsulated flame retardant

Jinrong SHEN、Yizhou LU、Yuan FANG*
Nanjing Tech University

Epoxy resin and epoxy resin/glass fabric composites with improved flame retardancy were fabricated. To solve the problem of poor compatibility between flame retardants and substrates, the uniform microcapsules FR-PN@ETPTA with ethoxylated trimethylolpropane triacrylate (ETPTA) as the shell and phosphorus-nitrogen synergistic flame-retardant FR-PN as the core were fabricated by microfluidic technology. FR-PN@ETPTA/EP and FR-PN@ETPTA/EP/glass fabric composites were manufactured. The effects of FR-PN@ETPTA microcapsules on the flame retardancy, thermal stability, combustion performance and mechanical properties of epoxy resin and epoxy resin/glass fabric composites were studied. The results showed that the heat release rate (HRR), total heat release (THR), CO_2 generation rate, CO_2 content and effective heat of combustion of the specimens with 10 wt% FR-PN@ETPTA microcapsules all showed a decreasing trend compared to the pure epoxy resin. Compared with pure epoxy/glass fabric composites, 10 wt% FR-PN@ETPTA microcapsules achieved optimal impact resistance and passed a vertical burning test V-0 rating. The results of cone calorimeter tests showed that the addition of 10 wt% FR-PN@ETPTA microcapsules remarkably reduced the peak heat release (PHRR) and total heat release (THR) values, which were separately decreased by 14.4% and 37.9% compared with those of pure epoxy/glass fabric composites. The CO_2 generation rate, CO_2 content and effective heat of combustion of specimens were lower than those of the pure epoxy/glass fabric composites, and the ignition time was increased.

Key words Glass fiber reinforced composites; Microfluidic technology; Flame retardant microcapsule; Flame retardancy

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Onsite

Spherical Al_2O_3 prepared via thermal plasma and its applications in thermal management materials

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2. College of Energy Engineering, Huanghuai University, Zhumadian 463000, PR China
3. State Key Laboratory of Multiphase Complex Systems, Institute of Process Engineering, Chinese Academy of Sciences (CAS), Beijing 100190, PR China

The miniaturization and integration of electronic devices require polymer based thermal management materials have higher heat dissipation performance. Al_2O_3 has become one of the main fillers for polymer composites due to its high cost-effectiveness. However, the high interfacial thermal resistance between particles and matrix severely limits the improvement of thermal conductivity. In order to address this issue, we utilized the isotropic and controllable sintering properties of ultrafine spherical Al_2O_3 powder prepared by thermal plasma to prepare branched Al_2O_3 (b-Al_2O_3) with 2D structure. The particles formed continuous network structure by overlapping in phenolic resin, reducing the interfacial thermal resistance during heat transfer [1]. We further applied spherical Al_2O_3 to construct network Al_2O_3 sphere (N-Al_2O_3) with 3D continuous structure. The ultra-fine Al_2O_3 spheres were directionally assembled into larger Al_2O_3 spheres by spray self-assembly, and then the high-temperature controlled sintering was used to form sintering necks between the ultra-fine spherical Al_2O_3 particles, which decreased the interfacial thermal resistance between particles [2]. This structure possesses continuous network structure and interconnected channels, leading to the prepared composites have an inorganic-organic penetration structure, which not only greatly improved the thermal conductivity, but also enhanced the mechanical properties of composites. Based on the researches in the design, assembly, and development of high thermal conductivity composites using Al_2O_3, we have written a review article on the Al_2O_3 reinforced thermal conductive composites and summarized the research progress of Al_2O_3 particles in the field of thermal management materials [3].

Key words Thermal management materials; Al_2O_3; Interfacial thermal resistan

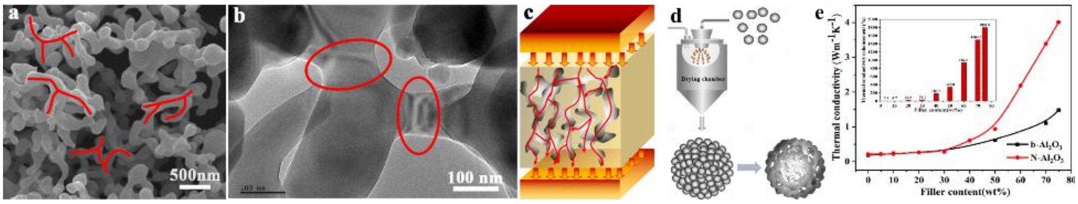

Fig. 1 (a) SEM and (b) TEM images of b-Al_2O_3, (c) heat flow model of composites with b-Al_2O_3, (d) preparation process of N-Al_2O_3, and (e) thermal conductivity of N-Al_2O_3/PR composites.

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Session: Thermal Fire Retardant Composites

Presenting Type: Oral–Onsite

Thermally conductive silicone composites with efficient flame retardancy for lithium-ion batteries enabled by temperature-triggered fire extinguisher microcapsules

Dan LI[1]、Ying ZHAO[2]、Shusheng CHEN[2]、Yapeng CHEN[2]、Yurun ZHANG[1]、Jiaqiang HUANG[3]、Jinglei YANG*[2,4]

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2. Department of Mechanical and Aerospace Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong Special Administrative Regions
3. The Hong Kong University of Science and Technology (Guangzhou), Sustainable Energy and Environment Thrust, Nansha, Guangzhou, Guangdong 511400, China.
4. HKUST Shenzhen-Hong Kong Collaborative Innovation Research Institute, Futian, Shenzhen, China

Despite its noticeable advantages such as high energy density and long cyclicity, explosion or firing risks occasionally resulting from thermal runaway of lithium-ion batteries have caused great concerns about the safety issues of electric vehicles. Thermally conductive composite materials with highly-efficient flame retardancy and high stability are strongly desired. Flame retardants as additives are commonly applied to suppress fire propagation but usually lead to severe environmental impact and bio-toxicity. This work provides a feasible strategy for the safety issue of lithium-ion batteries by embedding eco-friendly fire extinguisher microcapsules with liquid-to-gas phase-change properties on commercial thermally conductive silicone rubbers. Under normal work conditions, heat generated was efficiently transferred out through silicone rubber. Under some strict conditions such as mechanical attack and electrical or thermal abuse, the fire extinguisher was released to cool down the surroundings and put out flames before the thermal runaway when the temperature rises above 90 oC. The thermal properties of silicone composites such as thermal stability and thermally conductivity were characterized by thermogravimetric analysis and HotDisk method. The flame retardancy of the silicone composites without or with fire extinguisher microcapsules was characterized by the Limited Oxygen Test (LOI) method. The battery thermal management performance of the silicone composites integrated with phase-change fire extinguisher microcapsules was well examined. The preparation of fire extinguisher microcapsules based on a one-step double emulsion solvent evaporation method was also described. The silicone composites with temperature-triggered properties exhibited effective duplicate protection for the thermal management of lithium-ion battery systems, especially for electrical vehicles.

Key words lithium-ion battery, flame retardancy, fire extinguisher microcapsules, synthesis method

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Onsite

Enhanced thermal conductivity and high mechanical properties of carbon fiber laminated composites by efficient interlayer graphene interpenetrating networks

Xinyang SUN[1,2]、Han Wang[1]、You Zeng*[1,2]
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2. School of Materials Science and Engineering, University of Science and Technology of China

In order to obtain high-performance carbon fiber reinforced polymer (CFRP) composites with enhanced thermal conductivity and high mechanical properties, we fabricated carbon fiber laminated composites by utilizing graphene interpenetrating networks as functional layers and infiltrating with epoxy. High-quality CVD graphene foam (GF) and graphene nanosheets (GNPs) were used to construct the interpenetrating thermal conductive network between the carbon fiber layers. Thermal conductivity and mechanical properties of the CF/graphene laminated composites were investigated in detail. We found that, with the addition of the graphene interpenetrating networks (as low as only 3.0 vol%), the CF/graphene laminated composites exhibited remarkable enhancement in through-plane and in-plane thermal conductivity, increasing by 166% and 37.7% in comparison with that of CFRP. Meanwhile, the tensile, flexural, compressive, and interlaminar shear strength of the laminated composites were also increased by 14.2%, 5.8%, 16.7%, and 16.7% compared with that of CFRP. Such remarkable reinforcement in thermal and mechanical properties is mainly attributed to the highly-conductive graphene interpenetrating networks, strong interfacial interactions, and high-efficiency stress transferring. The CF/graphene laminated composites have great potential to be used as multi-functional materials in the fields of aerospace, transportation, and electrical industry

Key words Carbon fiber reinforced polymer composites; Graphene; Interpenetrating network; Thermal conductivity; Mechanical properties.

Session: Thermal Fire Retardant Composites

Presenting Type：Oral−Onsite

A green and facile strategy to enhance thermal stability and flame retardancy of unidirectional flax fabric based on fully bio-based system

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2. The Shanghai Key Laboratory of Space Mapping and Remote Sensing for Planetary Exploration, Tongji University,1239 Siping Road, Shanghai, 200092, PR China

Although layer-by-layer (LBL) self-assembly technology played a wide range of applications in the field of flame-retardant profiting from the advantages of various ingredient combinations, working on a variety of substrates and ambient processing, it required repeated assembly to achieve the desired flame retardancy, which increased the time-cost and complexity of the process, restricting further application. In this work, fully bio-based flame-retardant system based on phytic acid (PA) and ammonium alginate (AA) was designed, which endowed flax fabric with excellent flame retardancy with only the assembled layers of 1 biolayer. Compared with pristine flax fabric, the limiting oxygen index (LOI) of Flax-AA/PA reached 32.2% (~68.6% increase), and revealed faster self-extinguishing behaviour. Moreover, the peak heat release rate (PHRR), total heat release (THR), peak smoke release rate (PSPR) and total smoke release (TSR) were decreased by 65.1%, 52.7%, 64.4% and 32.1%, respectively. Both the number of assembled layers and the flame-retardant effect were superior to the previously reported systems through LBL self-assembly technology. Mechanism analysis illustrated that the AA/PA flame-retardant system reduced the production of flammable volatiles (carbonyl compounds, aromatic compounds, hydrocarbons, etc), and promoted the dehydration of flax fabric to form phosphorus-containing hybrid char layer which inhibited the heat and mass transfer between the pyrolysis zone and the combustion zone, thus delaying the spread of combustion. This bio-based flame-retardant system provides a facile LBL self-assembly at an ultra-low number of assembled layers to endow the unidirectional flax fabric with excellent flame retardancy.

Key words Flame retardancy; Bio-based; phytic acid; ammonium alginate; layer-by-layer (LBL) self-assembly

Session: Thermal Fire Retardant Composites

Presenting Type: Oral−Virtual Platform

Experiment and Numerical Simulation for Peanut Shell-based Flame Retardant combined with manganese oxide for Epoxy Resin

Jing LIANG[1]、Anthony Chun Yin Yuen*[1]、Timothy Bo Yuan Chen[1]、Wenhao Yang[2]、Shuilai Qiu[2]、Wei Wang[1]、Yuan Hu[2]、Guan Heng Yeoh[1]

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Two-dimensional (2D) nano-based flame retardants have recently aroused much attention due to their intrinsic structural properties, such as the aspect ratio and heat barrier effect. In our previous work, a flake-like structure carbon derived from peanut shell (CPS) has been prepared and employed as flame retardant for epoxy resin and exhibited a similar physical barrier effect. When CPS combined with nano Cobalt, 3 wt.% addition leads to a remarkable 37.9% drop of peak heat release rate (PHRR) and 19.6% reduction of total heat release (THR), respectively. To further enhance the flame-retardancy of the peanut shell, CPS was designed to combine with green transition metal manganese utilizing a facile method. Cone calorimeter results show that with 3wt.% loading of this flame retardant, PHRR and THR decrease dramatically by 60.2% and by 53.9%, respectively. Thermogravimetric analysis results demonstrate that the char residue increases from 15.87% to 21.04% and the maximum mass loss rate drop from 1.63%/min to 1.53%/min. Scanning electron microscope, X-ray photoelectron spectroscopy and Thermogravimetry-Infrared Spectroscopy were conducted to investigate the flame retardancy mechanism. The outstanding performance of this green flame retardant is mainly attributed to the physical barrier effect provided by 2D carbon and compact char residue with high quality. To further comprehend the combustion process and reconstruct the cone calorimetry flaming process, a large eddy simulation model with an in-house pyrolysis sub-model was utilized and a surface regression model was uniquely embraced to simulate the fire phenomena, including thermal degradation, charring, radiation feedback and combustion of the polymer composite.

Key words Two-dimensional; peanut shell; physical barrier effect; computational fluid dynamics (CFD) model; pyrolysis kinetics

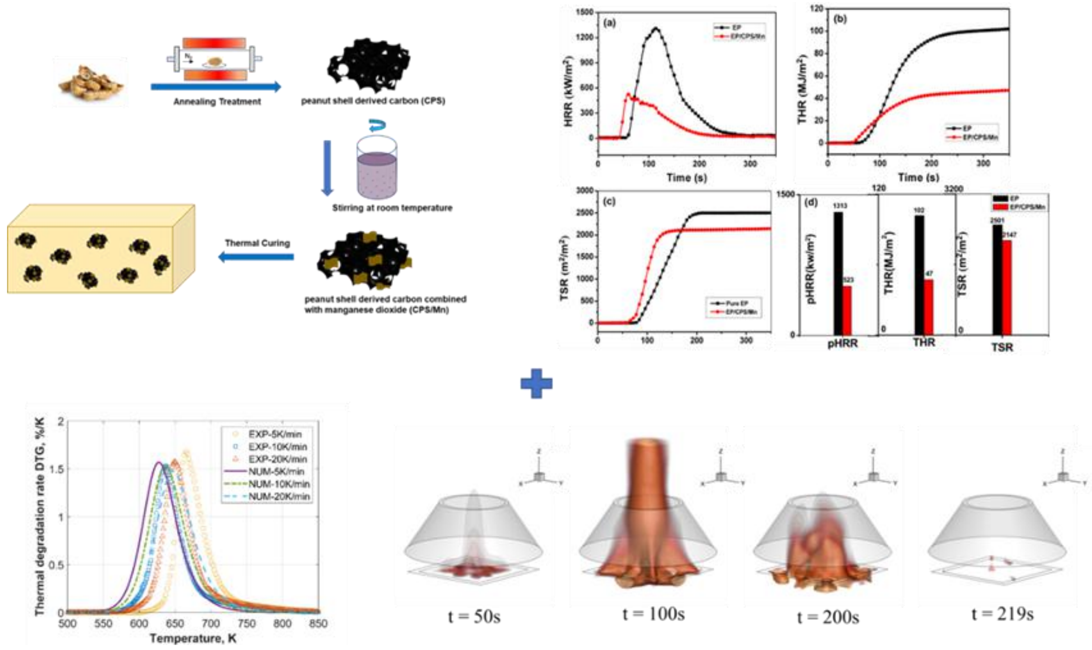

Fig. 1. Framework of experiment and numerical simulation for EP with CPS/MnO_2 as flame retardant.

Session: Thermal Fire Retardant Composites

Presenting Type: Oral−Virtual Platform

Thermally Insulating Boron Nitride Composite Aerogel for Thermal Management in Buildings

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Novel porous materials with enhanced thermal insulating properties are required to minimize heat exchange between the building interior and external surroundings. This is necessary to reduce the energy consumption required for comfortable interior temperature regulation. To achieve this goal, the thermal insulating materials should possess an excellent sunlight reflectance, in addition to low thermal conductivity (TC), to lessen the heat absorbed during daytime. Conventional insulating materials cannot meet this requirement as they possess a low sunlight reflectance and a TC higher than TC of air (24 mW/m-K). Herein, unidirectional freeze-casting (UFC) technique was used to prepare highly porous anisotropic polyvinyl alcohol/boron nitride nanosheet (PVA/BNNS) composite aerogel with a low density. The UFC technique endows the composite aerogel with an aligned porous structure and the presence of BNNS in the cell wall increases the anisotropy. The aerogel delivers an ultralow TC of 20.3 mW/m-K in the thickness direction and efficient heat dissipation in the alignment direction, thus preventing heat localization within the composite. It also possesses an exceptional solar-weighted reflectance of 95.0 % over the sunlight wavelength (0.3 – 2.5 μm) and a high emissivity above 93% within the atmospheric window (8 – 13 μm). With its ultralow TC combined with a high solar reflectance and emissivity, the composite aerogel presents a low temperature of 37.3 °C under a simulated sunlight intensity, which is 12.1 and 23.9 °C lower than commercial expanded polystyrene foam (EPS) and transparent glass envelope. The introduction of BNNS also enhances the mechanical properties of the aerogels. These superior characteristics make the composite aerogel ideal for both outdoor and indoor thermal management applications.

Key words Boron nitride, aerogel, freeze-casting, thermal insulation, optical reflectance

Session: Thermal Fire Retardant Composites

Presenting Type: Oral-Virtual Platform

Thermally Insulating Boron Nitride Composite Aerogel for Thermal Management in Buildings

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As the general structural reinforcements for advanced composites, PAN-based carbon fiber (PAN-CF) exhibits high ratios of stiffness and strength to weight. However, it is not competitive enough in the heat conduction field compared with mesophase pitch based carbon fiber (MPCF) and vapor-grown carbon fiber (VGCF). In order to promote the applications of PAN-CF and its composites in the thermal management field, surface modifications were applied in this work to enhance the radial thermal conductivity of fiber and through-thickness thermal conductivity of its composites. Firstly, crosslinked Ni/CNT hybrid networks were electrodeposited on PAN-CF surfaces to provide extra highly thermal conductive paths among the carbon fiber filaments. And the through-thickness thermal conductivity value of CF@Ni/CNT reinforced composite with 55% filler loading was measured as 1.12 W/(m·K), increased by 51% in contrast with the PAN-CF counterpart (0.74 W/(m·K)). Furtherly, vertically aligned graphene oxide (GO) was grafted onto CF@Ni/CNT through freeze-drying of GO dispersion, aligned by the growth of ice crystal. The improved thermal conductivity of CF@Ni/CNT@GO reinforced composite with the same filler loading was 1.84 W/(m·K), providing 149% enhancement compared to PAN-CF composite. Moreover, the freeze-drying assisted grafting of vertically oriented PBO/GO polymer and subsequent high-temperature heat treatments were conducted to form micron well-ordered graphite structures. The through-thickness thermal conductivity values of its composites increased to 5.39 W/(m·K) with the 55% carbon fiber volume fraction, enhanced by 573%. This work proves the feasibility of constructing continuous conductive networks and vertical thermal conduction paths onto carbon fibers for enhancing the through-thickness thermal conductivity of carbon fiber reinforced composites.

Key words Carbon fiber, Three-dimensional networks, Vertical alignment, Thermal conductivity

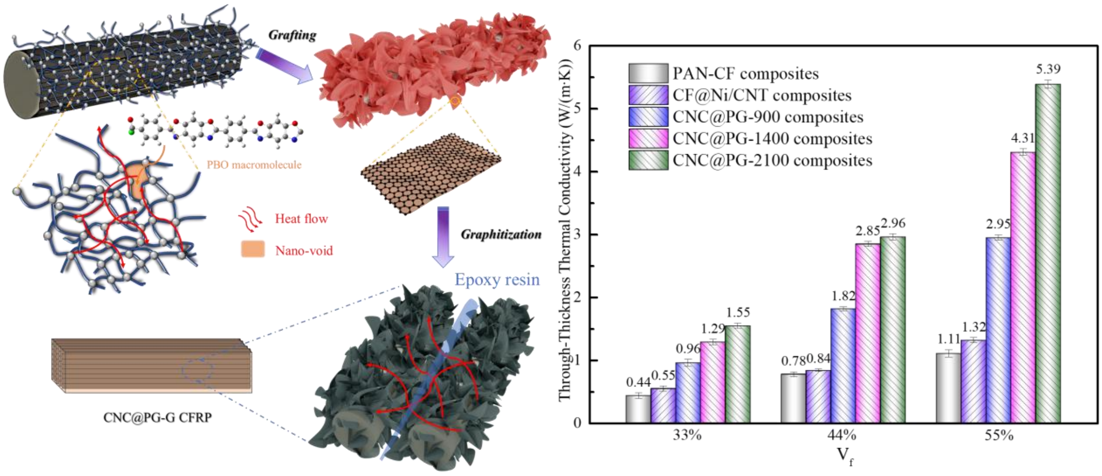

Fig. 1. Graphical abstract. Preparation of high thermal conductive PAN-CFs, and the thermal conductivity performances of their composites.

Session: Thermal Fire Retardant Composites

Presenting Type：Oral–Virtual Platform

Solvent-free synthesis of organic-inorganic polyphosphoramide-halloysite nanohybrids for thermally stable and fire-resistant polylactide

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Biodegradable and renewable polylactide (PLA) exhibits excellent mechanical properties, but is prone to high flammability, limiting its application to textiles, electronics, and packaging. In PLA, polyphosphoramides have shown their exceptional fire-retardant properties, but their existing synthesis methods often involve toxic solvents. Despite high efficiency, our recently reported two polyphosphoramides synthesized via green synthesis led to a reduced thermal stability of PLA. Herein, we report a series of organic-inorganic hybridized polyphosphoramides-halloysite nanotubes (HNTs) nanohybrids (DM-OHn) via a one-pot solvent-free copolymerization. The results show that addition of only 1.5 wt% DM-OH16 leads to a 5 °C increase in the initial decomposition temperature of PLA and enables the latter to achieve a desired UL-94 V-0 rating and a high limiting oxygen index (ca. 32.6%), in addition to a well-preserved tensile strength. This work provides an eco-benign green strategy for the design of organic-inorganic polyphosphoramides nanohybrids for creating fire-retarding PLA with improved thermal stability and preserved mechanical strength, which are expected to be used as sustainable fire-proof bioplastics for many industrial applications.

Key words Polylactide; Polyphosphoramide; Green synthesis; fire retardancy; thermal stability

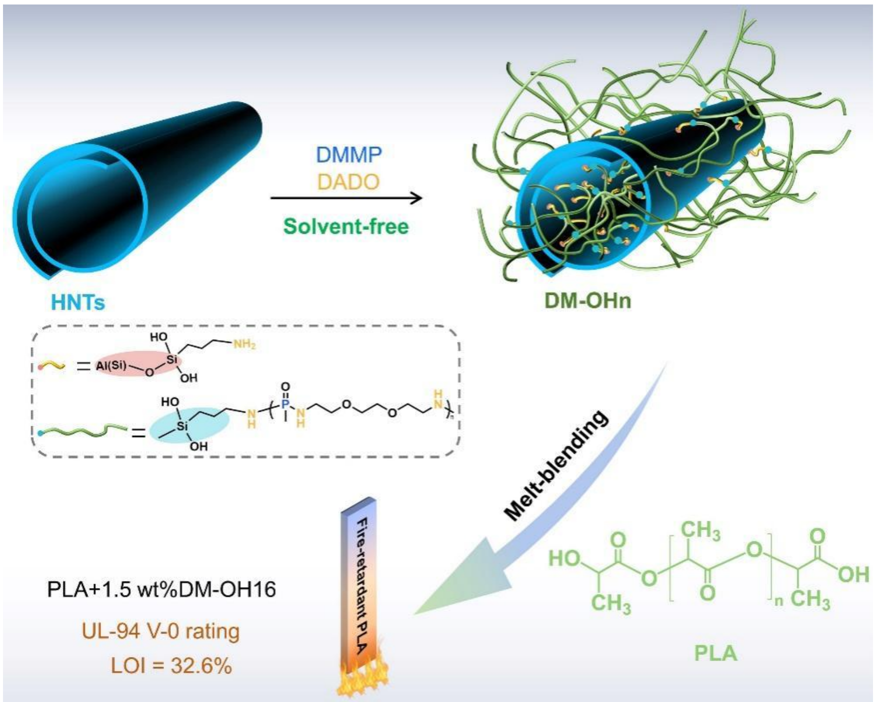

Fig. 1. A solvent-free approach for synthesizing organic-inorganic phosphoramide-halloysite nanohybrids for creating fire-retarding PLA.

Session: Thermal Fire Retardant Composites

Presenting Type: Oral−Virtual Platform

Continuous Freeze-Casting for Thermally Insulating Anisotropic Aerogels

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Thermal management materials for building envelopes are vital to energy-efficient and sustainable buildings, easing the pressure on achieving carbon neutrality. Recent developments of thermally super-insulating aerogels having a thermal conductivity lower than air (24 mW/m K) are promising to isolate the heat for more energy-efficient cooling [1, 2]. In addition to low thermal conductivity, aerogel envelopes should also have a low solar absorption to mitigate the solar heat gain under direct sunlight. However, most aerogels tend to absorb the sunlight for undesirable solar heat gain, and it is demanding to scale up the anisotropic aerogel fabrication while maintaining consistent properties [1, 3]. Here, a large-scale thermally super-insulating, solar-reflective anisotropic aerogel containing in-plane aligned pores is developed by a novel additive freeze-casting technique, as shown in Fig. 1. The freezing dynamics are controlled by using a moving cold source to maintain aerogel panels having uniform in-plane pore alignments with decimeter length. The pore walls are further engineered using boron nitride nanosheets (BNNS) to leverage their unique anisotropic thermo-optical properties. The coupling between BNNS and in-plane pore channels delivers an ultralow out-of-plane thermal conductivity of 16.9 mW/m K and an outstanding solar reflectance of 97%, minimizing both parasitic and solar heat gains. The as-fabricated aerogel panel achieved an up to 7 °C lower interior temperature than commercial silica aerogels when used as cooling panels under direct sunlight. This work demonstrates the facile bottom-up fabrication of scalable anisotropic aerogels towards practical energy-efficient cooling applications.

Key words Anisotropic aerogels, thermal superinsulation, solar reflectance, energy-efficient buildings

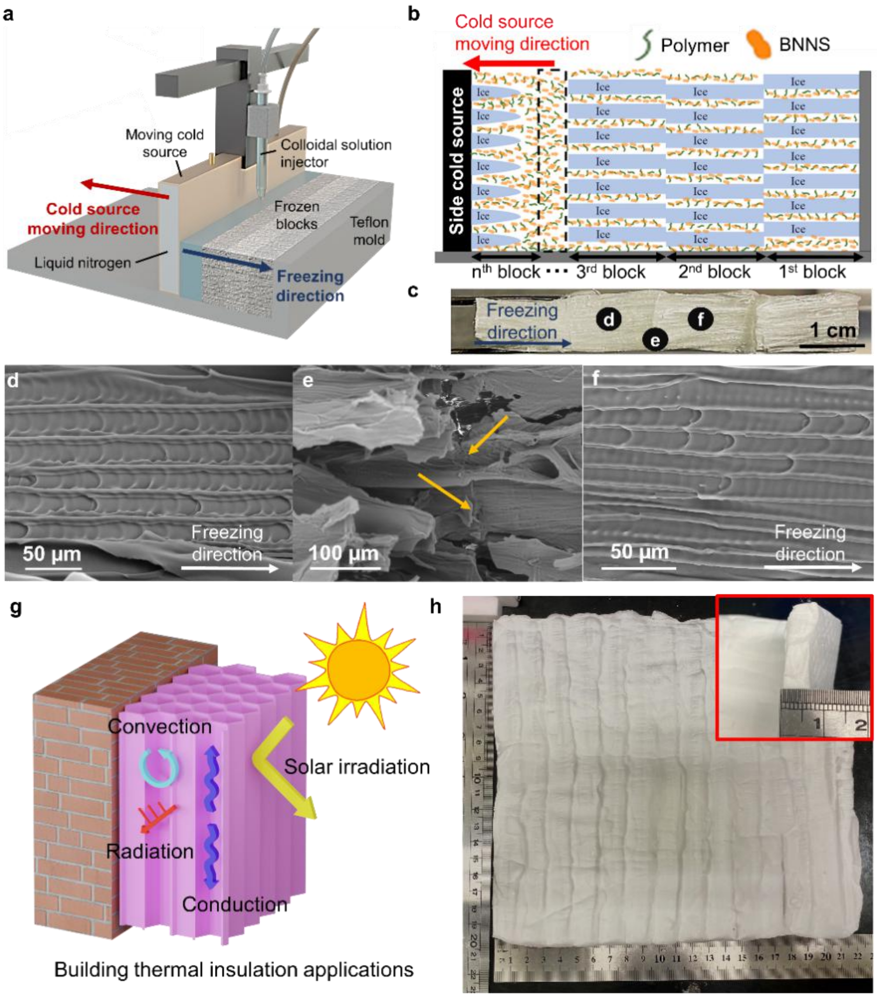

Fig. 1. Design and continuous freeze-casting of thermally insulating anisotropic aerogels. (a) Schematics of the set-up and (b) mechanism of the additive freeze-casting for the fabrication of large-scale anisotropic aerogel. (c) Photograph and (d-f) scanning electron microscope (SEM) images showing the uniform pore alignment and structural integrity of the aerogel. (g) Anisotropic aerogel panel with ultralow thermal conductivity and high solar reflectance for energy-efficient building applications. (h) Photograph of anisotropic aerogel panels with lateral dimension of 20 × 20 cm^2 and thickness of less than 1 cm, fabricated using the continuous freeze-casting.

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Session: Thermal Fire Retardant Composites

Presenting Type: Poster

Solvent-free synthesis of phosphate-containing imidazole fluid for flame retardant one-component epoxy resin with long pot life, low curing temperature and fast curing rate

wei wang*、yuan liu
sichuan university

The design of flame retardant one-component epoxy resin (EP) with long pot life, low curing temperature and fast curing rate has been challenging in the industry. Herein, we synthesized a phosphate-containing imidazole fluid (TA) as the thermal latent curing agent of EP. Based on simple structural design, TA endows EP with excellent curing properties, storage properties, and flame retardant properties. According to DSC results, EP/TA systems exhibit low curing temperature and fast curing rate during operation. The rotary rheometer test confirms that the viscosity curve of EP/TA system maintains long-term stability at 40 °C. The X-ray photoelectron spectroscopy (XPS) data reveals that TA releases imidazole intermediates and phosphorous compounds during curing. The former provides conditions for fast curing of EP, while the latter gives EP intrinsic flame retardant properties. With the addition of 20 wt% TA, EP/TA-4 achieves UL-94 V-0 rating and 28.5% of LOI value. Compared with EP/AI (954.6 kW/m2), the peak of heat release rate (PHRR) of EP/TA-4 decreases to 597.6 kW/m2. Fourier transform infrared spectroscopy (FTIR), scanning electron microscope (SEM), energy dispersive spectrometry (EDS), thermogravimetric analysis/infrared spectroscopy (TG-FTIR), and XPS are used to study flame retardant mechanism. These results indicate that the flame retardancy of TA mainly comes from the protective effect of phosphorus-rich char layer, the dilution effect of non-combustible gas and quenching effect of phosphorous compound. Besides, due to no solvent involved, the synthesis strategy of TA is environmentally friendly, showing a great potential of industrial application.

Key words one-component epoxy resin; latent curing agent; solvent-free synthesis; flame retardancy; smoke suppression

Session: Thermal Fire Retardant Composites

Presenting Type: Poster

Synergistic Coating for Flexible Polyurethane Foam According to Sol-Gel Technology Based on Montmorillonite and AP: Flame Retardancy and Gas Barrier

Ping Li、yun Liu*
Qingdao University

Flexible polyurethane foam (FPUF) has been widely used in home decoration, packaging and transportation seats, but its high flammability and unique open-cell structure bring serious fire risk. However, the synthetic flame retardants gradually exposed serious environmental pollution problems, and threatened human lives. Therefore, on the basis of montmorillonite (MMT), ammonium phytate (AP) has been paired with MMT to form flame-retardant coatings through sol-gel technology. After AP/MMT treatment, uniform flame retardant coating was obtained, and the results of thermogravimetric analysis showed that the existence of AP/MMT coating reduced the maximum thermal degradation rate of FPUF and increased char residues, suggesting that the char formation abilities of AP_5MMT_5/FPUF had been significantly increased. Compared with pure FPUF, a 67% reduction of total heat release for AP_5MMT_5/FPUF had achieved, and the toxic smoke release was significantly reduced. The flame-retardant samples avoided the generation of droplets, as well as AP_5MMT5/FPUF reached a UL-94 V-0 rating. The results mentioned above confirmed that AP/MMT coatings had improved the fire safety of FPUF. AP_5MMT_5/FPUF decomposed more non-flammable products (such as CO_2) during thermal degradation, which played the key role of diluting oxygen and combustible gases. The analysis of char residues revealed that AP/MMT coating can form solid and stable char layers after heating, which might act as a physical barrier against heat and oxygen exchange. Therefore, AP/MMT coating effectively improved the fire safety and smoke suppression performance of FPUF.

Key words Eco-friendly coatings, Sol-gel technology, Gas barrier, fire safety, Montmorillonite

Session: Thermal Fire Retardant Composites

Presenting Type：Poster

Design and Synthesis of a Highly Efficient Phosphate Flame Retardant for Polycarbonate

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Due to its excellent heat resistance and mechanical properties, polycarbonate (PC) has been widely applied in many fields such as aerospace, electronics and electrical appliances. On account of the aromatic structure in macromolecular chains, PC can pass the UL-94 V-2 rating. Nevertheless, the large amount of heat release during combustion cannot meet the use requirements of high flame retardancy in certain fields. Phosphorus based flame retardants commonly used in PC including Resorcinol Bis(diphenyl phosphate)(RDP) and Bisphenol A Bis(diphenyl phosphate)(BDP), but their flame-retardant efficiency is unsatisfactory. In this work, a novel phosphate flame retardant DHPP containing benzophenone structure was synthesized. With the addition of 10 wt% DHPP, PC/DHPP achieved the UL-94 V-0 rating and a 9% higher limiting oxygen index (LOI) value. In addition, the peak heat release rate (pHRR) and total heat release (THR) also decreased by 33.2% and 27.7% respectively compared with pure PC. In the combustion process, the released phosphorus free radicals captured the flame radicals pyrolyzed by PC, and at the same time, the benzophenone structure can form a compact char layer, hindering transfer of mass and heat. This work is expected to have potential applications in aerospace and other fields which have high flame retardancy requirements.

Key words Polycarbonate；flame retardant

Session: Thermal Fire Retardant Composites

Presenting Type: Poster

Synergistic effect of piperazine pyrophosphate and epoxy-octavinyl silsesquioxane on flame retardancy and mechanical properties of epoxy resin

Shansu Li*、Yuan Liu、Yuansen Liu、Qi Wang
Sichuan University

In order to solve the contradiction between the flame retardancy and mechanical properties of epoxy resin, piperazine pyrophosphate (PAPP) and epoxy-octavinyl silsesquioxane (EOVS) are applied as flame retardants for epoxy resin (EP). In the presence of PAPP and EOVS, the properties of the EP composites are improved significantly in the terms of flame retardancy, mechanical properties, and smoke suppression. EP/9 wt% PAPP/1 wt% EOVS (EP3) passes a vertical burning (UL-94) test V-0 rating and acquires the LOI value of 32.4%. Meanwhile, the results of cone calorimeter tests confirm that the incorporation of PAPP and EOVS significantly reduces the total heat release (THR), total smoke production (TSR), peak carbon monoxide produce rate (pCOP) and peak carbon dioxide produce rate (pCO2P) values, which are respectively decreased by 25%, 57%, 62%, and 80% compared with those parameters of pure EP. Scanning electron microscope (SEM), energy dispersive spectrometry (EDS), Laser Raman spectroscopy (LRS), and X-ray photoelectron spectroscopy (XPS) are adopted to analyze the char residue of EP3, and the results indicate that the introduction of PAPP and EOVS form a dense and stable carbon layer through a synergistic effect. Benefitting from the presence of epoxy groups and Si-O bonds in EOVS, the tensile and impact strength of EP3 also increase. This paper proposes a new method to prepare the mechanically reinforced and flame-retardant epoxy resin.

Key words Epoxy resin; Synergistic effect; Flame retardancy; Mechanical properties; Smoke suppression

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Thermal Fire Retardant Composites

Presenting Type: Poster

Flame Retardant Rigid Polyurethane Foam based on Melamine Polyols

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2. Jiangsu Changshun Polymer Material Institute Co., Ltd., Zhangjiagang

Rigid polyurethane foam (RPUF) as a thermal insulation material is widely used for the heating and cooling of buildings due to its low thermal conductivity, good mechanical properties, and low apparent density. Unfortunately, RPUF can be ignited easily, and the flame spreads rapidly during combustion. Moreover, a large amount of heat, smoke and toxic gases will be released. Generally, the introduction of phosphorus-containing flame retardants deteriorates smoke release and affects thermal insulation performance. Therefore, it is highly urgent to develop flame retardant and smoke suppression RPUF with low thermal conductivity. In this work, two melamine polyols (3360,8119) were successfully synthesized to replace polyether polyol (4110) in RPUF. A 1.8% improvement in the limiting oxygen index (LOI) was achieved by RPUF-100%3360. Furthermore, the peak heat release rate (pHRR), total heat release (THR) and maximum smoke density (Dsmax) of RPUF-100%3360 were reduced by 40.0%, 42.0% and 70.5%, respectively. Similarly, the LOI of RPUF-100%8119 was increased by 4.6%. The pHRR, THR, and Dsmax were reduced by 38.8%, 61.1% and 43.4%, respectively. This was attributed to the flame retardant RPUF releasing nonflammable gases such as NH_3 and H_2O. Meanwhile, it can form a dense char layer to hinder the transfer of heat and mass. In addition, according to the thermal conductivity results, the more melamine polyols added, the lower the thermal conductivity of RPUF. Therefore, replacing polyether polyols with melamine polyols not only improves flame retardancy and smoke suppression but also enhances thermal insulation performance. This work can be expected to demonstrate many potential applications in fields relating to buildings, cold chains and piping insulation.

Key words Rigid polyurethane foam ; Flame retardant ; Melamine polyols ; Smoke suppression

Session: Thermal Fire Retardant Composites

Presenting Type: Poster

Flame-retardant and Smoke-suppressing Silicone Foam Materials

Wenxiong Li*、Xiuli Wang、Haibo Zhao、Yuzhong Wang
Sichuan University

Low-density silicone foam (SiF) is used in power batteries, rail transit, aerospace and other fields due to its excellent high and low temperature resistance, heat insulation, shock absorption and compression resilience. However, its partial application is limited due to the large amount of flammable organic side groups contained in its molecular segments. To overcome this drawback, the conventional strategy is to use the condensed phase flame retardant or gas phase flame retardant mechanism to achieve flame retardancy and smoke suppression. Nevertheless, these approaches tend to require the addition of a large amount of flame retardant ingredients or generate additional harmful gases during the combustion process. In this paper, two nano-layered double hydroxides (LDHs) with different metal element compositions were successfully prepared and added to SiF as flame-retardant and smoke-suppression modifiers. It was found that the two LDHs with only one different metal element showed completely different flame retardant and smoke suppression performances in SiF. Among them, the LOI value of SiF/1MgAl-LDH is 29.6%, passing the UL-94 V-0 rating, and the peak smoke production rate (pSPR) value is reduced by 42.4%, while the LOI value of SiF/1MgFe-LDH is 26.6%, failing the UL-94 test, and the pSPR value is increased by 82.7%. This is attributed to the fact that the multi-metal oxides generated by MgAl-LDH and MgFe-LDH at high temperature have different effects on the thermal decomposition behavior of SiF. In short, by loading a very small amount of modifier, the thermal decomposition process of SiF is changed, and finally, the purpose of efficient flame retardancy and smoke suppression is achieved, and no additional gas phase products are produced, which provides a new solution for the preparation of flame-retardant and smoke-suppressing SiF materials.

Key words Silicone foam; Flame retardancy; Smoke suppression; Layered double hydroxides; Thermal decomposition behavior

Session: Thermal Fire Retardant Composites

Presenting Type: Poster

Design and synthesis of intrinsically flame-retardant PA

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2. Sichuan University

With the increase of peoples' awareness of sustainable development and environmental issues, sustainable polymers prepared from renewable raw materials has been attracting more and more attentions. Bio-based aliphatic polyamide 1010 (PA 1010), as a potential substitute for traditional polyamides, has found wide application in various fields. However, PA 1010 is highly flammable, and will burn rapidly and generate tremendous melt drips during burning. In order to improve the flame-retardant properties of PA 1010 without destroying its mechanical properties, this work prepared novel intrinsically flame-retardant PA 1010 copolymer PA 1010-co-FR by introduced the flame-retardant monomer FR. The effect of FR monomer on the thermal stability, flame retardancy and mechanical properties of PA 1010-co-FR was studied in detail. The results showed that PA 1010-co-FR exhibited good thermal stability and melting-crystallization properties. The tensile strength of PA 1010-co-FR decreased by only 14%, while the flexural strength remained basically unchanged. More importantly, PA 1010-co-FR passed the UL-94 V-0 rating and achieved an LOI value of 28%, which was significantly higher than pure PA 1010 (21.0%), and the data of cone calorimetry test showed that the peak heat release rate pHRR decreased by 29%. However, with more FR were introduced, the mechanical properties of copolymers were be seriously damaged, and the flame retardancy could not be further improved. The flame-retardant mechanism of PA 1010-co-FR was further investigated in detail.

Key words PA 1010; copolymerization; flame retardancy; mechanical property

Session: Thermal Fire Retardant Composites

Presenting Type：Poster

Facile Fabrication of a NiTi-LDH and Its Application on Silicone Foams for Flame Retardancy and Smoke Suppression

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Institute of Functional Textiles and Advanced Materials, College of Textiles & Clothing, Qingdao University

Flexible silicone foam (SiF) is polymeric elastomer with high porosity and relatively low density, shows excellent properties of both silicone rubbers and traditional polymeric foams. SiF has a high specific surface area and abundant flammable organic groups on its side chain, resulting to smolder and release smoke during combustion. In this work, an ultra-thin NiTi-LDH was successfully fabricated by a facile one-step coprecipitation method, and the chemical structure and microtopography of NiTi-LDH were characterized by Fourier transform infrared spectroscopy (FTIR), X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), scanning electron microscope (SEM) and transmission electron microscopy (TEM). The result of atomic force microscope (AFM) shows that the NiTi-LDH possesses an ultrathin structure and the average thickness is 1.93 ± 0.02 nm. The NiTi-LDH has been used to prepare fire-retardant and smoke-suppressing silicone foam composite. The results of the vertical flame testing (VFT) and limiting oxygen index (LOI) reveal that silicone foam with only 1 phr NiTi-LDH can pass UL-94 V-0 rating with a higher LOI value of 30.3%. The cone calorimeter results indicate that the introduction of only 1 phr NiTi-LDH significantly reduce the total smoke production of silicone foam by 73%. In conclusion, this ultra-thin NiTi-LDH nanosheets show high flame retarding and smoke suppression efficiency for silicone foam.

Key words Silicone foam; NiTi-LDH; Flame-retardant; Smoke suppression

Session: Thermal Fire Retardant Composites

Presenting Type: Poster

Natural polyphenols-inspired polyester with enhanced flame retardancy and UV-shielding property

Guanqi Zheng、Xiuli Wang、Bowen Liu、Yuzhong Wang*
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From the perspective of practical applications, the ever-increasing demand for high-performance and multifunctional materials has been driving scientists to put forward new methods to improve the performance of polymers. We herein propose a novel concept of improving the mechanical, flame-retardant and ultraviolet (UV)-blue light shielding properties of PET copolyesters by constructing polyphenols structures in the polymer chain. As expected, the UV light was totally shielded when the polyphenol content reached 2 mol%. More importantly, PETD completely shielded the short-wavelength blue light at a wavelength of 425 nm, which is harmful to human health. The PETD exhibit exceptional UV-blue light shielding capability, while retaining great transmittance in the visible light range. At the same time, the mechanical properties of materials are also crucial. Here we find that with the incorporation of polyphenol monomeric units, the tensile strength of PETD is 81.0 MPa at polyphenol contents of 5 mol%, which is 1.9 times that of PET. In addition, the tragic fire disasters pushing the common awareness of public fire safety and the demand for fire-safe polymeric materials to an unprecedented height. Here, the polyphenol structures largely enhanced the fire safety of PETD by cross-linking between polyphenols and the succeeding char formation. The large melt viscosity and strong charring ability contributed good flame-retardant and anti-dripping properties to polymers. The resulting $PETD_{30}$ achieved a V-0 rating in the UL-94 test and a limiting oxygen index of higher than 30%, and the peak heat release rate (p-HRR) and total smoke release (TSR) of $PETD_{40}$, decreased by 56% and 40% respectively. This simple strategy would direct the potential application of PETD in various fields, and also provided a new strategy for preparing high-performance and multifunctional polymers.

Key words Polyphenols; PET; flame retardancy; UV-shielding

Session: Thermal Fire Retardant Composites

Presenting Type: Poster

Novel fire-safe polycarbonate composite with good mechanical properties

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With the fast improvement of the industry and technical level, the fire-safe requirements of materials are particularly prominent. As an engineering plastic with excellent mechanical properties, polycarbonate (PC) is widely used in the fields such as electronics and public transportation, thus strict fire-safe performance is required for PC. Although pure PC exhibits certain flame retardancy, its relatively low limiting oxygen index (LOI) value of 24% and UL-94 V-2 rating are unable to power its applications. In this study, polydimethylsiloxane and sulfonate salt were added into the PC matrix by melt blending to obtain fire-safe PC composite PC/PDMS/SK. As a result, PC/PDMS/SK shows good thermal stability whose initial decomposition temperatures are all above 380 °C. Furthermore, PC/PDMS/SK exhibited a high LOI of 29.6% and successfully passed the UL-94 V-0 rating. In the Cone calorimetry test, the peak heat release (pHRR), total heat release (THR), and total smoke release (TSR) decreased by 22.3%, 39.8%, and 23.5% respectively. In addition, the mechanical properties of PC/PDMS/SK were also well maintained, whose impact strength is above 16 kJ/m^2, the tensile strength is higher than 48 MPa, and the flexural strength is above 115 MPa. This research provides a novel method to produce fire-safe polycarbonate with good mechanical properties.

Key words fire-safe ,polycarbonate,good mechanical properties

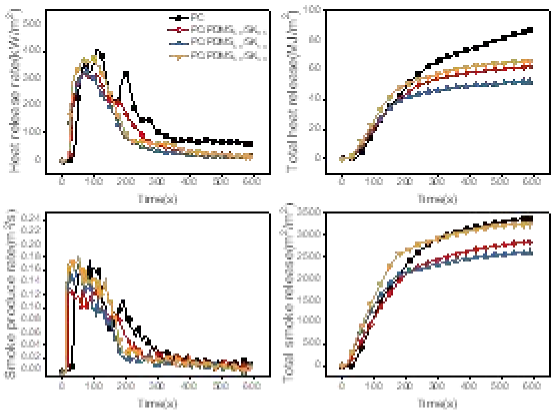

Fig. 1. The graph of CCT test.

Session: Thermal Fire Retardant Composites

Presenting Type: Poster

Preparation and Properties of APP Flame Retardant Ramie Reinforced Epoxy Resin Composites

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In this study, the flame retardant ramie fabric reinforced epoxy resin composite (EP/RF-APP) was prepared by a hand lay-up method after finishing ammonium polyphosphate (APP) on the surface of ramie fabrics (RF). With the weight gain of APP on RFs is about 20%, EP/RF-APP achieve a UL 94 V-0 rating with a limiting oxygen index value of 33.8%. The thermogravimetric test shows that the char residues of EP/RF-APP are as higher as 34.5% at 700 °C under nitrogen, which is 105% higher than that of ramie reinforced epoxy resin composites (EP/RF). The data obtained from cone calorimetry test show that both the heat and smoke production released during burning are reduced. The peak heat release rate and total heat release values have decreased by 26% and 41%; what is more, total smoke production has decreased by about 44%. The above data indicate that the fire safety of EP/RF-APP is significantly improved. By analyzing the gas phase products, EP/RF-APP suppresses the generation of flammable gases to achieve the flame retardancy. In terms of mechanical properties, the presence of APP affects the internal compatibility of the composite to a certain extent, which makes the tensile strength and impact strength of EP/RF-APP decrease compared with EP/RF, but the decline was not significant. However, the flexural strength is hardly affected. Overall, it can be considered that EP/RF-APP preserves basically satisfactory mechanical properties. EP/RF-APP, which exhibits excellent flame retardant properties and maintains mechanical properties, provides a feasible solution for the preparation of flame retardant natural fiber reinforced composites.

Key words Ammonium polyphosphate; Flame retardancy; Ramie fabrics; Epoxy resin

Session: Thermal Fire Retardant Composites

Presenting Type: Poster

N-containing hybrid composites coatings for enhanced fire retardant properties of cotton using one-pot sol-gel process

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Changwon National University

Textile products made of cotton are used in numerous sectors of life, ranging from home-made accessories to advanced industrial goods. However, one of the major safety concerns with these products is fire vulnerability, due to their lower flammability ratings, such as limiting oxygen index (LOI)~19.0 and combustion temperature (360~425°C). Silica sols were prepared via sol-gel process. 6.72 mL (0.03 mol) of TEOS, 3.5 mL (0.06 mol) of ethanol, 2.16 mL (0.12 mol) of deionized water. The molar ratio of TEOS, C2H5OH, and H2O was set as 1:2:4. Total solution of 208ml was prepared with the stated ration, and 3 mL of HCl (0.01 M) were added to a beaker, and then the solution was stirred continuously for 4 h at room temperature until a transparent solution was obtained.

A separate 10% ethanol solution of the melamine and chitosan was prepared and stirred for 5 hr. The solution was then mixed with the prepared sol and used for coatings. Cotton samples were dipped in the solution for various time periods and then dried and cured for 10 hr. at 90oC. The obtained samples were then treated for 2 min at 180oC and then washed out for 5 min. the samples were then characterized using LV-SEM, FTIR, and EDS analysis. To understand the thermal properties of the samples, MCC, TGA, and Flame test analysis were carried out. From the investigation, it appeared that the chitosan-based coatings offer effective resistance to retard the flame and protect the sample from fast burning. From the UL-94 test, it can be seen the overall efficient role of chitosan-based coating as the amount of leftover residue is higher compared to other samples

Key words Fire retardant coatings, Solgel, Hybrid coatings, UL-94, LV, SEM, TGA

Session: Thermal Fire Retardant Composites

Presenting Type: Poster

An interfacial radiation-absorbing hydrogel film for efficient thermal utilization on solar evaporator surfaces

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sichuan university

Solar-driven interfacial evaporation, as one of the most promising sustainable technologies to alleviate global water scarcity, has garnered intensive attention for water purification in the past decade. For energy-intensive interfacial vapor generation, various heat loss processes restrict the energy efficiency of interfacial heat localization. Generally, the heat loss to the bulk water can be suppressed by reducing the thermal conductivity of the substrate or introducing thermal insulation layer. However, energy loss to air via heat radiation and convection occurs yet are ignored, which also severely limits the energy efficiency. Therefore, it is impressive to precisely regulate the interfacial thermal energy for interfacial vapor generation. In this contribution, we developed a hierarchically porous radiation-absorbing hydrogel film (hp-RAH) through in-situ gelation strategy, which can be used for high-efficiency thermal management of the existing solar evaporators. The hydrogel film is capable of absorbing and re-utilizing the thermal radiation energy emitted by the photothermal layer and eradicating thermal convection of photothermal layer into air. Consequently, the heat radiation and convection losses are reduced from 6.6% to 0.39% under 1 sun, giving rise to an evaporation efficiency, up to 95%. This strategy concerning thermal management offers a new opportunity for addressing the challenges at energy utilization efficiency of emerging solar-driven interfacial evaporation technology.

Key words thermal management, interfacial evaporation

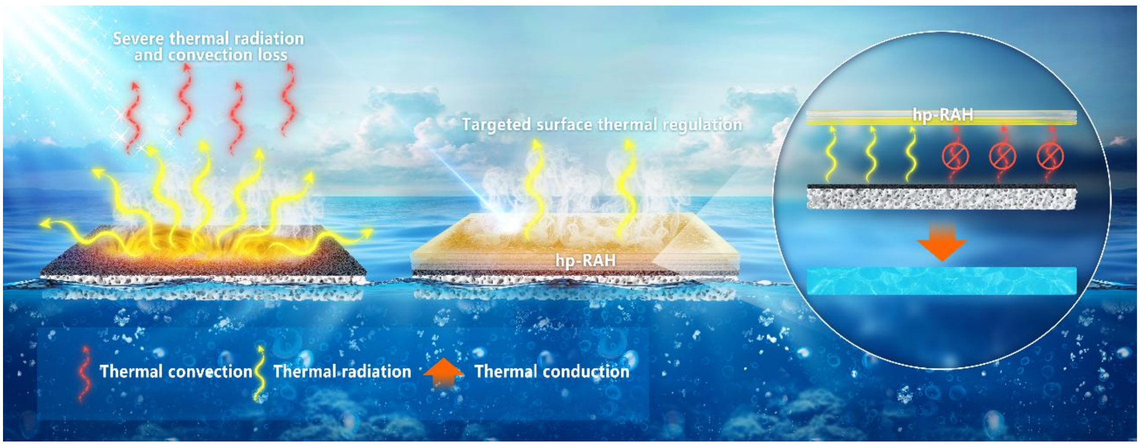

Fig. 1. Schematic illustration of interfacial evaporation system based on the hierarchically porous radiation-absorbing hydrogel film (hp-RAH) for solar water purification.

Session: Thermal Fire Retardant Composites

Presenting Type: Poster

Hybrid copolymerization strategy based on dynamic covalent to prepare flame retardant silicone polyurethane with re-processability

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SiChuan university

Traditional silicone thermoplastic elastomer is highly attractive as construction materials for good mechanical strength, aging resistance, but little attention is paid to the fire safety behavior and durability in practical application1-3. Since unrecoverable structure, most of available flame retarded silicone polymer would be invalidated after long term storage. Those waste silicone cause the gross consumption of raw materials. Herein, durable silicone polyurethane (STPU) with intrinsic P/N synergistic flame retardancy (FR) and re-processability are fabricated by copolymerization between reactive phosphorus-containing monomer (MDP), acrylamide (AM) and dynamic phenylboronic ester group. The addition of only 7 wt% AM and 10 wt% MDP enables STPU to achieve a desirable VTM-0 rating during vertical burning tests and a limited oxygen index (LOI) value of 26.1%. Besides, through the twice reprocessing, it is able to remain the 87.58% of mechanical strength due to breaking and reformation of dynamic covalent bonds of phenylboronic ester group. This work provides an innovative and practical strategy for the synthesis of polysiloxane composition, aiming to implent high-performance flame retardants and further the sustainable development of flame retardants polymer materials. This work was financially supported by the Jiangsu Province Science and Technology Project (BA202066), and Sichuan Science and Technology Project (No. 2021YFG0083 and 2020YFSY0036).

Key words Silicone polyurethane; Flame retardancy; Reprocessability; Synergistic effect; Dynamic covalent bond

Session: Thermal Fire Retardant Composites

Presenting Type: Published only

A phosphorus/nitrogen/silicon-containing hyperbranched flame retardant for epoxy resin

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The flammability of epoxy resin (EP) restricted its industrial application. In this paper, a hyperbranched P/Si/N-containing flame-retardant additivec (TTD) was synthesized. Nuclear magnetic resonance (NMR) and fourier transform infrared spectroscopy (FTIR) were used to confirm the TTD structure. The effect of TTD on the comprehensive properties and durable flame retardancy of EP was investigated in detail. The results showed that the EP sample with 7% TTD featured the best flame retardancy among all EP samples, which achieved a UL-94 V-0 rating and a limiting oxygen index (LOI) of 40%. After 7 days of thermal aging test, the LOI of EP sample with 7% TTD was still as high as 38%. Thus, TTD endowed EP with durable flame retardancy.

Key words Epoxy resin, Hyperbranched, Flame retardancy, Aging resistance

Session: Thermal Fire Retardant Composites

Presenting Type: Published only

Hollow nanocages preserving nanodots-based metal-organic framework provides enhanced fire safety for epoxy nanocomposites

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2. National Engineering Research Center of Flame Retardant Materials

Metal–organic frameworks (MOFs) have gained tremendous popularity in every field owing to their outstanding design ability and flexibility in composition and structure to acquire desirable physical/chemical properties and functionality. Hollow nanocages derived from MOFs feature more exposed active sites, stronger interactions, and better compatibility within the polymer matrix than solid blocks.

In this study, using step-by-step carving in the sequence of organic phytic acid and inorganic boric acid, ZIF-67 can be retained in the form of its nanodots (ZNs) with the (235) high-energy plane decorated on the cobalt phytate hollow shells, endowing the hybrid superstructure product (ZNs-Borate/Co-PA, ZNs-B/CP) with a relatively high surface area (348.3 m^2/g) and enhanced catalytic properties, whose stoichiometric formula was speculated to be $Co_2(BO_3)_{1.6}(C_6H_9O_{24}P_6)_{0.05}(C_4N_2H_5)_{0.1}$ by elemental analysis coupled with ICP. Hollow superstructure nanocages assembled by nanosheet superstructures were created and decorated with abundantly retained ZNs that adsorbed borate ions in the matrix. The presence of ZNs endowed the hollow nanocages more number of exposed active sites involving the high-energy plane, which is beneficial for improved interaction and compatibility within the polymer matrix.

Owing to the ingeniously designed chemical composition and nanostructures, a load of 2 wt% ZNs-B/CP into epoxy resin improved the limiting oxygen index to 28.4%, and the peak of heat release rate (pHRR), total heat release (THR), and the peak of smoke production rate (pSPR) were 648 kW/m^2, 74.1 MJ/m^2, and 0.225 m^2/s, respectively, which decreased by 43.1%, 11.9%, and 17.9% compared with pure epoxy resin, assisted by the fast char formation mechanism. Moreover, the mechanical properties of EP nanocomposites, including impact and tensile strengths, were slightly compromised by ZNs-B/CP.

Under the background of burgeoning investigations for MOFs, this work supplements a feasible synthetic artifice for MOF nanodots and proposes a potential application as a flame retardant for epoxy resin.

Key words Metal-organic framework; Step-by-step carving; Nanodots; Hollow nanostructure; Flame retardant

Session: Thermal Fire Retardant Composites

Presenting Type: Published only

Hyperbranched polymers endow epoxy resins with favorable flame retardancy and toughness

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Epoxy resin (EP) is flammable and its combustion are threats to human life and property with the generation of dense smoke. In this study, a novel P-P hyperbranched polymer (DT) with multiple phosphorus-oxygen states was designed and synthesized, and applied to EP as an additive. It was found that adjusting the ratio of phosphorus-oxygen state has a considerable influence on the flame retardancy. Only 2 wt% of DT (EP/2DT) was added to pass UL-94 V-0 rating. In addition, the peak heat release rate, total heat release and total smoke release of EP/4DT decreased by 23.8%, 22.5% and 19.9%, respectively, compared to EP. Moreover, EP/2DT and EP/1DT exhibited better strength and toughness in comparison to EP. The findings show that hyperbranched polymers with multi-phosphate oxygenation have significant potential in the direction of environmental, toughened and flame retardant epoxy resins.

Key words Flame retardancy, Mechanical properties , Transparency, Epoxy resin

Session: Thermal Fire Retardant Composites

Presenting Type: Published only

A novel and efficient P/N/B-containing mono-component intumescent flame retardant for improving the flame retardancy of polyolefin elastomer

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To further improve the flame retardant efficiency of intumescent flame retardants (IFR) in polyolefin elastomers (POM), a novel mono-component P/N/B-containing intumescent flame retardant poly(methylphosphonic-boric acid piperazine neopentylgcol ester) named MBPNE was synthesized. The chemical structure of MBPNE was analyzed by FTIR, 13C and 31P solid-state NMR tests. The results of thermal gravimetric analysis indicated that MBPNE possessed excellent charring capability and its residual char was 27.5 wt% at 800 oC. Besides, MBPNE occurred melting and expansion process during charring evolution process. MBPNE was used to prepare flame retarded POE composites. The 1.6 mm POE/MBPNE specimens achieved UL-94 V-0 rating and their LOI value was 25.5% when 22 wt% MBPNE was incorporated. The sheet was extinguished quickly after departing the flame and no dripping appeared. Furthermore, the incorporation of MBPNE effectively enhanced the residual char mass after cone calorimeter tests, and the heat release was suppressed. The compact, expanded, partially graphitized and coherent char layer were generated on POE composites surface during burning process and exerted isolation effect in condensed phase. Meanwhile, the degradation products of MBPNE quenched active free radicals in gaseous phase, which effectually interrupted the combustion chain reaction of POE composites. Consequently, the POE composites were endowed excellent flame retardant performance.

Key words Phosphorus-nitrogen-boron containing; Mono-component intumescent flame retardant; Flame retardancy; Flame-retardant mechanism; Polyolefin elastomer

Session: Thermal Fire Retardant Composites

Presenting Type: Published only

Flame-retardant aerogels with excellent mechanical properties and high-temperature structural stability

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Aerogels, as new porous materials with three-dimensional network structures, are highly favored in the field of thermal insulation materials due to their low density, high porosity, and low thermal conductivity. The traditional inorganic silica aerogel exhibits excellent fire resistance but shows brittleness and poor mechanical properties. Organic polymer aerogels with better mechanical properties show high flammability and poor high temperature resistance. Here, our work designed an organic–inorganic hybrid aerogel with a chemical/physical double cross-linking structure by combining a chemically cross-linked matrix constructed by polyorganosiloxane and gelatin polymers with inorganic fillers with high thermal stability. The obtained aerogel (GTM) possesses excellent mechanical properties (compression modulus is 7.73 MPa), high thermal stability, and outstanding flame retardancy. It could pass the V-0 rate in the UL-94 test and achieve an LOI value of 40%. Meanwhile, the PHRR of the GTM aerogel was reduced by 43% compared with the sample without fillers, and its mass of carbon residue was up to 74.3%. Moreover, the GTM aerogel maintained its original shape without collapse after treatment at 800 °C for a long time, exhibiting outstanding skeleton stability and high temperature resistance under high-temperature conditions. These characteristics make the aerogel a potential application for the development of insulation materials in the field of high-rise buildings and aerospace.

Key words aerogel，double cross-linked structure，flame retardancy，thermal stability

Session: Thermal Fire Retardant Composites

Presenting Type: Published only

The Flame-retardant Contribution and Burning Behavior of Aryl ether, Aryl ketone, and Aryl Nitrile Structure Groups

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Sichuan university

Uncontrolled polymer combustion leads to fire disasters and is one of the most feared hazards in daily life. Flame retardancy is a way to interfere with or control combustion, slowing down the flame spread and reducing the severity of fire events. Some chemical groups (halogen, DOPO, phosphate, Shiff-based, phenylacetylene, azobenzene, aromatic groups, etc.) have been used as flame-retardant motifs to enhance the flame retardance of polymers. Notably, revealing the contribution of flame-retardant motifs shows a significant effect on material design. Among these groups, the aromatic groups have unleashed high flame-retardant efficiency by promoting charring in the condensed phase, thus not only enhancing flame retardance but also suppressing fire hazards (heat, smoke, and droplets) during burning. Herein, we quantitatively discuss the flame-retardant contribution of aryl ether, aryl ketone, and aryl nitrile structure by analyzing their charring ability, limiting oxygen index, vertical test rating, and the heat release rate, the pyrolysis/burning behaviors. The aryl ether structure can enhance the flame retardance by binding small aliphatic segments, the aryl ketone structure can promote the char ability by self-forming macro-aromatic rings, and the aryl nitrile structure can suppress the burning via cyclotrimerization to thermal-stable triazine rings. Due to the different pyrolysis/burning ways, these motifs can enhance flame retardance and suppress the heat lease to different degrees. This work supplies the quantitative structure-activity relationship for flame retardance of some aryl structures and provides key guidance for the design of safer polymers.

Key words flame retardant, structure-property relationship, Group contribution

Session: Thermal Fire Retardant Composites

Presenting Type: Published only

Flame-retardant coating of polyurethane foam

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In this study, we demonstrate a facile flame-retardant coating that can effectively suppress smoke and toxic gas release in a fire for flexible polyurethane foam (FPUF). In this coating, nanoporous sepiolite (SEP) nanofibers are wrapped by phytic aid (PA) for stable dispersion to have a negative charge, and then together with the positively charged chitosan (CH), are stably deposited onto the surface of FPUF through Layer-by-Layer assembly. The CH/SEP@PA coating significantly reduces the flammability and smoke toxic gas release of FPUF. Compared with the pure foam, the peak heat release rate of the coated one is reduced by 46% at a coating loading of about 15%. Moreover, the smoke density is reduced by 83%, and the peak production of CO and CO2 was reduced by 52% and 44%, respectively. The results show that this organic-inorganic hybrid coating has good flame-retardant properties and can significantly improve the fire safety of flexible polyurethane foam and its wide source of raw materials and low cost also make the work have a broad application prospect.

Key words nanocoating, smoke suppression, toxic gas reduction, flame retardancy

Session: Thermal Fire Retardant Composites

Presenting Type: Published only

Study on Anti-ultraviolet Aging of Flame Retardant Modified Epoxy Resin

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The effect of UV aging on the properties of flame retardant modified epoxy resin (E51) after adding different ratios of light stabilizer Tinuvin 770 and antioxidant Irganox 1010 was studied. Chemical structure, surface morphology, mechanical properties, flame retardant properties and thermal properties were tested, it is found that UV irradiation destroys the structure of flame retardants, and degrades and oxidizes epoxy resins. Different ratios of anti-aging agents improve the retention rates of mechanical properties and flame retardant properties. Antioxidant-only samples showed the best performance after 28 days of aging. The retention rates of tensile and flexural strengths increased to 100.10% and 92.50%, compared with 80.37% and 81.61% of the samples without anti-aging agent. The limiting oxygen index (LOI) increased from 34.4% to 37.5% and the antioxidants made the thermal stability of the samples better. The results show that the addition of antioxidant Irganox 1010 is the best for improving the anti-ultraviolet aging properties of flame retardant modified epoxy resin.

Key words ultraviolet aging, epoxy resin, intrinsic phosphorus flame retardant, light stabilizer, antioxidant

Hangzhou, PR China 25-28 April, 2023

Session: Thermal Fire Retardant Composites

Presenting Type: Published only

Durable flame-retardant coating for cotton fabrics

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Cotton fabrics, as one of the significant natural textiles, have been applied in all aspects of production and life, including home, public transportation, shopping malls, etc. However, despite many benefits, cotton fabrics pose a serious fire hazard due to its high flammability, which threaten property and life safety. Once the fabrics are ignited, the flame spreads quickly and is difficult to extinguish. In addition, the fabrics are usually complex to produce and difficult to recycle, which requires them to be reusable and have a long service life. As a result, excellent durable flame-retardant cotton fabrics are expected to be developed urgently. In this work, inspired by dye-fixing process, we propose a new strategy for constructing durable flame-retardant coatings based on the dynamic coordination balance of Ca2+ and TA during the tap water-washing process. The coating can keep high durability during the long-term tap washing process. Even, after 20 cycles of tap water washing, the coated fabric could still pass VFT with a short damage length of less than 10 cm. This eco-friendly biomass-based coating based on dynamic coordination provides a new strategy for fabricating durable flame-retardant fabrics.

Key words Cotton fabrics，Flame retardant，durable，coating

Session: Thermal Fire Retardant Composites

Presenting Type: Published only

A multifunctional polyethylenimine curing agent towards transparent, durable fire-safe, mechanically-robust and tough epoxy resins

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2. NingboTech University

Epoxy resin (EP) features superior comprehensive performances, but inherent flammability seriously limits its industrial applications. Current flame-retardant strategies often bring about enhanced flame retardancy but deteriorated mechanical, thermal and optical properties and neglect flame retardant durability. Herein, a phosphorus/silicon-containing polyethylenimine (PES) is designed as a multifunctional curing agent for EP. Replacing polyethylenimine (PEI) with PES maintains high visible light transmittance of EPs and improves the UV-blocking properties. The EP cured by 30wt% PES (EP/30PES) exhibits great mechanical properties. EP/30PES achieves a limiting oxygen index (LOI) of 35.0% and a UL-94 V-0 rating, and its peak smoke release rate (PSPR) reduce by 63.8% relative to that of EP cured by 15wt% PEI (EP/15PEI). Hence, the superior flame retardancy, smoke suppression and mechanical performances of EP/30PES enable it to outperform previous flame-retardant EP/aliphatic amine counterparts. Meanwhile, EP/30PES shows durable flame retardancy, which still achieves a UL-94 V-0 classification after acid/alkali/aging resistance tests. This work provides an integrated design of multifunctional curing agents to create durable fire-safe EPs with superior optical and mechanical performances, thus holding great promise for different industrial applications.

Key words Epoxy resin; Phosphorus; Silicon; Polyethylenimine; Comprehensive performances.

Session: Thermal Fire Retardant Composites

Presenting Type: Published only

Carbon fiber/vinyl ester resin composites with improved fire resistance and smoke suppression

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Carbon fiber/vinyl ester resin composites (CF/VER) have been widely used in industry for their excellent mechanical properties, chemical corrosion resistance, low viscosity, etc. However, CF/VER exhibits high flammability with producing great amounts of toxic or harmful gases/smokes during burning and posing grave threats to human health and property loss, thus leads limited applications in some specific fields such as rail transit and ship transportation. Thus, it is necessary to improve their flame retardancy and smoke suppression property. Herein, a novel phosphorus-containing flame retardant (HPLA) is designed to fabricate carbon fiber/vinyl ester resin composite (CF/VER/HPLA) with excellent flame retardancy, smoke suppression, and good mechanical properties. HPLA shows good compatibility and dispersion with VER, which makes the CF/VER/HPLA30 containing 30 wt% HPLA reach the UL-94 vertical burning test V-0 rating and an upgraded LOI (36.8%). In the cone calorimeter tests, compared with the virgin CF/VER, the peak value of heat release rate (pHRR), total heat release (THR), smoke production rate (SPR), and total smoke production (TSP) of CF/VER/HPLA30 exhibits a 57.0%, 22.5%, 65% and 49.8% decrease, respectively, and the residue is greatly increased. Moreover, the mechanical properties of the flame-retardant composites remain at a high level, flexural strength and notched impact strength reach 1170.0±54.4 MPa and 160.6±3.3 MPa, respectively. In addition, the Thermal Gravimetric Analysis (at N2 atmosphere) illustrates that, the flame-retardant VER also have acceptable thermal stability (T5%= 329.7°C). In a word, our work provides a practical method for fabricating fire-safety VER composites with high flame-retardance, low smoke release, and good mechanical properties.

Key words Vinyl ester resin; Smoke suppression; Flame retardancy; Mechanical properties

Session: Automated Manufacturing

Presenting Type: Oral-Invited

Multi-sensing and online evaluation of continuous fiber-reinforced composites via AM

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Multi-sensing and correlation analysis are essential for the online process evaluation and optimization so as to ensure the quality of as-fabricated products. Defect-free process control is significant for the additively manufactured (AM) continuous fiber-reinforced composite (CFRP) because a large number of defects and poor quality control in AM-fabricated CFRP restrict its mechanical performance and product service life. In this work, a framework of multi-sensor fusion for CFRP additive manufacturing is proposed for its in-situ process evaluation and to establish the correlations between process parameters/pattern features with layer-wise defects and surface quality. IR and visual cameras, force, and laser displacement sensors are assembled with printing head to obtain the online datasets. Multiple signal denoising, feature extraction, and classification are conducted to incorporate deep-learning neural networks and correlation analysis. The critical features of these signals are extracted for quantitative analysis of layer-wise surface roughness, level of fiber misalignment, and the number of defects. Multi-sensor fusion can be a practical approach for online monitoring and process evaluation, and the established knowledgebase is helpful in predicting and adjusting the localized process parameters upon the fabrication process.

Key words Additive manufacturing, Multi-sensor fusion, Online evaluation, Defect detection

Session: Automated Manufacturing

Presenting Type: Oral-Invited

An investigation on a new sliding cutting strategy for Carbon Fiber-Reinforced Polymers

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The current cutting strategies for carbon fiber reinforced polymer (CFRP) inherit essentially from metal cutting. The frequently occurred damages such as burrs, cracks and delamination suggest that the existing strategies may not be the best choice for CFRP cutting. This study proposed a sliding cutting strategy especially for CFRP. The novelty is adding an extra lateral velocity on cutting edge to act sliding motion between fiber-matrix and the cutting edge. Then the stress in the materials in front of cutting tip will become more concentrated, which will help to break fibers in desired positions. Thus, the machining quality can be improved. The sliding cutting process was analyzed and experiments were conducted to examine the proposed strategy. Two types of cutting tools that offered sliding and orthogonal cutting were designed. Four factors, namely machined surface roughness, subsurface damages, forces and tool wear, were obtained to evaluate the cutting quality. Results show that sliding cutting has more advantages than orthogonal cutting in the four aspects.

Key words CFRP; sliding cutting; cutting strategy; orthogonal cutting

Hangzhou, PR China 25-28 April, 2023

Session: Automated Manufacturing

Presenting Type: Oral-Onsite

The Prediction Model for Resistance of CFRP Interference joint Subjected to Current Strike

Yuchen Zhu、Hui Cheng*
Northwestern Polytechnical University

Composite interference joints are widely used in the aerospace industry due to their high load-carrying capacity and connection reliability. However, composite joint structures are more susceptible to lightning damage in extreme environments such as lightning. The presence of multiple assembly interfaces and assembly damage in composite joint structures leads to the formation of complex damage patterns under lightning strikes. Using electrical conductivity as an entry point, this study analyses the prediction resistance model of a CFRP interference joint structure under a low current strike. Based on the conductive network, the dependence of the contact resistance of the assembly interface on the interference amount, structure size, and current waveform at different stages of a lightning strike is analyzed. The analytical expressions for the initial resistance related to the interference volume and structure dimensions before the lightning strike, and the dynamic resistance change law under the influence of the current waveform after the lightning strike were established, respectively. Nondestructive tests were designed to verify and refine the initial resistance values and the equivalent resistance law. The results show that the initial resistance of the CFRP interference-connected structure is correlated with the amount of interference and that the equivalent resistance under small current shocks is influenced by both the amount of interference and the peak current. The medium amount of interference provides a significant protective gain effect on the composite connection. This work provides a method for calculating the electrical conductivity of CFRP laminates with fasteners.

Key words Carbon fiber reinforced polymer, Interference joint structure, Resistance prediction models, Lightning current strike

Session: Automated Manufacturing

Presenting Type: Oral-Onsite

Fibrous shell approach for textile composite forming

Renzi BAI*、Bo Chen、Julien Colmars、Naim Naouar
INSA Lyon - LaMCoS

The use of numerical composite model is necessary to optimize composite manufacturing process. However, standard shell approach gives a bending stiffness that related to the membrane rigidities and the thickness which led to a value too large. There exist also some membrane-bending decoupled methods. However, they are not based on the physics of textile reinforcement and will have some artificial aspects. This paper aims to present a fibrous shell approach for composite forming based on the physics of the textile deformation.

Key words Fabrics, Fibrous material, Finite element method, Forming

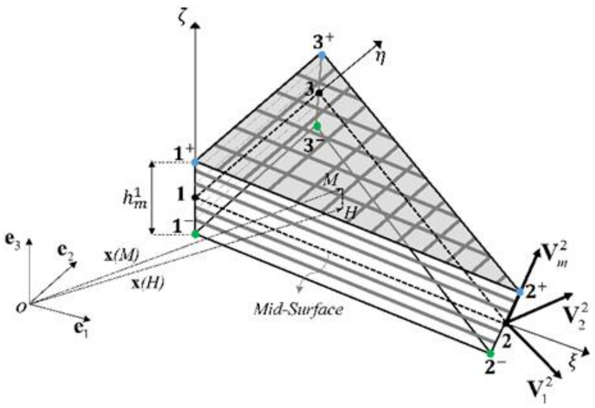

Fig. 1. Geometry of the 3D fibrous shell element

Session: Automated Manufacturing

Presenting Type: Oral-Onsite

Research progress on composite manufacturing technology and the key problems from practical prospective

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Advanced composite materials have completed the application transformation from secondary to primary structures, and the amount of composite materials in aircrafts have become one of the representative indicators to characterize their progressiveness. The great advancement on composite materials puts forward the strict requirements on the manufacturing technology of composite materials. In the present presentation, the effort that we made on the advanced composite manufacturing technology is briefly introduced, and key achievements on some representative composite parts are outlined.

In addition, three key scientific problems from practical prospective are discussed in detail in order to find the corresponding solutions for composite material manufacturing industry.

(i) The process induced deformations and their control methods. The modelling strategies have been vigorously researched, and different elaborate models have been proposed. Meanwhile, simulations have been gradually used in practical engineering for process engineers by collaborating with the key universities and research institutes. However, simulations are employed as guidance for manufacturing. Research on simplified models with higher computational efficiency should be carried out for industry. Moreover, more attention should be paid to the control method of process induced deformations since the related research is still in initial stage.

(ii) Wrinkle defect formed in manufacturing process. Wrinkles formed in automated fiber placement and angled composite parts are the key problems that we recently encountered. Defect generation mechanisms did not draw too much attention of us in the past, and some European institutes have made progress on this issue. Considering the great significance for industry, it is urgent to carry out investigations on wrinkle generation mechanisms and counter measures for wrinkle control.

(iii) Intelligent manufacturing. The sizes of primary composite structures are extremely large thanks to the integrally manufacturing process. The only manufacturing solution of large composite parts is the intelligent manufacturing. However, as a special process, there are much more work to do for the intelligent manufacturing of composite materials.

Key words Intelligent manufacturing; process induced deformation; Defect; Wrinkle;

Session: Automated Manufacturing

Presenting Type：Oral-Onsite

Experimental characterization and numerical modeling of the bending behavior of carbon fiber unidirectional thermoset prepregs

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To improve the accuracy of forming simulations of carbon fiber unidirectional thermoset prepregs (UD prepregs), in particular the wrinkle predictions, the bending behavior of UD prepregs in the forming needs to be properly characterized and modeled. In this paper, a bending test device was firstly designed to characterize the bending deformation behavior of UD prepregs at different temperatures and loading rates. Both the temperature and the loading rate have significant effect on the bending stiffness of UD prepregs, particularly the bending stiffness of UD prepregs increases greatly with the increasing of loading rate. To simulate the bending deformation of UD prepregs, a shell-membrane hybrid element method was proposed to realize the decoupling of the tensile-bending deformation. The shell element primarily accounts for the bending deformation energy of UD prepregs, while the membrane element mainly simulates the in-plane tensile and in-plane shear deformations of UD prepregs. The comparison results show that the proposed model can effectively simulate the bending deformation of the UD prepregs.

Key words UD prepregs; Forming process; Bending behavior characteriation; Numerical simulation

Session: Automated Manufacturing

Presenting Type：Oral–Onsite

A hyperelastic constitutive model considering tension-shear coupling in the preforming modeling of 3D woven fabrics

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3D woven fabrics have been increasingly used in the fan blade of aero-engine. Complex deformation modes exist in the preforming of 3D woven fabrics, their accurate characterization and modeling would directly affect the prediction accuracy of preforming. Fiber tension is regarded as an important factor to affect the in-plane shear behavior of 3D woven fabrics. In this paper, an improved in-house picture frame tester was firstly developed to investigate the influence of fiber pretension on the in-plane shear behavior of 3D woven fabrics. Then, a hyperelastic constitutive model considering the tension-shear coupling was proposed. The parameters of the proposed constitutive model were identified through some specific tests. The constitutive model was finally validated by the preforming simulations of representative shapes.

Key words 3D woven fabrics; preforming; hyperelastic constitutive model; tension-shear coupling; finite element analysis

Session: Automated Manufacturing

Presenting Type: Oral-Onsite

Multiscale evaluation and optimization of cure process during composite manufacture

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Inspired by the multiscale characteristic of composite structure, this present work proposes a novel modeling framework to evaluate and optimize the cure process of carbon fiber reinforced resin matrix (CFRP) composites where the thermochemical and thermomechanical behaviors are investigated from macroscale to microscale. For evaluating the cure process, a nonlinear heat transfer problem which involves the heat release from the cure reaction is solved by the macroscale laminate model under the manufacturer recommended cure cycle (MRCC). Through the thermochemical analysis, the temperature gradient is calculated. The obtained temperature and degree of cure information are introduced into the microscale representative volume element (RVE) model so as to analyze the cure process effect on the composite material properties. The viscoelasticity, thermal expansion and cure shrinkage of the constituents are considered during the thermomechanical analysis. The microscale cure residual stress is predicted owing the mismatch of material properties. Besides, to improve the CFRP composite performance and reduce manufacturing cost, a multi-objective optimization is also implemented based on non-dominated sorting genetic algorithm-II (NSGA-II). The maximum temperature gradient, the maximum residual stress and the process time are significantly reduced by the optimized cure profile

Key words CFRP; Cure process; Optimization; Multiscale method

Session: Automated Manufacturing

Presenting Type: Oral-Onsite

A comprehensive modelling framework for defect prediction in automated fibre placement of composites

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Automated fibre placement (AFP) has become one of the mainstream techniques in advanced composite manufacturing, bringing much higher efficiency and reducing waste compared to hand layup. However, one critical issue in the AFP technique is manufacture-induced defects, such as wrinkles, when the materials are deposited along a curved path or on a doubly-curved surface. These defects can lead to the degradation of the finished part's mechanical performance by up to 25%. Currently industry largely depends on costly physical trials to tackle the issues. Process simulation of the manufacturing provides a feasible alternative way by conducting the trials in virtual space. This is, however, challenging due to the complexity of the AFP deposition process, i.e. large numbers of machine processing parameters (such as deposition path, processing temperature, layup speed, pressure, etc.) coupled with the nonlinear behaviour of the prepreg tape material. Current academic research is mostly limited to qualitative prediction under a single condition, which is quite far from real-world industrial applications.

In this work, recent advancements achieved in process simulation of AFP, are presented. The work starts with the characterisation of material under key mechanisms that are known to affect defect formation. Constitutive models for each mechanism are then derived and implemented in the form of material subroutines for commercial finite-element (FE) packages, which are further integrated into a full FE simulation platform. The new framework was validated against real-world data and good agreement was observed. An investigation of the processing parameters on deposition quality demonstrated the capability of the platform to work in varied processing conditions rather than single isolated ones. The work provided insights into how manufacturing parameters of AFP affect the part quality and pave the way to replace physical trials with virtual tests, thus it can effectively reduce cost and increase production rate.

Key words Automated Fibre Placement; Manufacturing-induced defects; Process modelling

Hangzhou, PR China 25-28 April, 2023

Session: Automated Manufacturing

Presenting Type: Oral-Virtual Platform

Modeling-based optimization of blank geometry for multi-layer woven composites preforming

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The design of preforming parameters is crucial to efficiently produce woven composite parts using automatic manufacturing process. To optimize blank geometry in thermoforming and minimize material waste from part trimming, a complete numerical modeling-based optimization method for woven composites preforming is developed combined with a non-orthogonal material model that can continuously trace warp and weft yarn directions. Preforming simulation is conducted to predict part geometry and fiber orientation, and the geometry represented by finite element mesh is then modified and applied to the secondary preforming. An ideal blank geometry can be created with optimization iteration and applied to final actual preforming of parts. Applicability of the established optimization approach is demonstrated through comparing numerical results of preforming with the corresponding experimental results of three-layer woven composites. The draw-in distances, wrinkling appearance and variation of angles between warp and weft yarns caused by preforming all show good consistency, verifying that this numerical modeling-based optimization method can accurately design blank geometry under various process conditions in order to minimize material consumption and process cost.

Key words Optimization design, Woven composites, Preforming, Process simulation, Finite element analysis

Session: Automated Manufacturing

Presenting Type: Oral-Virtual Platform

Meso-scale damage modelling of plain woven carbon-fiber reinforced composites with different layup sequences

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Meso-scale finite element method is an effective numerical modelling technique in predicting mechanical properties, studying stress-strain fields of RVE, determining damage initiation and visualizing the damage evolution of fiber reinforced composites. Under this circumstance, the influences of different plain woven fabric layup sequences on the performance and damage of the fiber reinforced composites were systematically investigated by using meso-scale finite element method. The stress-strain field of the yarn scale, the stress distribution and stress concentration of the yarns in intra/inter-ply, as well as the main failure modes of the woven fiber reinforced composites were analyzed. Results show that the local load-bearing mechanism is different under different layup sequences, the ply angle changes the direction of intra-ply stress to promote the local shear strain of matrix between the plies and consequently leads to the damage and failure of the matrix. The obtained highlighted results can provide a theoretical basis and practical guidance for the optimal design and optimization of composite structures in real process.

Key words Plain woven carbon-fiber reinforced composites, meso-scale FEM modelling, Layup sequences, Performance prediction, Damage mechanism

Session: Automated Manufacturing

Presenting Type: Oral−Virtual Platform

A hypoelastic stress resultant shell approach for simulating the specific bending behavior in the draping of the textile composite reinforcement

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Due to the quasi-inextensibility and the possible slippage between fibers, the textile material bending stiffness is much lower than the value provided by the classical shell theory. To simulate the material bending behavior in the draping of textile composite reinforcement, a hypoelastic stress resultant shell approach is introduced based on the material deformation mechanism. The stress resultants and stress moments are related to membrane strains and curvatures by the rate constitutive equations (hypoelastic laws). Several forming experiments with different configurations have been conducted and compared with the simulation result which shows the correctness and effectiveness of the proposed approach.

Key words Hypoelastic, Stress resultant shell, Textile composite, Drape simulation

Session: Automated Manufacturing

Presenting Type: Oral-Virtual Platform

Multi-scale modeling of mechanical behavior of 3D braided CFRP composites under uniaxial tension

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An innovative multiscale modeling approach based on local homogenization is developed to investigate the mechanical behavior of three-dimensional (3D) braided CFRP composites under uniaxial tension. A microscopic representative volume element (RVE) consisting of carbon fibers, resin matrix and interface is generated, to capture the effective properties of the yarn. Two sets of mesoscopic RVEs are constructed according to the complex braided architecture, which are surface and interior RVEs, respectively. Combined with continuous damage mechanics (CDM) and cohesive zone model (CZM) approaches, the damage behavior of the mesoscale model is predicted under various loading conditions. A local homogenization procedure is proposed to transform the yarns of each direction and the attached resin into subcells accordingly. Furthermore, different equivalent cells are constructed by assembling these subcells according to the yarn paths, to simplify the corresponding surface and interior mesostructures. Through extending these cells based on the arrangement of the two RVEs in the internal architecture, the macroscale model is constructed to predict the mechanical behavior of 3D braided CFRP composites under uniaxial tension. The force-displacement curve and elastic modulus predicted from the numerical simulations, concur well with the experimental measurements, validating the reliability of the proposed multiscale modeling approach. The damage behavior and mechanisms of 3D braided composites subjected to uniaxial tension are analyzed via multiscale modeling.

Key words Multi-scale modeling; Composite structures; Mechanical behavior; Representative volume element; Local homogenazation

Session: Automated Manufacturing

Presenting Type: Poster

A thermal-chemical-mechanical fully coupling model for the prediction of the residual curing stress of the composites adhesive bonding

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Adhesive bonding is one of the popular methods to connect carbon fiber reinforced composites. However, residual curing stress would be generated in the curing process, if it is not controlled appropriately, will significantly affect the mechanical strength of the adhesive bonding. A thermal-chemical-mechanical fully coupling model was proposed in this paper to predict the residual curing stress of the adhesive bonding. The fully coupling model contains three sub-models: heat transfer model、curing kinetics model and viscoelastic mechanical model. These sub-models were calibrated in detail using the corresponding experimental data. A set of specifically designed experiments were conducted to validate the proposed fully coupling model. Good agreement between the simulated and experimental results is achieved, demonstrating the effectiveness of proposed model.

Key words adhesive bonding,residual curing stress,fully coupling,composites

Session: Automated Manufacturing

Presenting Type: Published only

A micromechanics-based model for investigating the influence of cure process on the bridging mechanism of a single z-pin in fiber-reinforced composites

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Z-pinned laminates are a significant class of composites with current applications in aircraft and emerging uses in other light-weight engineered products due to their excellent interlaminar properties and specific strength and stiffness. This paper presents a three-dimensional (3D) micro-mechanical modelling of single z-pin pull-out in a Mode I dominated regime, where curing residual stresses induced in cure process are taken into account. The microstructures including fiber distortion and resin-rich pocket caused by z-pin insertion are characterized. The evolutions of the material properties during the cure are captured using cure hardening instantaneous linear elastic (CHILE) model. The initiation and propagation of the interfacial damage between the z-pin and resin-rich pocket are determined in terms of a bi-linear cohesive law. The numerical results indicate that the mismatched thermal expansion and chemical shrinkage between the z-pin and base laminate produce large residual stresses and even result in interfacial cracking around the z-pin after the cure. The partially debonding of the z-pin provides small closure tractions to the delamination crack faces and thus strongly affects the effectiveness of the bridging mechanism under pull-out loading. Good agreement between experiments and simulations can be drawn. In addition, the influences of the curing cycle parameters on the partially debonding and bridging properties of the z-pin are further studied using the proposed method.

Key words Z-pin; Curing residual stresses; Interfacial cracking; Bridging mechanism; Finite element analysis.

Hangzhou, PR China 25-28 April, 2023

Session: Automated Manufacturing

Presenting Type: Published only

An analytical joint stiffness model of interference-fit bolted single-lap composite laminates and its parametric sensitivity research

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Because of the excellent static and fatigue performance, the composite interference-fit bolted structure has a wide application prospect in the joint field. In this paper, an improved spring-mass stiffness analytical prediction model is established for the single-lap composite structure having interference-fit. The influences of interference-fit percentage, bolt preload, secondary bending moment and interface friction are considered in the model. According to the experimental results, the value of secondary bending moment coefficient β is studied, and the correctness of the analytical model is verified. Further parametric research and regression analysis on the interference-fit percentage, preload, friction, laminate width and material properties show that the overall structure stiffness is obviously affected by β value and laminate width. The stiffness decreases with the increase of β and increases with the increase of laminate width. And as the key factors, the interference-fit percentage mainly affects the joint local friction fc and bolt shear stiffness Kb-sh, the preload and friction coefficient mainly affect the local friction fc, and the material size and properties will directly affect the overall structural stiffness.

Key words Improved spring-mass model, Interference-fit bolted joint; composite laminate; Secondary bending; Stiffness; Parametric sensitivity.

Session: Out-of-Autoclave Process

Presenting Type: Oral-Onsite

On-line monitoring and regulation of radial contact pressure in thermal expansion process

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The autoclave process is unable to provide uniform pressure on composite complex structural parts, which shrinks the service life and structural safety of composites. The thermal expansion method can effectively eliminate this shortcoming by generating uniform pressure in all directions through the thermal expansion of the silicone rubber core. However, the hysteresis of heat transfer in silicone rubber results in the lack of controllability of thermal expansion stress during the process. In this work, a negative feedback regulation system for thermal expansion stress monitoring and control was established. The thermal expansion stress and temperature variation of different silicone rubber core were monitored by closed-loop experiment of cylindrical structure. The core fabrication with hollow heating mandrel was designed. The temperature difference between the inside and outer surface of the core were less than 5 °C, and the molding pressure of the core with hollow heating mandrel can reach 0.6 MPa. During the process, the thermal expansion stress is stable and controllable, the thickness difference of the resultant product is only 0.013 mm, and the surface is smooth without debonding. This method provides theory and academic guidance for the manufacturing of complex composite structures.

Key words Thermal expansion method, Negative feedback regulation, On-line monitoring, Silicone rubber core

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Out-of-Autoclave Process

Presenting Type: Oral-Onsite

Research on RTM Process Technology of High-precision Load Connecting Frame Structure with Special-shaped Variable Cross-section by internal cross bars

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Aiming at the research and development technology of high-precision load connecting frame structure with special-shaped variable cross-section reinforced by internal cross bars, the two-step weaving and stitching fiber preform forming process scheme and the general RTM product forming process scheme of load connecting frame are discussed by using the comparison method; The virtual simulation of RTM glue injection process is studied by using ESI Group software, which guides the design of RTM molding design; The key points of product implementation, such as the glue injection and curing process of the product and the quality control of the technological process, are analyzed, and the performance of the final formed product is evaluated. Through the process research, we have broken through the key molding technologies, such as the two-step fiber preform molding technology of weaving and stitching, the RTM molding design and processing technology of complex special-shaped composite materials, and the split molding, secondary bonding and combination finishing processing. The results show that the formed products have better forming quality, dimensional accuracy and thermal cycle dimensional stability. The nondestructive testing results of composite parts show that the internal structure of the product is good, the fiber volume fraction is controlled at (55±3)%, the flatness of the important surface of the product is 0.05 mm and 0.03mm respectively, and the dimensional accuracy of the important interface is controlled within ±0.02 mm. After the thermal cycle test, the dimensional stability is good, and all indicators of the product meet the user's requirements, It provides a technical basis for design and manufacture of high-precision and high stiffness composite structures for deep space exploration and manned spaceflight.

Key words load connection frame structure, weaving and stitching, fiber preform, RTM forming technology

Session: Out-of-Autoclave Process

Presenting Type: Oral-Onsite

An improved vacuum assisted resin infusion process and analytical modeling

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Vacuum assisted resin infusion (VARI) is widely used for manufacturing of large and complex-shaped composite structures such as wind turbine blades and various aerospace parts at a low cost and high productivity. However, it is challenging to decrease air voids and thickness variation that cause loss of the product's quality and mechanical performance. This study introduced an improved VARI process to overcome these limitations. In this process, the resin outlet was optimally designed and sealed over by a semi-permeable membrane, as opposed to at the surface of the part in the patented VAP method. In the case of one-dimensional flow in the axial direction, a fully analytical modeling was derived to present the resin pressure distribution, resin flow front position, fiber volume fraction distribution, and part thickness change during the resin infusion process. Parametric studies were further provided to investigate the influences of process parameters on the process feasibility. The effectiveness of the introduced process and analytical was verified by fabricating composite laminates at various filling times with a dimension of 500×300 mm^2 and investigating the evolution of these parameters during the infusion process and the cure part. Here, the spatial distribution of voids was characterized by employing a flatbed scanner to capture the high-resolution planar scan of the fabricated laminates. Part thickness change was monitored using the GSI INCA3 camara and V-STARS system. The results indicated that this process leads to a more uniform spatial distribution of voids with a content of less than 1% and improved thickness variation with a deviation of less than 6%. Finally, a selected foam-core sandwich panel from an airplane wing with a dimension of 1450×680 mm^2 was manufactured using the proposed process to validate its effectiveness further.

Key words vacuum assisted resin infusion, analytical model, thickness variation, void content

Session: Out-of-Autoclave Process

Presenting Type: Poster

Embedded resistive heating for curing of composites joints

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In order to achieve the light-weighting structures, adhesive bonding technique is widely used in the aerospace field. while the traditional autoclave curing preparation of adhesive bonding components has problems such as high cost, high energy-consumption and less efficiency. In response to this problem, this paper proposes a less energy consumption out-of-autoclave(OoA) composites bonding technology. Using the embedded resistive heating method, a copper mesh is embedded between two layers of epoxy resin adhesive films. The proportional-integral-derivative (PID) control module is used to precisely control the curing temperature of the adhesive to prepare carbon-fiber/epoxy composite joints, as shown in Fig. 1. The composites joints formed by different processes are processed into single lap joints and tests have been conducted to evaluate the mechanical performance. At the same time, the deformation and fracture processes of the joints during the tensile process are monitored by a charge couple device (CCD) cameras. The digital image correlation (DIC) method is used to analyze the strain distribution and strain evolution on surface of adhesive joints. The macroscopic studies on the failure mode and failure morphology analysis of the composites joint were studied. The results show that the joints prepared by embedded copper mesh heating method have better tensile strength than the heat blankets cured composites joints. During the tensile process, the joint is subjected to a secondary bending effect, resulting in out-of-plane deformation. Due to the complex force of the joint and the influence of the embedded copper mesh, the failure mode of the composites joint is a mixed failure mode of cohesive failure, adhesive failure, copper mesh failure and light-fiber-tear failure.

Key words CFRP composite，Adhesively bonded joints，Electrical heating and curing，DIC in bonded joints

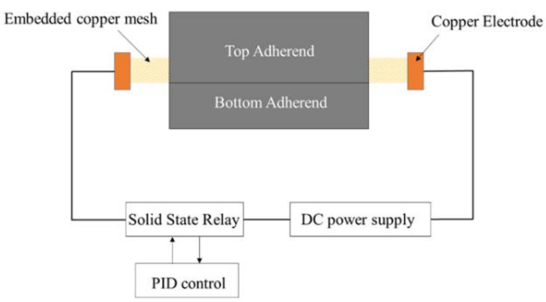

Fig. 1. Schematic of the experimental setup for embedded copper mesh curing.

Session: Out-of-Autoclave Process

Presenting Type: Published only

A review of research progress of out-of-autoclave prepreg process

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The out-of-autoclave (OoA) prepreg process, which can manufacture composite primary and secondary structural parts with the same quality and performance as the autoclave process, has been developed in the aerospace field in order to reduce the cost, improve production efficiency and product more large parts. Compared with the autoclave process, OoA process has lower investment and operation cost, wider range of curing equipment, tooling and materials can be used, and can manufacture super large structural parts that exceed the size of existing large autoclaves. This paper summarizes the research progress of the process of OoA prepreg. Furthermore, the form of OoA prepreg, the debulking, fiber consolidation, formation of defect and curing cycle of the process of OoA prepreg are investigated. Finally, the future development of OoA prepreg materials and processes is discussed.

Key words Out-of-Autoclave; Prepreg; Voids; Out-life; Cure cycle

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Invited

Continuous Fiber/Thermoset Composites Additive Manufacturing

Kelvin Fu*
University of Delaware

Fiber reinforced polymer composites (FRPC) made with continuous carbon fibers and thermoset polymers exhibit excellent specific mechanical properties (high strength, stiffness, and toughness), thermal stability, and chemical resistance. As such, they are lightweight and energy-efficient structural materials used widely in aerospace, automotive, marine, construction, and energy applications. Additive manufacturing (AM) of lightweight and energy-efficient composites using continuous carbon fibers and thermosetting polymers offers great opportunities for advancing composite manufacturing with design flexibility, low cost, reliability and repeatability. However, the material, architectural, and technical limitations make existing AM technologies unavailable for printing structural and functional thermoset/continuous carbon fiber composite. To date there has been no AM technique available to make such composites. In this talk, Dr. Fu will talk about a new 3D printing technique, called localized in-plane thermal-assisted (LITA) 3D printing, developed at Dr. Fu's lab. The LITA technology is by creating a controllable and dynamic processing window to enable curing of liquid thermoset polymer in continuous carbon fiber structure, realizing a feasible 3D printing of thermoset/continuous carbon fiber composite with near net shape, complex geometry, and programmable performance. LITA 3D printing technique has received CAMX Awards for Composites Excellence (ACE) in Manufacturing: Equipment and Tooling Innovation Award by American Composites Manufacturers Association (ACMA). LITA technology provides a new 3D printing concept and process knowledge beyond existing AM technologies to potentially enable high throughput processing and geometric complexity of printed composite, and has been demonstrated to be applicable to a wide range of fiber materials, including carbon fibers, carbon nanostructured-fibers, aramid fibers, and glass fibers, and could promisingly produce a transformative impact on the upgrade of additive manufacturing for many applications.

Key words 3D printing, composites, continuous fiber, thermoset

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Invited

On the Applications of Composite Failure Strength Theory to Predict the Ultimate Strengths of Layered 3D Printing Polymers

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Ningbo University

Due to the geometrical similarity, the rasters in the fused deposition modeling (FDM) technique were likened to the fibers of composite laminates in previous research, so composite strength criteria such as the Tsai-Hill criterion were directly employed to predict the ultimate strengths of 3D printing materials made with FDM. But these direct applications have significant limitations because these criteria were mainly applicable to the yield strength rather than the ultimate strength prediction, and the previous material was limited to one material without significant plastic deformation. Hence, this paper proposes a combined experimental and theoretical investigation of a simplified strength criterion and its targeted applications for two polymers made with FDM and the selective laser sintering (SLS) technique. Tensile experiments of the specimens with different build directions were conducted and their ultimate strengths were predicted by different strength criteria. The results showed that the Tsai-Hill criterion was not effective to predict the strengths of SLS specimens. However, the proposed strength criterion predicted the lower-bound ultimate strengths for all specimens made with FDM and SLS, and guaranteed safety.

Key words strength; 3D printing polymer; fused deposition modeling; selective laser sintering.

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Onsite

Development of a Robot-assisted Additive Manufacturing System for Continuous Fiber Reinforced Polymeric Composite Structures

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Southern University of Science and Technology

Additive manufacturing (AM) has shown great promises for creating advanced composite structures with complex designs and high performance that otherwise would be unattainable. However, several challenges, such as the anisotropic mechanical property within the build parts, must be overcome to make AM of composites a viable option for production. Advances in multi-axis additive manufacturing provide a solution to mitigate the anisotropic effect by stacking curved layers instead of planar layers of solidified materials. This study presents a robot-assisted additive manufacturing system for continuous fiber-reinforced polymeric composite structures. Critical issues in the software and hardware development of this system will be discussed. The effectiveness of this recently developed system will be demonstrated through the fabrication of several complex structures, including grid-stiffened curved panels and curvilinearly grid-stiffened conical shells. The paper concludes with a brief discussion of the remaining challenges and future works.

Key words Additive Manufacturing, Continuous Fiber-reinforced Polymeric Composite, Robot-assisted Additive Manufacturing

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Onsite

Effect of Structural Configuration on Mechanical Response of NiTi Triply Periodic Minimal Surface Lattice Structures

Shuaishuai Wei*
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NiTi shape memory alloys with triply periodic minimal surface (TPMS) lattice structures have aroused increasing interests due to their great application potential in bone tissue engineering. In this study, the solid and shell lattice structures of Gyroid and Diamond with the same volume fraction (20%) were fabricated by laser powder bed fusion (LPBF), which were systematically investigated their manufacturability, compressive mechanical properties, and shape memory behaviors after compression. A mathematical model was established to analyze the geometric influence factors on manufacturing fidelity of NiTi TPMS lattice structures fabricated by LPBF. The aggravation of powder adhesion caused the increase of specific surface area and overhanging rate of struts affecting the manufacturability. Three equations based on the Gibson-Ashby models were established to describe the mechanical properties of compressive modulus, nominal yield strength, and ultimate strength. All the as-built NiTi lattice structures exhibited high total shape recovery ratios after compressive deformation at room temperature (RT) and higher temperature (Af + 20°C). And the Diamond shell lattice structure exhibited the best recoverable strain. This was ascribed to the enhanced stability of stress-induced martensite at RT caused by the increased specific surface area at the same overall compressive deformation.

Key words NiTi shape memory alloys; triply periodic minimal surface; lattice structure; shape memory recovery

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Onsite

CuZrAl/Mo Bulk Metallic Glass Composites with Excellent Mechanical Properties Fabricated via Selective Laser Melting

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For the first time, high-density (99%) and crack-free bulk metallic glass composites (BMGCs) based on a Cu47Zr47Al6+Mo were produced via selective laser melting (SLM) with a powder mixture consisting of 5 vol% of refractory- Mo powders and Cu47Zr47Al6 BMG powders to improve strength and plasticity. The results show that the addition of Mo particles plays a vital role in reducing the cracks, and also decreases the amorphous phase percentage. The original shape and distribution of the refractory Mo particles remained unaffected in the matrix due to the low energy density (25.6 J/mm3) used for the whole process. At the interface between Mo particles and BMG matrix diffusion zone in the range of 600-800 nm was observed. Excellent mechanical properties such as high hardness and compressive strength were achieved in comparison with the as-cast and SLM Cu47Zr47Al6 BMG samples. BMGCs samples showed an impressive fracture strength of 1827 ± 42 MPa and fracture strain of 2.6 ± 0.2 %. Fracture morphologies show that some fracture occurs at the interface of Mo particles and BMGs matrix, and some fracture causes the deformation of the inner grain of Mo particles. These prove that Mo particles play a role in the deformation mechanism of Cu47Zr47Al6 +Mo BMGs composites. This study will pave a way for the design and synthesis of SLM BMGs composites with improved strength and plasticity by refractory-metallic particle addition.

Key words Additive manufacturing; Bulk metallic glass composites; Mo addition; Microstructure; Mechanical properties

Session: 3D/4D Printing and Emerging Technologies

Presenting Type：Oral–Onsite

A Numerical Model of 3D Printed Continuous Carbon Fiber Reinforced Composites with Auxetic Chirality under Uniaxial Deformation

Zhipeng Lu、Cheuk Yu Lee、Qinghua Qin、Chao Hu*
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Auxetic materials with negative Poisson’s ratio have gained great attention in decades by virtue of their exotic properties, while most of them are built upon lattice structures with hollow configurations. It to a large extent hampers the application in load-bearing engineering field. Recently, the integration of continuous fiber reinforced composites with 3D printing of geometrically complex metamaterials offers an effective strategy to largely improve the mechanical performance. In this study, an analytic mechanical model for the elastic behavior of tetra-chiral auxetic composites via fused deposition modeling was established based on the principle of Hooke’s law, which is an ordinary differential equation in arc length parameter of second order. In the special case of constant curvature constraint, it becomes a first order equation. Solving the established equations enables us to simulate the distribution of stress within chiral ligaments under deformation measured by the Poisson ratio, facilitating the optimization of general 2D auxetic metamaterial designs. The solutions depend on very few parameters including the Young’s modulus, initial stationary position data, fiber/polymer matrix configuration and interlayer porosity. Theoretical solutions regarding the special case of constant curvature and conditional numerical analysis on solutions were given in general. Our method contributes to building models of low computational complexity for designing 3D printed continuous fiber reinforced composites with auxetic chirality instead of time-consuming finite element method models.

Key words Auxetic Metamaterials; Continuous Fiber Reinforced Composites; 3D Printing; Numerical Modeling

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Onsite

Study on the Additive Manufacturing of Carbon Fiber Reinforced Silicon Carbide Composite Based on Vat Photopolymerization

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This paper explored the feasibility of 3D printing of carbon fiber reinforced silicon carbide composites (C_f/SiC) that based on vat photopolymerization, and analyzes the microstructure and mechanical properties of C_f/SiC composites. The research shows that it is feasible to prepare C_f/SiC by 3D printing technology based on vat photopolymerization, but the addition of carbon fiber will improve the viscosity of the slurry, reduce the fluidity of the slurry, improve the absorbance value of the slurry, and have an adverse impact on the 3D printing of the slurry. By optimizing the composition of photosensitive resin, slurry preparation process, 3D printing process and the debinding process of C_f/SiC green body, the C_f/SiC components with complex fine structure can be realized. It is found that the addition of carbon fiber have a great impact on the strength and toughness of the the C_f/SiC, and it has the anisotropy of strength and shrinkage, the linear shrinkage rate in the X-axis direction (parallel to the moving direction of the scraper) is the lowest (1.22%-1.62%), and the linear shrinkage rate in the Y-axis direction (perpendicular to the moving direction of the scraper) is the highest (3.35%-3.99%). When the carbon fiber is distributed along the length direction, it is beneficial to realize the strengthening and toughening of the green body. The strength of the test strip reaches 10.68 MPa. When the carbon fiber is distributed along the direction perpendicular to the length, the strength of the test strip is 5.15 MPa, the arrangement direction of the carbon fiber has little help to the strengthening and toughening of the green body.After debinding, the strength of C_f/SiC decreases (7.32 MPa), and the brittleness increases. We took natural gas and nitrogen as raw materials,through Chemical vapor infiltration (CVI) process under 1040°C and realized the densification, toughness and structural homogenization of C_f/SiC samples. After CVI, the density of C_f/SiC samples is increased, the weight of samples is increased by ~50 wt%, the density is increased from 1.40 g/cm^3 to 2.06 g/cm^3, the three-point bending strength is increased from 7.32 MPa to 121.22 MPa, and the Weibull modulus is increased from 0.25 to 5.19.

Key words carbon fiber reinforced silicon carbide composites, additive manufacturing, vat photopolymerization, the microstructure and mechanical properties

Session: 3D/4D Printing and Emerging Technologies

Presenting Type：Oral-Onsite

Application of Machine Learning Methods on Mechanical Properties Analysis for Additive Manufactured Composites

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Central South University

Material extrusion-based additive manufactured products have the potential to be applied in industry through proper selection of the materials and processing parameters. In the present study, the effects of printing materials and processing parameters on the mechanical properties of additive manufactured composites were mainly studied experimentally. However, the experimental methods are time-consuming and costly. As an efficient and accurate method, machine learning has been applied to additive manufacturing with promising results. This work first investigated the performance of different machine learning methods in capturing the relationship between materials and processing parameters and mechanical properties based on limited data in additive manufacturing. Thereafter, suitable machine learning methods were selected to predict the mechanical properties of additive manufactured composites with different printing materials and under different processing parameters. According to the prediction results, suitable materials could be selected and processing parameters could be optimized. In addition, machine learning methods were also applied to analyze the mechanical properties of additive manufacturing composites under different strain rates. Finally, how to generate more data and how to apply the improved algorithm to establish more widely applicable and more robust models for analysing the mechanical properties of additive manufactured composites were discussed.

Key words Additive manufacturing; Composites; Mechanical properties; Machine learning

Session: 3D/4D Printing and Emerging Technologies

Presenting Type：Oral-Onsite

low-cost titanium alloys with attractive mechanical properties by additive manufacturing

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The low buy-to-fly ratio of traditional preparation methods and the addition of precious elements for properties enhancement are responsible for the expensive nature of titanium products, restricting the application of titanium alloys with excellent properties only to highly sophisticated industries. Here we demonstrate a novel, cost-effective, ultra-strong titanium alloy with a yield strength of ~1600 MPa by selective laser melting, doped only with inexpensive elements Fe and O. Furthermore, superior strength-ductility combinations are achieved after simple heat treatments. For example, the combinations of an outstanding yield strength of 1163 MPa at ~17% elongation to fracture and an excellent ductility of 27.8% at a yield strength of ~1000 MPa, demonstrate significant improvements over the most extensively investigated additive-manufactured Ti-6Al-4V alloy. The superior properties are attributed to the ultra-fine grain formation achieved by rapid cooling of the additive manufacturing process without severe plastic deformation and the bimodal microstructure with α nano-precipitations in the β phase obtained in a single simple heat treatment stage. This work provides a brilliant perspective on the cost-effectiveness and strengthening of titanium alloys, which is expected to catalyze the adoption of titanium alloys in more potential engineering applications.

Key words additive manufacturing, Titanium alloy, ultra-high strength, cost-effectiveness

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Onsite

A Study on 3D Printing Short-Continuous Carbon Fiber Synergistic Reinforcement Thermoplastic Composites: Pre-Impregnated String Manufacturing and Its Tensile Performance Testing

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Dalian University of Technology

The 3D printing technology of carbon fiber reinforced thermoplastic composites can realize the integrated manufacturing of complex structural parts with excellent performance, such as light-weight and high-strength. Therefore, this technology owns broad application prospects in the field of high-end equipment manufacturing. For its application, it is essential to ensure the superb mechanical properties of 3D printed carbon fiber reinforced thermoplastic composite (CFRTP) parts. To further improve it, both short and continuous carbon fibers were used in the CFRTP 3D printing process to manufacture short carbon fiber-assisted continuous carbon fiber thermoplastic composites (S/C-CFRTP) at the same time. The sufficient impregnation between continuous carbon fibers and the thermoplastic resin matrix containing short fibers in the 3D printed S/C-CFRTP parts is extremely important for performance improvement. To achieve that, this paper proposes a manufacturing method for short fiber-assisted continuous fiber thermoplastic composite pre-impregnated string. The melt mixing module, rolled impregnation module, and mold setting module are designed to develop the pre-impregnated string manufacturing equipment. Then, the process experiments are conducted to determine the optimal manufacturing procedure. The maximum load-bearing tensile force of the pre-impregnated string is nearly 114N. Finally, compared with the S/C-CFRTP parts printed by in situ impregnated process, the tensile strength and tensile modulus of S/C-CFRTP parts printed with this pre-impregnated string are increased by nearly 19% and 12%, respectively.

Key words 3D printing, S/C-CFRTP, Pre-impregnated string, Mechanical property

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Onsite

3D Printed Wood Biomimetic Porous SiC with In-Situ Grown SiC Nanowires for Efficient Electromagnetic Wave Absorption

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Efficient silicon carbide (SiC) electromagnetic wave (EMW) absorption materials derived from biomaterials are enjoying increasing attention due to their unique porous structures. This work has developed an original strategy to fabricate wood biomimetic porous SiC ceramics for EMW absorption through combining selective laser sintering (SLS) 3D printing, carbonization and carbothermal reduction processes. The wood powder retaining natural pores and fiber structure was obtained from timber waste. The phenolic resin coated wood powder was prepared by a solvent evaporation method and processed by SLS to build porous precursors with isotropous microstructures. Following a vapor-liquid-solid mechanism, porous SiC networks aligned with SiC nanowires were obtained by SiO vapor carbothermal reduction. Porous, inner crosslinked structures promote zigzag reflections and the in-situ grown SiC nanowires facilitate energy consumption, synergizing effects on improving EMW absorption. The 3D printed porous SiC shows more outstanding absorption abilities compared with relevant SiC-based materials reported in recent literature, realizing a minimum reflection loss of -49.01 dB at 2.8 mm thickness and an effective absorption bandwidth of 5.1 GHz. Further, the timber waste is recycled and reused through our sustainable 3D printing strategy with the advantages of low cost and environmental protection. Most importantly, efficient EMW absorption functional SiC components with complex structures, high mechanical properties and thermal stability can be fabricated throughout this sustainable strategy based on 3D printing, indicating potentially wide applications in specific harsh environments.

Key words Selective laser sintering; Wood biomimetic; Sustainability; Silicon carbide; Electromagnetic wave absorption

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral–Onsite

Three-Dimensional Printing of Mechanochromic Double Network Hydrogels

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Beihang university

Mechanochromic double network hydrogels have the capabilities to change their visible appearance or fluorescent color in response to mechanical force, showing great potential for the practical applications in the stress sensing, camouflaging, crack visualization and information encoding. The mechanochromic hydrogels are usually obtained by the two-step crosslinking processes, which is difficult and time consuming. It remains challenging to produce the mechanochromic double network hydrogels with desired shapes and patterns. Herein, we report a three-dimensional printing technique of the mechanochromic double network hydrogels with the direct ink writing (DIW) method. The printing ink is made of suspension solution of AAm which contains poly(2-acrylamido-2-methyl-1-propanesulfonic acid) (PAMPS) microgels. The microgels are crosslinked with the rhodamine mechanophores. We optimize the printing parameters and demonstrate the printing of various 3D shapes of mechanochromic hydrogels. The printed shapes would change their appearance and fluorescent color in stimulation to the external force, indicating excellent mechanochromic properties. We further demonstrate the multi-material printing of the mechanochromic hydrogels with encoded patterns. We believe the printing strategy would be beneficial for the design and manufacturing of the mechanochromic hydrogels.

Key words direct ink writing; mechanochromic hydrogels; multimaterial printing

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Onsite

Mechanistic Modelling of Continuous Fibre Reinforced Composites Fabricated using a FFF Process

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This study develops a platform to analyse a 3D printing process for better understanding of processing-structure-property relationship of additively manufactured continuous fibre reinforced composites. The platform is integrated with a highly precise dynamometer to achieve *in-process* monitoring of three-dimensional forces during a FFF process, enabling detailed evaluation of the process-structure-property relationship of continuous carbon fibre reinforced polyamide 6 (CCF/PA6) composites fabricated using the FFF process. Both the compressive force (F_z) and shear force (F_s) were found to be relatively low during the deposition process of CCF/PA6. Besides, an in-depth study was performed to investigate oscillation of the forces, suggesting the feasibility of monitoring the quality of composites during the FFF process based on *in-process* measurement of forces. Lastly, both microstructural and theoretical analyses, addressing intimate contact and autohesion mechanisms, were conducted on the 3D printed CCF/PA6 composites. The results suggest that insufficient interlayer fusion bonding in the composites was developed as a result of incomplete intimate contact and autohesion established at the interface, highlighting the critical roles of applied compression force, deposition speed and printing temperature in the quality of CCF/PA6 composites fabricated using the FFF process.

Key words Continuous Fibre Reinforced Composites; 3D Printing; Fused Filament Fabrication; Mechanistic Modelling; Intimate Contact;

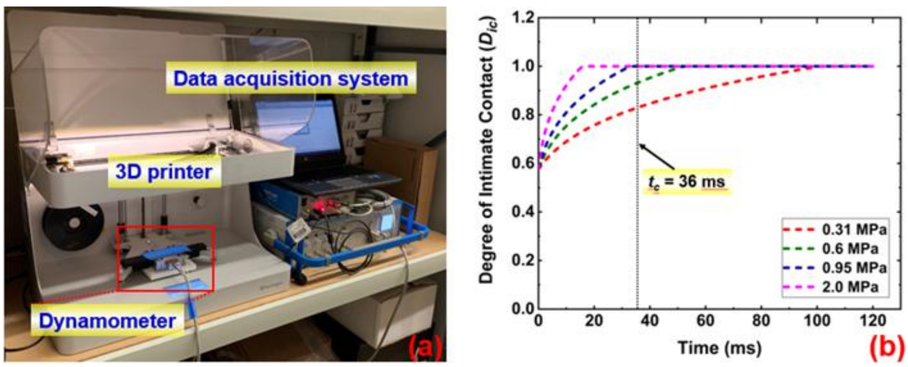

Fig. 1. Mechanistic modelling of CCF/PA6 composites fabricated using a FFF process (a) *in-process* measurement of forces, (b) degree of intimate contact versus contact time under different applied compression forces.

Session: 3D/4D Printing and Emerging Technologies

Presenting Type：Oral-Onsite

A Novel 3D-Printed Continuous Carbon Fiber Composite Grid Stiffened Thin-Walled Structure Prepared by Induction Heating

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The composite grid is a promising structure with the advantages of lightweight, high-strength and inherent impact resistance, which is widely used in aircraft, trains, containers, and other thin-walled components. This study proposed a new concept of a lightweight thin-walled structure stiffened with a 3D-printed continuous carbon fiber composite grid. A two-step procedure was adopted to prepare the composite grid stiffened thin-walled structure. First, the 2D pattern of the composite grid was generated by flattening the 3D shell surface, and the thin-walled thermoplastic part and continuous carbon fiber composite grid were printed separately using the fused deposition modeling (FDM) technique. A second fusion was then carried out to produce the carbon fiber composite grid stiffened shell structure with induction heating and vacuum pressure. It is demonstrated that high-frequency induction heating is a selective and penetrable heating technology that could efficiently heat the carbon fiber composite grid to melting temperature while having no heating effect on the thermoplastic shell. The 2D composite grid was reshaped into a 3D curved structure, forming a good interface bond with the thermoplastic thin shell. The flexural test results show that stiffened with three layers of 3D printed carbon fiber composite grids, the flexural stiffness and energy absorption of the thin-walled structure are increased by 267% and 140%, respectively, while the mass is only increased by 18%, showing an excellent mechanical reinforcing efficiency. The fracture morphology indicates no significant delamination between the composite grid and thin-walled shell during the flexural tests. It is expected to improve the bearing capacity and lightweight level of the thin-walled components for aerospace vehicles.

Key words Continuous fiber 3D printing,composite grid, induction heating, mechanical properties

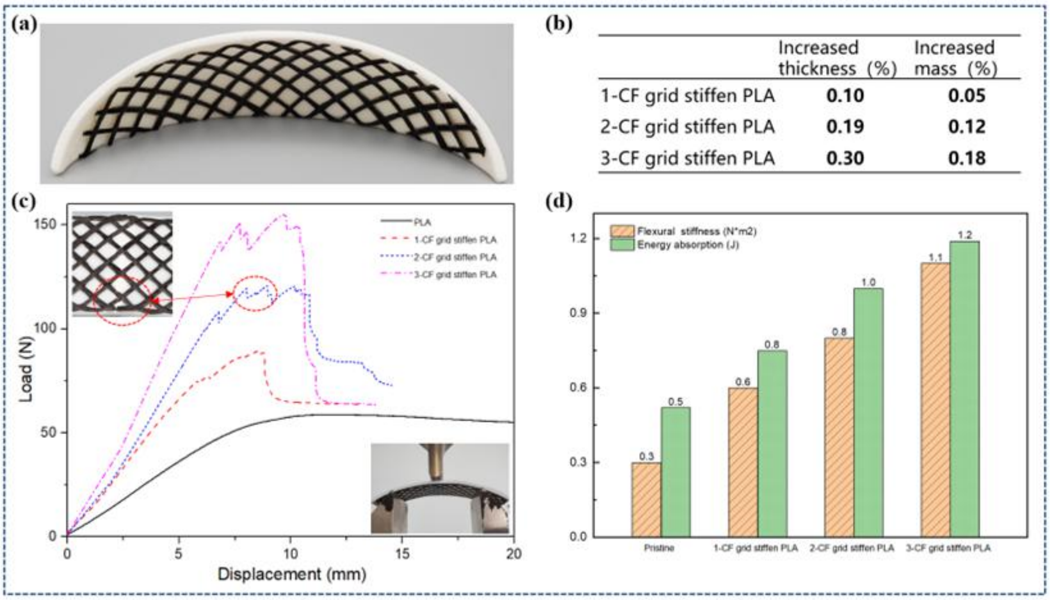

Fig. 1. (a) photograph of 3D-printed continuous carbon fiber composite grid stiffened thin-walled structure (b) variation of physical properties (c) load-displacement curve of the flexural tests, and (d) flexural test results.

Session: 3D/4D Printing and Emerging Technologies

Presenting Type：Oral-Onsite

Printing of Metal Droplet Streams Using Continuous Ejection of A Laser Heated Feedstock

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Metal additive manufacturing (AM) has the potential to impact an immense range of applications across industries, including the production of advanced structural, propulsion, and thermal management systems. State-of-the-art metal AM processes involve layer-by-layer deposition and selective binding or melting of metal powders. However, these methods do not easily permit multi-material printing or printing directly onto existing objects and typically produce near-net-shape parts with poor dimensional resolution and surface finish unless extensive post-processing is applied. Here, we present two novel high-resolution direct metal printing routes that potentially address these limitations. In the first method, individual metal microparticles are electrohydrodynamically ejected on-demand from a liquid meniscus and laser-melted in-flight before landing and solidifying on a substrate. We demonstrate the printing of solder and platinum droplets ranging in size from 30-150 μm and explore the process parameter space as limited by the ejection conditions and the kinetics of in-flight melting, impact, and solidification. For the second process, we developed a wire feed mechanism that advances a fine metal wire at a controlled speed and a desired trajectory, heated the tip of the moving wire with a modulated laser, then liquefied the wire and generated a stream of molten droplets. We demonstrate the stable feeding of a Φ50 um 304L stainless steel wire at a feed rate ranging from 0.5 to 1.5 m/s and continuous breakup into molten droplets with a corresponding diameter of around 160 μm. Via experiments and numerical modeling, we analyzed the mechanism of wire breakup and factors influencing the stability of the droplet stream. The proposed printing methods could prove valuable for many industries, for example, in the manufacturing of high-frequency antennas or medical implants, where there exist significant challenges and limitations associated with the fabrication of fine metal features, and for the integration of multiple metals in finished goods.

Key words metal additive manufacturing, electrohydrodynamic ejection, laser melting, droplet impingement, solidification

Session: 3D/4D Printing and Emerging Technologies

Presenting Type：Oral-Onsite

Isotropic Negative Thermal Expansion Metamaterials with Continuous Carbon Fibers by 3D Printing

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Isotropic negative thermal expansion materials are important in science and engineering applications. The artificially designed negative thermal expansion materials can make up for the lack of natural materials. Previously reported metamaterials with negative thermal expansion are difficult to balance the wide range of coefficient of thermal expansion (CTE) and isotropy, and the bimaterial elements used have significant interface layering and detachment risk. Here, the structural designs and fabrication strategy using 3D printing of bilayer serpentine metamaterials have been proposed. And the bimaterial elements consisting of polyamide (PA) and continuous carbon fiber reinforced polyamide composites (CCF/PA), that just avoid interfacial delamination with the common composition. The theoretical and experimental results show the isotropic negative thermal expansion of the sample. The effective CTE of the proposed structure is proved to depend on the width ratio of, arc radius and arc angle of the curved bilayer beams. And there is an optimal width ratio to maximize the CTE based on the determination of the composition of the biomaterial elements. The measured CTE of the sample with the best performance is one of the highest values in the experiment so far. Our findings reveal the influence of structural parameters on CTE, and the metamaterial with tunable CTE can be obtained.

Key words negative thermal expansion, 3D printing, metamaterial, continuous carbon fibers

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Onsite

Sintering by Intense Thermal Radiation (SITR): Experimental Evidence

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In recent years, novel sintering technology such as spark plasma sintering, flash sintering, and cold sintering has developed rapidly. The main mechanisms for heat transfer in a sintering process involve heat conduction, heat convection and thermal radiation. According to the famous Stefan-Boltzmann's law, heat transfer at high temperatures is much more significant. This study aimed at using a modified spark plasma sintering device to generate intense thermal radiation and achieve rapid densification in a short period of time, which is named as "Sintering by Intense Thermal Radiation (SITR)" technology. This approach has been successfully applied in the fields of preparing dense zirconia ceramics, porous silicon nitride ceramics, gradient silicon carbide ceramics and so on within a few minutes. At the same time, this method was also employed to the efficient fabrication of wave-transparent composites with a sandwich structure as well as perovskite-type oxynitride ceramic powders. SITR has shown the advantages of short processing time, adjustable temperature distribution, and near-net formation, which is promising in the area of fast manufacture of ceramics.

Key words Spark plasma sintering, Heat transfer, Densification, Thermal radiation, Porous ceramics

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Onsite

Microstructure Refinement for Superior Ductility of Al–Si Alloy by Electron Beam Melting Additive Manufacturing

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Refining the Si phase in Al–Si alloy has been a research interest for decades. Previous studies suggested many Al- and Si-enriched nano-segments (approximately 100 nm) can coexist in a melted Al–Si liquid solution when they were reheated to a temperature between 1080 and 1290 °C. These nano-segments could be retained to become crystal nuclei and grew into fine grains under a very fast cooling rate. Thus, this provides a novel approach of refining the microstructure of Al–Si alloy using electron beam melting (EBM) technology because the temperature exceeds 1500 °C in the melting pool with a cooling rate higher than 103 °C/s during EBM building process. In this study, EBM is used to refine the microstructure of AlSi10Mg alloy to enhance the ductility. The formation mechanism of the microstructure during EBM build process was discussed.

An argon gas-atomized AlSi10Mg (wt%) powder was used to fabricate as-built specimens using an Arcam A2X EBM system (Arcam AB, Mölndal, Sweden). AlSi10Mg alloys with well surface finish were fabricated using EBM. The microstructure observation shows mixed fine island-like and scattered granular Si phase particles (approximately 2 μm) having rounded corners and edges were embedded in the Al matrix. Fine Al sub-grains with size of 0.5–2 μm formed during EBM building process. A maximum ductility of approximately 32.7% with a tensile strength of approximately 136 MPa were achieved for the as-EBM-built AlSi10Mg alloy as shown in Fig.1 [1]. The improved ductility compared with cast ones was attributed to the fine Si phase and the bimodal Al grains (large and fine sub-grains). A novel pathway of refining the Al–Si alloy microstructure to improve the tensile ductility without adding any modification element was developed in this study.

Key words Additive Manufacturing, EBM, Al-Si alloy, Superheating

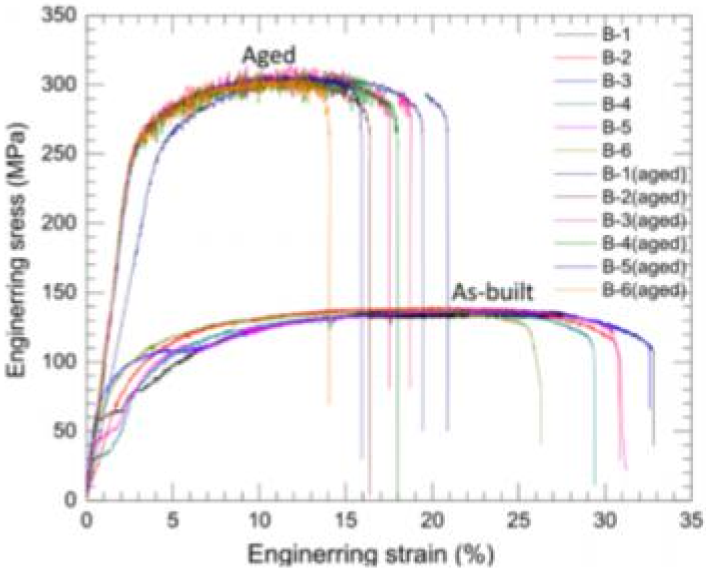

Fig. 1. The tensile strength and elongation of AlSi10Mg alloy fabricated using EBM[1].

[1] H. Bian et al. Additive Manufacturing, 2020, 32, 100982.

Session: 3D/4D Printing and Emerging Technologies

Presenting Type：Oral−Onsite

A 3D printed stucture with negative Poisson's ratios

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In this paper, a 3D six-link chiral structure with negative Poisson's ratios is proposed based on the 2D four-link chiral cell-structure. The connecting nodes are arranged at specific positions (not endpoints) of the central sphere, and the direction of the connecting rod is oriented along the axial direction of stretching (not tangential direction). The 3D cell-structure is employed to obtain the chiral model by array arrangement and the antichiral model by mirror arrangement. The effects of the geometric parameters and cell-structure numbers on the Poisson's ratios of the chiral and antichiral models are investigated by finite element method. Then, the chiral and antichiral specimens are prepared by 3D printing, and tested by the Universal Testing Machine, and the validity of the simulation results is verified by comparing with the experimental results.

Key words 3D printing technonlogy，negative Poisson&#039, s ratios，Metamaterial

ACM 12
Hangzhou, PR China 25-28 April, 2023

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral−Virtual Platform

Powder Fabrication and Laser Additive Manufacturing of Nanoceramic-Reinforced Mo Alloy Matrix Composites

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Tohoku University

Due to the high melting point and superior stiffness, Mo alloys are considered as novel heat-resistant materials for aerospace and aircraft applications. Unfortunately, their application reliability is seriously hindered by the poor oxidation resistance and insufficient elevated-temperature strength. In this regard, fabricating ceramic-particle-reinforced metal matrix composites (MMCs) has been deemed to be an effective approach. Nanofillers can improve the mechanical strength of MMCs via impeding the dislocation motion or grain boundary sliding at high temperatures; furthermore, the penetration rate of oxygen atoms is limitted into the matrix for improved oxidation resistance. However, the traditional manufacturing techniques usually cause the insufficient densification rate and the aggregation and irregular microstructure of reinforcements, being harmful for the mechanical performances of MMCs. Thanks to its flexibility in materials and processing, laser powder bed fusion (L-PBF) provides new technological opportunities for producing high-performance MMCs with tailored architectures. Unfortunately, to the best of our knowledge, the fabrication of Mo alloy matrix composites by additive manufacuring has been rarely reported, since it is challenging to fabricate suitable composite powders having homogenous dispersion, good flowability, suitable particle size or distribution. In this study, a facile strategy was developed to prepare nanoceramic/Mo composite powders by using functionalized carbon nanotubes (CNTs) as an agent. Subsequently, a tight ceramic coating consisting of an α-Al2O3 matrix with dispersed TiC particles was formed on the surface of the build, which has been proved to effectively increase resistance to oxidation. Meanwhile, the nanoparticles were homogenously dispersed and tightly contacted with the Mo matrix, giving rise to an enhanced hardness. This work shed light on designing and producing high-performance refractary materials for application to ultrahigh-temperature materials.

Key words Metal matrix composites (MMCs); Laser powder bed fusion (L-PBF); Mo alloys; Carbon nanotubes; Oxidation resistance

Hangzhou, PR China 25-28 April, 2023

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Virtual Platform

Preliminary Study on Additive and Subtractive Manufacturing of High-Quality Surface Parts Equipped with Picosecond Laser

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1. South China University of Technology
2. UNIVERSITE DE TECHNOLOGIE DE BELFORT-MONTBELIARD

Laser powder bed fusion can rapidly manufacture metal entities with complex structures, but the highly surface roughness and low dimensional accuracy limit the mechanical properties and application scenarios of powder bed process parts. In recent years, ultrafast laser micromachining has shown great potential in the field of precision machining. Therefore, ultrafast laser machining was combined with laser powder bed manufacturing in this study. After additive manufacturing, the additively molded samples were micromachined using ultrafast laser. By combining processes of LPBF additive and pulsed laser subtraction, the processing quality of parts can be improved. In this paper, the thin-layer 316L stainless steel structure (made by LPBF) was fabricated by continuous laser melting, and then the surface was micromachined using a picosecond pulsed laser, and the picosecond laser processing characteristics and surface topography of LPBF 316L components were studied. A pulsed laser with the pulse width of 10ps was used to machine a microgroove, with a depth of 185.06 μm, on the LPBF thin layer 316L part in this stu[WD1] dy. Furthermore, the cutting wall has good flatness, as the line roughness Sa of it is 1.52 μm (the additively manufactured surface is above 10.18 μm), and the sidewall taper angle of it was ~ 6.9°.

Key words hybrid manufacturing, Additive and Subtractive manufacturing, laser powder bed fusion, picosecond laser, surface roughness

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral−Virtual Platform

A Novel Approach of Fabricating Monodispersed Refractory Alloy Powders for Laser Additive Manufacturing

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Department of Materials Processing, Tohoku University

Increasing demand for improvements in the energy efficiency of heat engines such as gas turbines and jet engines calls for the availability of novel refractory materials that can operate above the operating temperature of Ni-based superalloys. Recently, a TiC-strengthened Mo-Si-B-based alloy have been the focus of much research attention because of its outstanding creep strength at ultrahigh-temperatures and high fracture toughness. However, it is difficult to fabricate parts with complex geometry by conventional technologies due to its high melting point and stiffness. To overcome those limitations, we are focusing on the laser powder bed fusion (L-PBF) process. Presently, the powders, including Ti-, Fe-, Al- and Co-alloys, used for L-PBF, are mostly fabricated by mechanical milling, gas atomization, plasma atomization, plasma rotating electrode process, and plasma spheroidization. However, each of these methods has significant limitations in the preparation of composite refractory alloy powders because of their high melting points and complex compositions. In this work, a novel technique, freeze-dry pulsated orifice ejection method (FD-POEM), was developed to fabricate spherical composite particles without a melting process. A variety of nano powders were dispersed in water to prepare a high-concentration slurry, which was subsequently extruded from an orifice by diaphragm vibration and frozen instantly in liquid nitrogen. After a freeze-drying process, spherical composite particles with uniform size distribution and good dispersion of component elemental particles were obtained. The powder characteristics and their impacts on the microstructure and mechanical performance of L-PBF builds were systematically illustrated. This study contributes to the understanding of fabricating high-performance refractory alloys with advanced architectures by combining powder design and L-PBF techniques.

Key words Freeze-dry Pulsated Orifice Ejection Method (FD-POEM); Laser powder bed fusion (L-PBF); TiC added Mo-Si-B alloy

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Virtual Platform

Effect of Severe Oxidation on the Powder Properties and Melting Behaviors of Stainless Steels for Laser Powder Bed Fusion

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The recycling of metal powders reduces the costs of laser powder bed fusion (L-PBF) and is an essential practice towards sustainable manufacturing. However, oxidation of the recycled metal powders may result in the deterioration of the properties of the powders and, therefore, to the integrity of the build. In this work, commercial AISI 316L stainless steel (SS) powder was used to experimentally determine the impacts of severe oxidation on the powder characteristics and L-PBF melting behaviors. The morphology, particle size, surface state, and laser absorptivity of both virgin and oxidized powders were systematically characterized. Their impacts on the flowability and powder bed quality were monitored by custom-designed recoating experiments and powder shear tests. The results of an in situ wetting analysis and microstructure evaluation were compared to establish a correlation between the powder characteristics and laser fusion. It was found that powder oxidation enhanced L-PBF processability by improving the homogeneity of powder spreading and the formation of stable, consecutive laser beads. A thin ceramic layer-coated SS alloy reinforced with uniform (Si, Mn)-based oxides ~several—100 nm in size was synthesized by the L-PBF processing of severely oxidized powders. The mechanical strength of this alloy was found to be similar to that of the same alloy processed using the virgin powders, whereas the elongation was slightly decreased, likely due to the amorphous oxide feature and the mechanical oxide-Fe interface. This study provides a systematic understanding of powder reuse and new insight into the potential for economically developing high-performance parts by the positive utilization of powder oxidation and the L-PBF process.

Key words Laser powder bed fusion; Stainless steel; Oxidation; Microstructures; Powder flowability

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Virtual Platform

Numerical Simulation of Composite Tubes Fabricated by FFF

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With the rapid development of additive manufacturing technologies, carbon fiber reinforced composites are of increasing interest in a variety of industrial applications. In this study, numerical models were developed to analyse and assess the manufacturing quality (i.e., stress distribution, crystallinity and warpage mechanisms) of two commonly used short carbon fiber reinforced polylactic acid (SCF/PLA) composite tubes fabricate by fused filament fabrication (FFF). First, a multi-physical field model based on solid mechanics, thermodynamics and crystallization kinetics was developed to simulate the FFF printing process using numerical 'activation elements'. The predominant numerical parameters were then experimentally evaluated to refine the numerical model for prediction and analysis. Finally, the manufacturing quality of the 3D printed SCF/PLA composite tubes was evaluated with the aid of both numerical and experimental approaches. The results show that the square composite tube has significant residual stress distributions and is prone to stress concentrations at the corners. Specifically, a comparison analysis reveals that the warpage severity at the corners are much higher than those at other locations. Besides, influenced by heat transfer during FFF, the crystallinity is higher at the bottom of the square tube and the overall crystallinity tends to decrease from the bottom upwards.

Key words Additive manufacturing (3D printing); short carbon fibre; PLA; finite element analysis; FDM

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Oral-Virtual Platform

Effect of Low Velocity Impact Times on Residual Compressive Strength of 3D Printed Continuous Carbon Fiber Honeycomb Structure

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Continuous fiber reinforced composites are widely used in aerospace and automotive fields due to their high specific strength and high specific stiffness. 3D printing technology has the advantages of rapid manufacturing without mould, which makes up for the shortcomings of traditional composite material processing technology that it is difficult to form complex structures. In this paper, continuous carbon fiber reinforced honeycomb structure (CCFRHS) was prepared based on fused filament fabrication (FFF). The effect of low-velocity impact times on the residual compressive strength of honeycomb structures was also studied. The results show that the CCFRHS has higher impact resistance and compressive strength than the pure matrix honeycomb structure. At the same time, when the total impact energy is 10J, with the increase of impact times, the residual compressive strength gradually increases. Compared with a single impact, the damage caused by multiple small-energy impacts is smaller, so it has a higher residual compressive strength. The cracks after low velocity impact mainly occurred in the matrix part without fiber reinforcement between the two printing paths, and the carbon fiber in honeycomb structure did not break obviously. Therefore, compared with pure matrix honeycomb structure, CCFRHS has higher residual compressive strength after low velocity impact. The research in this paper is of great significance for the application of 3D printed CCFRHS in complex environments.

Key words 3D printing; Low velocity impact; Residual compressive strength; Continuous carbon fiber reinforced composites; Honeycomb structure

Session: 3D/4D Printing and Emerging Technologies

Presenting Type：Poster

Multi-Functional Metamaterial Device with Regulating Thermal Wave and Electromagnetic Wave

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Due to their unusual characteristics and the ability to consciously manipulate electromagnetic waves, electromagnetic metamaterials have emerged during the past ten years as essential building blocks for the creation of innovative and cutting-edge technologies in a variety of real-world applications. Although electromagnetism and optics have traditionally been connected with the metamaterial notion, the same ideas can also be applied to other wave phenomena, such as thermodynamics. This is why the goal is to create a multi-functional metamaterial that can concurrently regulate and alter thermal and electromagnetic waves. First, the structure is created utilizing additive manufacturing methods. Through the coupling design of the metamaterials structure, the device can not only realize the ultra-broadband electromagnetic wave absorption, but also realize the regulation of the heat current direction. These multifunctional metamaterials can fully alter and process both electromagnetic and thermal waves, according to experimental findings. The proposed structures contributes to the development of the field of multifunctional structures, intelligent metamaterials.

Key words Metamaterials, Active control, Thermal regulation, Broadband absorption

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Poster

Achieving superior tensile superelasticity of laser additive manufacturing NiTi alloy via nickel-rich nanodomains

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NiTi alloys, a type of shape memory alloy, are widely used in medical devices, aerospace, and other fields because of their remarkable superelasticity and shape memory properties. However, L-PBF fabricated NiTi parts have lower tensile superelasticity and mechanical property than those fabricated using traditional metallurgical technology. To overcome these limitations, researchers have developed a new method that introduces nanoscale chemical composition fluctuations in L-PBF fabricated NiTi alloys through unique heat treatments of low-temperature solid solution, followed by subsequent low-temperature aging.

The heat treatment method results in the formation of Ni-rich nanodomains that resist dislocation motion, enhancing the yield strength of the NiTi alloys. Moreover, these nanodomains undergo stress-induced martensitic transformation upon loading to relieve local stress concentration raised by defects, leading to an improvement in superelasticity. The L-PBF fabricated-NiTi alloys exhibit a tensile fracture strain exceeding 10%, a tensile fracture stress of approximately 1000MPa, a tensile superelastic strain of up to 7%, and a cumulative residual strain of less than 1% after ten superelastic cycles.

This new approach provides a promising way to enhance the mechanical properties of NiTi alloys fabricated by L-PBF. It expands the range of additive manufactured alloy materials and boosts the application prospects of additive manufactured NiTi alloys. The ability to improve the mechanical properties of L-PBF fabricated NiTi alloys opens new opportunities for their use in high-stress applications, such as in aerospace and medical fields. This method provides a new avenue for strengthening LPBF fabricated superelastic NiTi alloys, thereby significantly improving their mechanical strength. Future research can explore the optimization of the heat treatment method to further improve the mechanical properties of NiTi alloys fabricated by L-PBF.

Key words NiTi alloys, laser powder bed fusion, superelasticity, mechanical property, nanoscale chemical composition fluctuations

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Poster

Additive manufacturing of a nanocrystalline Ti-Fe-O-Cu alloy with high strength and ductility combination

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Among various types of microstructures in titanium alloys, martensite microstructure has the highest strength, but with poor ductility, which restricts its applications in the engineering practice. The present work investigates the microstructure and mechanical properties of Ti-Fe-O-xCu sample component fabricated by the directed energy deposition additive manufacturing process. The mechanical properties of the component in quasi-static and dynamic loading with respect to the laser energy were measured under uniaxial tension and compression. While the average ultimate tensile strength of greater than 1000 MPa with prior studies on those specimens, the achieved preferable elongations. The obtained ductility is attributed to the columnar prior-beta grain morphology and the presence of grain boundary alpha, which serves as a path along which damage can preferentially accumulate, leading to fracture. In addition, the effect of copper content on the strength and ductility of the component was studied. The findings indicate that a combined effect of an increase of copper and a decrease in alpha-lath width due to refine grains to the nanoscale greatly enhance the strength of metals without a significant loss of ductility. Furthermore, this study demonstrates that quasi-static uniaxial tensile mechanical properties similar to those of wrought Ti-6Al-4V can be produced in an AM component without the need for post-processing heat treatments.

Key words Titanium alloys, Nanocrystalline, Additive manufacturing, Ultrahigh strength, Martensite

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Poster

Study on Additive Manufactured NiTiCu-based Composite

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As a family of NiTi-based shape memory alloys, NiTiCu alloy have been extensively studied due to their interest in exhibiting low martensite transformation hysteresis and high cycling stability up to a million. However, the main high-performance research results of NiTiCu are thin films fabricated by magnetron-sputtering, while large amount of brittle secondary phase in bulk counterparts significantly deteriorates their brittleness and then workability, which is a fatal obstacle for engineering applications. Additive Manufacturing has been extensively studied as a route toward the fabrication of near-net-shape metallic material parts with complex geometries. Unique layer-by-layer control processing of AM endows the unique multiphase microstructures responds differently with traditional manufacturing, which may redefine some novel performances. This study investigated the formability of NiTiCu alloys fabricated by selective laser melting (SLM) additive manufacturing, as well as their phase transformation and functional performances. The laser power, scanning speed and hatch spacing were optimized by orthogonal experiment method, and the NiTiCu alloy with good form qualities and high relative density up to 99.98% were successfully fabricated. This material shows a small hysteresis of reversible B2↔B19 orthotropic martensitic transformation rather than classical B2↔B19' monoclinic transformation due to the introduction of copper element. Based on the processing mode of local melting of metal powders followed by rapid solidification in SLM, the microstructure is a composite architecture of NiTiCu matrix and Ti2Ni hard intermetallic, endowing a superior superelasticity with low stress hysteresis during compression testing and a huge elastocaloric effect. The adiabatic temperature directly measured during the compression unloading process is lager than 5°C. This study has guiding significance for the fabrication of high-performance NiTiCu-based shape memory composites by additive manufacturing.

Key words Shape memory alloy; Additive manufacturing; Composite

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Poster

Effect of laser scanning strategies on the phase transformation, microstructure and mechanical properties of LPBF NiTi shape memory alloys

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Scanning strategy changes have been shown to cause the composition, internal stress, and microstructure evolution of LPBF-metallic. The phase transformation behavior and mechanical properties of NiTi alloys are more sensitive to these changes, however, systematic and accurate studies have not been obtained. Here, this work systematically and comparatively investigates the effect of scanning strategies on LPBF-NiTi alloys, four scanning strategies are selected as stripe rotation-67°, stripe orthogonal-90°, non-stripe rotation-67° and non-stripe orthogonal-90°. The results show that the changes in the length of the scan vector and the rotation angle have a significant effect on the melt pool morphology, B19' martensite transformation peak width and tensile ductility of LPBF fabricated NiTi alloys. The scanning strategy of 67° rotation angle and 4 mm vector length disrupted the continuous growth of columnar grains and forms a weak <111> texture along the building direction. This strategy also induces a narrower phase transformation peak and a lower critical transformation stress at A_f+10 °C compared to the other three. A fracture elongation of over 12% under fully austenite state is achieved for the first time in LPBF. Other three scanning strategies samples have broader phase transformation temperature peak and higher transformation stress at A_f +10 °C. The high critical stress of transformation and low fracture stress lead to incompleteness of the stress-induced martensitic transformation process, reducing their ductility. In addition, it is found that the scanning strategy has little effect on the mechanical properties of NiTi alloys at full martensite state, with all four scanning strategy samples achieving 13% fracture elongation. This work proves that the scanning strategy in the LPBF process is an important parameter affecting the microstructure, transformation behaviors, and tensile properties, which provides theoretical understanding for the realization of high-performance LPBF fabricated NiTi alloys.

Key words Laser powder bed fusion; NiTi shape memory alloys; Scanning strategy; Microstructure; Transformation behavior; Tensile properties

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Poster

Study on Two-way Memory Effect of NiTi Shape Memory Alloy Fabricated by Laser Powder Bed Fusion

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The two-way shape memory effect of NiTi alloy enables it to realize spontaneous shape change while changing the temperature, so it is considered to have broad application prospects in the field of actuation. Laser powder bed fusion (LPBF), as a kind of 3D-printing technology, has been widely used in NiTi alloy in recent years. In this work, the two-way shape memory effect of NiTi alloy fabricated by LPBF is systematically studied. Ti-50.2 at.%Ni alloy samples with different building orientations were fabricated and the two-way memory effect was studied by the method of matensite deformation. The results show that the building orientations has no obvious effect on the two-way strain obtained by the pre-deformation. The maximum two-way strain obtained by the pre-deformation method is 2.24%, which is lower than that of the conventional commercial NiTi alloys' 4% to 5%. The large plastic strain during the deformation process is considered to be the main reason for the smaller two-way strain. After ten times of training with a strain of 12%, the irreversible strain of the NiTi alloy fabricated by LPBF increased from 5.53% to 7.67%, but at the same time the two-way strain was improved to a certain extent (2.24%→2.72%). The result shows that the newly generated dislocation structure and the stress field during the cycling process is generally beneficial to the nucleation and growth of the preferentially oriented martensitic variant during the cooling process, which promotes the increase of the two-way memory strain. In addition, after 10 cycles of thermomechanical training with different constant stress, the maximum two-way memory strain is 1.90%, indicating that the two-way memory effect of NiTi alloy prepared by SLM is closely related to the constant stress value. The research provide support for the application of 3D-printing NiTi memory alloy in the field of actuation.

Key words NiTi shape memory alloy; Laser powder bed fusion; 3D-printing; Two-way shape memory effect

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Poster

Effects of powder reuse on powder characteristics, surface roughness, forming quality, phase transformation and properties of NiTi shape memory alloy fabricated by laser powder bed fusion

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NiTi shape memory alloys (SMAs) are a group of advanced functional materials, which have been used in many fields such as aerospace, automobile and medical technology for their unique thermomechanical properties of shape memory effect and superelasticity as well as good biocompatibility and high corrosion resistance. Laser powder bed fusion (LPBF) is a promising additive manufacturing technique for the fabrication of NiTi SMAs parts with complex geometries that are otherwise difficult to fabricate through traditional processing methods. Considering extremely high cost of NiTi SMAs powder, powder reuse is necessary for economic and sustainable LPBF process. Since powder quality is a key factor in determining the mechanical properties and shape memory function, it is essential to understand the effects of powder reuse on the powder quality and LPBF NiTi SMAs parts. However, the correlational research remains limited. In this study, A systematical investigation was made to explore the reused powder characteristics, surface roughness, forming quality, phase transformation and properties of LPBF NiTi SMAs parts. The results show that NiTi SMAs powder appears to be the sensitive to reuse with changes in morphology, particle size distribution, flowability, and with an increase in the oxygen content. The increased oxide content promotes the laser absorptivity of the powder bed during the LPBF process, leading to the increase in surface roughness and porosity of LPBF NiTi SMAs. The phase transformation temperature measurements demonstrate no dramatic change with respect to powder reuse. Compared to the LPBF NiTi SMAs manufactured from the virgin powder, the ultimate tensile strength and fracture strain for the ones with ten times reused powder decreased about 13% and 30%, respectively. This may be attributed to the formation of large-size and irregular-shaped pores in the LPBF NiTi SMAs, which significantly affects crack initiation and propagation, and simultaneously deteriorates the tensile strength and elongation.

Key words Laser powder bed fusion, NiTi alloy, Powder reuse, Mechanical properties

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Poster

Study on the superelasticity at low temperature of NiTiNb alloy fabricated by laser powder bed fusion

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NiTi shape memory alloys (SMAs) are widely used in aerospace, medical devices, and other fields because of their ability to exhibit high recoverable strain (6-8%), known as superelasticity. However, extreme environments during space exploration demand higher performance from NiTi SMAs, especially in terms of exhibiting good superelasticity at low temperature. In addition, NiTi SMAs are difficult to form complex structural parts through traditional processing methods due to their poor machining ability and weldability. In order to solve the above problems, based on the fact that Nb element can effectively reduce the phase transition temperature of NiTi alloy, with the help of the advantage of laser powder bed fusion (LPBF) technology in forming complex structures, NiTiNb alloys were successfully prepared by LPBF method. The LPBF-fabricated NiTiNb alloys exhibit excellent superelasticity over a wide temperature range at low temperatures. Additionally, the temperature dependence of superelasticity stress of LPBF-fabricated NiTiNb alloys is significantly lower than that of the as-casted NiTi alloys. To investigate the mechanisms behind these phenomena, multiple methods were used, including resistance tests, in-situ high-energy XRD, and in-situ transmission electron microscopy. Results obtained from experiments of in-situ high-energy XRD indicate that the LPBF-fabricated NiTiNb only contains the B2 phase and does not undergo temperature-induced phase transformation during cooling and heating processes. In-situ TEM results reveal the dispersion of electron diffraction pattern and the appearance of nano-domains in the B2 parent phase. The results are consistent with the phenomenon that the resistance monotonically increases with the decrease of temperature, implying the occurrence of martensitic pre-transformation. These results suggest that the excellent low-temperature superelasticity of the alloys is probably due to the appearance of nano-domains in the matrix and the occurrence of martensitic pre-transformation.

Key words NiTiNb; laser powder bed fusing; Superelasticity; Nano-domain

Hangzhou, PR China 25-28 April, 2023

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Published only

Mechanical combinations of materials for coextrusion 3D printing of core-shell structures with high stiffness and toughness

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Homogenous materials are always mutually exclusive for stiff and toughness. Core–shell composite materials with flexible core–brittle shell motifs are verified to possess both high stiffness and toughness in the 3D printing architected materials. Core-shell structures, however, are limited by the viscosity, which often requires the viscosities of the core and shell materials to be close to each other in order to achieve high-resolution co-extrusion, limiting the application scope of 3D printing. Coextrusion of core-shell materials with different viscosities is achieved by controlling screw parameters in this paper using nested twin-screw coaxial core-shell structures. Using the developed core-shell coaxial printing equipment, the effect of printing process parameters on the printing dimensional accuracy is studied, and a suitable range of printing parameters is determined to realize co-extrusion printing of core-shell structures. With a destructive energy absorption of 1.857J, the printed truss can withstand a maximum force of 1150N, indicating that the core-shell structure can substantially improve structural toughness without negatively affecting its strength.

Key words Additive manufacturing; Strength and toughness; Core-shell structure; Fiber reinforced composites, Coextrusion

Session: 3D/4D Printing and Emerging Technologies

Presenting Type: Published only

Enhanced energy absorption in 3D-printed bio-inspired functionally graded honeycomb composite

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Functionally graded structures are widely observed in nature and have been considered to have excellent mechanical properties. In this paper, a novel bio-inspired functionally graded honeycomb (FGH) with changing wall thickness fabricated by 3D printing is proposed to enhance structural energy absorption characteristics under bending load. Firstly, a finite element model considering elastic-plastic, damage, and failure behaviors of the FGH is developed and validated by a three-point bending test. Then, the effect of gradient pattern, gradient ratio (n) and maximum wall thickness (tmax) on the energy absorption performance of FGHs are investigated through a statistical method. It was found that functionally graded honeycomb with acceding pattern (A-FGH) exhibited potential to enhance energy absorption performance. Furthermore, gradient ratio n had a more important effect than maximum wall thickness tmax on energy absorption performance of A-FGH. Lastly, multi-objective optimizations of FGH was carried out with the aim of simultaneously improving specific energy absorption (SEA) and reducing peak force (Fmax), based upon the response surface model (RS) and non-dominated sorting genetic algorithm II (NSGA-II).

Key words Bio-inspired; 3D printing; functionally graded honeycomb; multi-objective optimization

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Oral-Onsite

Compressive characteristics of 3D-printed continuous fiber-reinforced auxetic structures with different Poisson’s ratio

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Enhanced by continuous fiber reinforcements, 3D printing technology is a promising composite fabrication process. It can meet the booming demands of the lightweight design and structural diversity in advanced transportation industries. The continuous fiber-reinforced 3D printing is introduced to design and manufacture auxetic structures with different Poisson's ratio. Four types of auxetic composite structures were tested and characterized for compressive performances under the specific quasi-static condition. The basis of the failure mechanism was comprehended through the capture of compression processes and the microscopical observation of fractures from an experimental viewpoint. Finite element models were established to further reveal the relationship between the failure mechanism and the Poisson's ratio of the auxetic structures. Through specifying the failure mechanism and expanding the designability, this research pave the way for the possible applications of 3D-printed auxetic structures of composite materials reinforced by continuous fibers.

Key words Auxetic structures; Negative Poisson's ratio; Additive manufacturing; Lateral compression; Carbon fiber-reinforced plastic (CFRP); Specific energy absorption (SEA).

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral-Onsite

3D modeling the material flow and induced fiber orientation for polymer composites made via large area extrusion deposition additive manufacturing

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Material flow and associated fiber orientation are one of the most important features in Large Area extrusion deposition Additive Manufacturing (LAAM) of short fiber-filled composites. Endeavors have been done in 2D flow models, where significant knowledges are achieved in explaining the material anisotropy of the deposited composite parts. Nevertheless, 2D flow models are limited by a couple assumptions that losing significant characters of the deposition flow. This study presents a 3D flow model focusing on the polymer composite melt flow within the nozzle and the subsequent 90-degree turning deposition onto the material substrate. Different rheology flow models are applied to quantify the flow kinematics. The fiber orientation is evaluated using the Advani-Tucker orientation tensor approach, via the one-way weakly-coupled flow/orientation analysis formulation. Computed results show the fiber orientation state on the entire cross-section of a deposited bead, which yields a clear view of how the material anisotropy is affected by the locally varied fiber orientation. 3D-model predicted orientation results exhibit a more favorable agreement with the reported experimental data than that yielded by the conventional 2D models. Additionally, it is found that the initial fiber orientation state in the nozzle inlet produces noticeable influences on the resulting fiber alignment within the LAAM-deposited composites.

Key words LAAM; Short fiber-filled composites; 3D flow model; fiber orientation

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral–Onsite

Vibration analysis of variable angle tow composite plates

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The composite plates have been increasingly used in mechanical, civil, marine, and aerospace engineering applications due to the superior material properties of high stiffness and high strength-to-weight ratio. Recently, the development of tow-placement technology allows the production of variable angle tow composite plates, in which the fibre orientations continuously varying over the plane of each plate. The use of curvilinear fibres enables the possibility of stiffness tailoring without increasing its weight. The composite plates in practice usually undergo excitation loadings, resulting in the severe vibration problems. There have been numerous studies on the free vibration of laminated composite plates with conventional straight fibres but those associated with variable angle tow composite plates are still less. This paper investigates the forced vibration characteristics of variable angle tow composite plates subjected to harmonic force. Both free and forced vibration analysis based on finite element methods have been carried out to obtain and compare natural frequencies and the steady-state dynamic responses. The vibration behaviour of variable angle tow composite plates with various fibre paths is compared with that of the laminated composite plates with conventional straight fibres. It is found that curvilinear fibres have significant influence on vibration characteristics of laminated composite plates. The results explicitly show that natural frequencies and dynamic responses could be tailored by designing fiber paths for vibration mitigation. A deep understanding of vibration behaviour of variable angle tow composite plates is substantial for enhanced vibration suppression of composite structure. The tailorable variable angle tow composite could be extensively applied in more advanced structures.

Key words vibration analysis; variable angle tow; fibre orientations; natural frequencies; dynamic response

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Oral-Onsite

Optimizing curvilinear fiber-reinforced composite structures through a parametric level set method

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Advanced manufacturing technologies allow continuous fibers to be steered, resulting in variable stiffness composite laminates (VSCLs). Such structures offer greater design freedom and potential for improving structural performance compared to constant stiffness structures with straight fibers. However, the design of VSCLs must satisfy several constraints imposed by fabrication techniques, such as fiber continuity, parallelism, and curvature requirements. If curvilinear fiber paths are not parallel or evenly spaced, gaps or overlaps between adjacent fiber tows would appear during the manufacturing process, thus leading to undesired thickness variation in the structure. In addition, if the turning radius of the fiber path is small, delamination and wrinkling will occur due to high stresses.

Structural optimization can be a powerful tool to fully exploit the potential of VSCLs. For the design optimization of these structures, a fundamental issue is the representation of fiber arrangement using an appropriate parameterization scheme. In the present study, we use iso-contours of a level set function to directly represent the fiber paths in one layer of the composite laminate. And the level set function is constructed by a set of compactly supported radial basis functions and corresponding expansion coefficients. In this way, the fiber orientation at any arbitrary point is defined by the orientation of the tangent vector of the iso-contour that passes through the point. To meet the main manufacturing requirements, the gradient norm and contour curvature of the level set functions are constrained in the design optimization. Then, the p-norm method is used to aggregate the constraints to improve computational efficiency. The expansion coefficients are taken as the design variables and they are updated using the method of moving asymptotes (MMA) based on the gradient information. In several numerical examples of compliance minimization and fundamental frequency maximization, the results prove that the proposed method is effective to optimize the VSCLs.

Key words optimization design, variable stiffness laminates, manufacturing constraints, level set method

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral-Onsite

Deployment Dynamics Behaviors of Composite Thin-walled Lenticular Tubes with Stress Relaxation Effects

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This work presents a comprehensive computational model to investigate the dynamic deployment behavior of the composite thin-walled lenticular tube that wraps around a central hub. The detailed description of the set-up of a finite element model, including the definition of both deformable thin-walled boom structures and rigid objects such as central hub and guide rollers, as well as the complex interactions between them, is presented. The composite thin-walled boom is firstly coiled and wrapped around a central hub to attain the stowed configuration. After that the deployment is activated by removing some of constraints and thus releasing the stored strain energy. Two different methods of coiling and deploying were considered, and the coiling and deployment mechanics such as the rotational moment, deployment rate, were analyzed. The computational results are validated against experimental results existing in literature and a reasonable agreement is found. Furthermore, the stress relaxation effect due to long-term stowage or temperature changes was also revealed through a rigorous study and it is found that the stress relaxation would lead to an increase in the deployment time and the amount of stress relaxation effect depends on the ratio of length of the boom and diameter of the central hub.

Key words Composite thin-walled structures; Deployable structures; Deployment dynamics; Finite element method.

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Oral-Onsite

Evaluating the recent advances in finite element models tailored for fused deposition modeling

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Fused Deposition Modeling (FDM) gains increasing popularity globally owing to its high-capability for building up intricate structures with low costs in time and materials. It shows great potential to take place of conventional manufacturing methods. Nevertheless, complex material behaviors of thermoplastics feedstock yield extensional difficulties for obtaining excellent surface finishing quality and dimensional precision of fabricated products, especially when composite materials are applied. To address such issues, numerical and predictive tools are developed, which provides significant insights in better understanding the complicated physics during FDM processes. This study evaluates the existing literature discussing the numerical simulations for FDM and related technologies. We explore four stages within a typical process of FDMs, i.e., the material flow in the nozzle, material deposition and bonding, post-treatments, structural performance evaluation. Throughout our investigations, it is found that the physical modeling studies on the post-treatments are limited as compared to the others, while the post-treatment (e.g, thermal annealing) is becoming a vital part for enhancing the mechanical performances of FDM parts. The strongly anisotropic material properties exhibited by the composite feedstock are under-considered in a couple of literature. In contrast, we suggest to count these inhomogeneous properties based on the material loading direction of FDMs.

Key words finite element analysis; fused deposition modeling; material property definition; predictive tools

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Oral−Onsite

Mechanics-driven optimization algorithms for laminated composite structures optimization

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Structural lightweighting is an important task in aerospace engineering equipment design, and carbon fiber composites have emerged as the preferred material due to their high specific stiffness/strength and tailorable design characteristics. However, the lightweight design of aerospace structures poses great challenges to the optimization design techniques due to the high-dimensional discrete variables of laminated composite materials, complex nonlinear engineering mechanics requirements and manufacturing limitations. Existing optimization methods do not consider the mechanical mechanisms of composite materials, which leads to excessive calculation. How to incorporate the unique mechanical mechanisms of composite materials into the optimization method for structural design of laminated composite structures to obtain an efficient optimization algorithm has become the key problem to be solved. To improve the optimization design efficiency of laminated composite structures and stimulate its tailorable design characteristics to the greatest extent, this work presents mechanics-driven optimization theories and algorithms for laminated composite structures. Using the the convexity of lamination parameters, the linear superposition law of stiffness, and the sensitivity information of bending stiffness, an efficient, robust and general optimization algorithm is proposed for laminated composite structures — two-dimensional sampling optimization method (2DSO). The concept of sampling optimization is introduced into the lamination parameter space for the first time. A good initial point is obtained by uniformly distributed points in the lamination parameter space, and local sampling optimization and layup optimization are performed, thereby avoiding the traditional optimization method that uses lamination parameters as the mid-variables, where feasible region constraints are required. The proposed algorithm is employed for the buckling and vibration optimization problems of laminated composite plates and shells and performances are compared with the existing optimization algorithms. The results show that the mechanics-driven optimization algorithms are 5-10 times of magnitude more efficient than the existing optimization algorithms and has similar robustness. It heralds the potential of mechanics-driven optimization algorithms in solving large-scale laminated composite structures optimization problems.

Key words mechanics-driven optimization algorithms, laminated composite structures, two-dimensional sampling optimization method (2DSO), buckling, vibration

Hangzhou, PR China 25-28 April, 2023

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Oral–Onsite

Experimental study of honeycomb sandwich composites under low energy impact

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Due to light weight, high strength and higher energy absorption, honeycomb sandwich composites are widely used in aeronautics and astronautics, but those structures were easily subjected to low energy impact, which threatened the safety of the whole structure. In this paper, a kind of T700 carbon fiber-Nomex honeycomb sandwich composites for aircraft were designed, two kinds of low energy impact tests were carried out by using Instron 9350 drop weight impact testing machine. The impact contact force-time curves were recorded, and the damage mode and damage mechanism of the honeycomb sandwich composite plates were studied under low energy impact, the relationship between impact energy and damage parameters (damage depth, damage area and damage width) were established, the ability to resist low energy impact (damage resistance) was obtained. The results of this paper would provide technical guidance for the large-use application of honeycomb sandwich composites in aircraft.

Key words Honeycomb sandwich composite; Low-velocity impact; Impact damage; Damage mechanism

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral-Onsite

Multiscale and Multiphysics modeling of process-induced distortion of composite laminates with Direct FE2

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Curing is an important process in the fabrication of composite laminates before pre-impregnated fibers can be used as a rigid and durable structure. Under a designed cure temperature/pressure cycle, composite materials, especially the resin will undergo a series of physical and chemical changes, which may induce dimensional inaccuracy and distortion such as warpage and spring-in after demolding. To alleviate these issues, accurate modeling of curing is critical for the optimization of process parameters.

In this work, a Multiscale/Multiphysics numerical approach based on Direct FE2 is presented for the curing analysis. Direct FE2 was first proposed by Tan et al. to enable a two-scale modelling in a single FE analysis and later extended by Zhi et al. to thermomechanical problems. With this framework, we can directly describe the complex behaviour of constituent materials during curing, that is, the evolution of resin properties by a cure-dependent viscoelastic material model together with a chemical kinetics model. Moreover, the non-mechanical strain induced by chemical shrinkage and thermal expansion is included. Coupling the RVE models and the laminate model through linear constraints, Direct FE2 can reflect these evolved microscopic mechanisms in the macroscopic response. To verify this approach, several numerical examples have been considered, including unsymmetrical flat laminate, L-shaped and C-shaped specimens subjected to a two-dwell cure cycle. The typical warpage and spring-in residual deformations are well captured for flat and curved specimens, respectively. Therefore, the proposed approach is promising to help manufacturers optimize structural configuration, lay-up and cure cycle without trial and error using physical tests.

Key words Curing process; Polymer matrix; Residual deformation

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral-Onsite

Multi-scale simulation of mechanical properties of carbon nanotube-reinforced PPTA fibers

Zebei Mao*、Tong Li、Bo Wang
Dalian University of Technology

PPTA fibers are used in a wide range of fiber-reinforced composites because of their high levels of tensile stiffness, tensile strength and toughness. The mechanical properties of PPTA fibers can be reinforced by adding nano-reinforcement items such as carbon nanotubes (CNT). In addition, the modified CNTs produce different reinforcing effects on the fibers. To further improve the strength of PPTA-based fibers, it is necessary to investigate the microstructure of the fibers and the deformation mechanism of the fibers when nano-reinforcements are added. Therefore, this study investigated the multi-scale deformation mechanism of PPTA fibers from molecular scale to macroscopic scale, hoping to guide the design of new aromatic polyamide fibers.

In this paper, a representative multi-scale model is developed to predict the mechanical properties of specialty PPTA fibers based from the molecular scale (nm) to the fiber bundle scale (mm). The model does not require any mechanical property inputs or modeling parameter assumptions. The microscopic part of the multiscale model is simulated by molecular dynamics techniques and the macroscopic part by finite element techniques. Using this multiscale model, the multilevel microstructure can be considered to predict the mechanical properties of PPTA fibers. The strength and stiffness results of Kevlar 29 and Kevlar 49 calculated with this model are in good agreement with the experimental results.

Also, molecular modeling techniques were used to investigate the enhancement of PPTA crystal interfaces by carbon nanotubes with different modifications. We found that the tensile strength of the PPTA/CNT interface was 27.8% ~ 39.7% higher than that of the unreinforced PPTA crystal interface. To explain the course of stiffness reduction during stretching, we simulated the CNT pull-out process and discussed the role of hydrogen bonding. CNT modified with PPTA groups has the best bonding stability with PPTA crystals due to the longer branched chain length of PPTA groups and the higher number of hydrogen bonds. Meanwhile, the stiffness matrix of PPTA-modified PPTA/CNT crystals was calculated in this paper, in which the tensile modulus was reduced and the shear modulus was increased. This study provides insight into the molecular mechanism of how CNT can be used to enhance the strength of PPTA fibers, which is of great significance for the future adaptation of

aramid fiber production technology to achieve large-scale engineering applications of super-tough fibers.

Key words PPTA fiber; Multi-scale model; Molecular simulation; carbon nanotube; tensile strength

Hangzhou, PR China 25-28 April, 2023

Session: Optimization Design/ Modeling and Simulation

Presenting Type： Oral-Onsite

Compression properties of carbon-fiber/aluminum-honeycomb sandwich tubes with the local-tight honeycomb core

gong cheng*、shanshan shi、jiasen zhang、xin zhou

dalianjiaotong university

Sandwich structures are investigated in the engineering field due to its excellent energy absorption characteristics. In the present study, a carbon-fiber/aluminum-honeycomb sandwich tube with the local-tight honeycomb core is designed considering load transferring paths of carbon-fiber/aluminum-honeycomb sandwich panel. Firstly, finite element model of carbon-fiber/aluminum-honeycomb sandwich panel with the local-tight honeycomb core is established. Basing on the finite element model, the initial peak load and specific energy absorption of carbon-fiber/aluminum-honeycomb sandwich panel with the local-tight honeycomb core are calculated. The calculated results show in a good agreement with experimental results. Finally, the parametric discussions , including energy absorption, specific energy absorption and initial peak load, are carried out on the carbon-fiber/aluminum-honeycomb sandwich tube with the local-tight core by changes in the number and configuration of the local-tight honeycomb cores The results indicate that the specific energy absorption of carbon-fiber/aluminum-honeycomb sandwich tube with the local-tight honeycomb core are improved under quasi-static axial compression load when compared with the carbon-fiber/aluminum-honeycomb sandwich tube. yet its specific peak load raise. The existence of the local-tight honeycomb structure can improve the energy absorption characteristics of carbon fiber/aluminum-honeycomb sandwich tube; the energy absorption of carbon-fiber/aluminum-honeycomb sandwich tube increases to a certain extent with the number of the local-tight honeycomb structure; When the configuration of carbon-fiber/aluminum-honeycomb sandwich tube with the local-tight honeycomb core is 45°, it shows 4.75% more than the carbon fiber/aluminum honeycomb sandwich tube. From this study, the local-tight honeycomb core sandwich sturctures have great potential in energy absorption.

Key words sandwich structures; CFRP; local-tight honeycomb core; energy absorption characteristics

Hangzhou, PR China 25-28 April, 2023

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral-Onsite

Compression and post-buckling damage analysis of a stiffened composite panel with initial interlaminar debonding

Junchen Zhou*、Zhengming Huang
Tongji University

Buckling behavior of a stiffened composite panel with a pre-assigned interlaminar debonding between the stiffener and the skin under in-plane compression is investigated in this paper. The significant delamination propagation is simply simulated through a stress modification method applied to the adhesive layer in between the skin and stiffener. It has been found that an initial geometric imperfection introduced by the eigenvalue buckling analysis is necessary to attain a continuous buckling induced delamination propagation. A stable buckling response will take place when the magnitude of major perturbation for the imperfection varies from 0.5 to 10 percent of the skin thickness. The influence of the local buckling on in-plane load-displacement response and skin-stiffener delamination are also analyzed. The most reasonable predictions have been obtained from the post-buckling analysis with geometric nonlinearity. All of the numerical results in this work exhibit insensitivity to the mesh sizes. In addition to the mechanical properties of unidirectional (UD) composite and adhesive, only the modes I and II interlaminar fracture toughnesses of the UD specimens lapped by the same adhesive joints are required for the input data. All the measurements can be carried out independently and following existing standards.

Key words buckling, delamination, adhesive layer, stress modification

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Oral-Onsite

A theoretical model of a composite flexible capacitive pressure sensor with microstructured electrodes for highly sensitive electronic skin

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Flexible pressure sensors are indispensable in electronic skin which has attracted much attention in smart wearables, prosthetics, and robotics. Introducing microstructures on the nanocomposite dielectric layer or on the electrode is a favorable method to make the pressure sensor more deformable, which is a key factor to improve pressure sensors' sensitivity. In this work, finite element method (FEM) was used to analyze the electromechanical coupling effect, which is a good way to optimize the structure and geometric design on sensitivity. We used Abaqus to simulate the microstructure sustaining pressure when its Young's modulus gradually decreases or its shape changes. When the electrode shape is round crown, the deformation and stress distribution of the nanocomposite dielectric layer have no difference no matter whether the round crown microstructrued electrode's Young's modulus is large or rigid. Most importantly, the compressive force-displacement relationship has a good consistency in the initial linear elastic small deformation stage, where the sensitivity is most significant for the pressure sensor. Furthermore, the stress distribution of the nanocomposite dielectric layer has no obvious difference between round crown and pyramid microstructured electrode shape. The compressive force-displacement relationship of the round crown and pyramid are non-linear and linear, respectively, but they have the same tendency in the linear elastic small deformation stage. We introduce a correction factor for the shape transfer of the microstructured electrode in the linear elastic small deformation stage. The utilization of FEM in indentation analysis of nanocomposite microstructures broadens the path of nanocomposite microstructures optimization design, which helps the electronic skin imitate or even recreate the properties of human skin.

Key words electronic skin, theoretical modeling, sensitivity, capacitive pressure sensor, microstructured electrode

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral-Onsite

Machine learning based characterization of carbon fiber reinforced shape memory polymer composites

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Carbon fiber-reinforced shape memory polymer composite (CFR-SMPC), which effectively improves the mechanical properties of the conventional shape memory polymer (SMP) without affecting the shape memory effect, has been facing an urgent challenge for the characterization of the nonlinear mechanical behavior. In this study, the multi-scale characterization method based on machine learning is adopted as an approach to the material behavior. A large amount of strain and stress database under different temperatures is generated based on the unit cell of CFR-SMPC and verified by limited experimental data. To train the database and represent the stress-strain relationship, a simple feedback neural network model is constructed. This neural network model is implemented in Abaqus as a user material subroutine to update the stress during high-level simulation. The results show that the model is able to represent the anisotropy and nonlinearity of the CFR-SMPC and is in good agreement with the experimental cases. This study proves the feasibility and efficiency of the machine learning based prediction of the mechanical behavior during the finite element analysis for the complex material behavior.

Key words Machine learning, Unit cell, Shape memory polymer, Carbon fabric

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Oral-Onsite

Structural design and mechanical properties of bio-inspired 3D curved gradient lattice metamaterials

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Architected lattice metamaterials have been widely used in various engineering applications as functional structure components including shock absorber, helicopter rotor blades, deployable solar panels for space missions, due to its high specific strength, outstanding energy absorption and unique volume control capabilities. In this work, a novel bio-inspired 3D curved lattice metamaterials with stable mechanical response and ideal deformation behavior were constructed by geometric tailoring. Through quasi-static compression tests and finite element simulations, the effect of scaling factor, gradient settings and continuous interface on the energy absorption indicators of curved lattice structures are systematically studied. The results illustrate that the proposed lattice can effectively reduce the stress concentration between the nodes of the lattice structure, and has stable deformation behavior and ideal energy absorption performance. The scaling of the curved lattice unit cells can trim the mechanical indicators to realize the tailoring of the mechanical properties of the lattice. The compressive modulus, plateau stress and SEA all exhibit a trend of first increasing and then declining with the decrease of the scaling factor. Under the same mass, the SEA of the NL-1 lattice (1.85J/g) is 25.85% greater than that of the NL-3-0.5 lattice (1.47J/g). Furthermore, the continuous interface is effective for realizing controllable mechanical response and tunable energy absorption performance of gradient lattice metamaterials. The Gradient-3 lattice has the highest SEA (1.26J/g) compared with other lattices under the same dimension due to the smooth mechanical response and ideal deformation behavior. This work can provide a reference for the construction of energy-absorbing devices with controllable mechanical response and tunable energy-absorbing performance.

Key words Energy absorption; Lightweight structure; Gradient lattice; Structural design

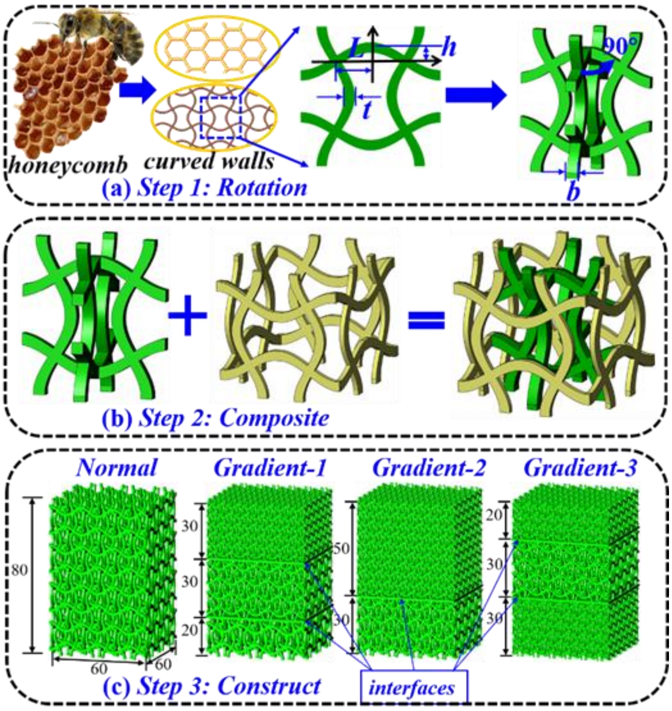

Fig. 1. Design methods of the bio-inspired 3D gradient lattice metamaterials, (a) the typical characteristics of curved-wall structure were extracted and rotate 90° around its own symmetry axis, (b) the hybridization method was utilized to obtain lattice unit cells, (c) gradient structures can be obtained by filling the volume space with unit cells of different scaling factors.

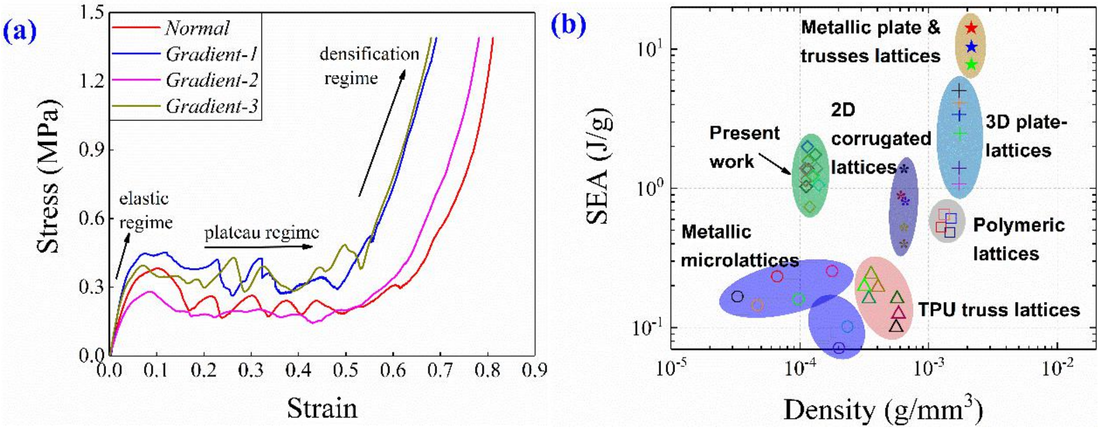

Fig. 2. (a) The mechanical response of the proposed lattice structures, and (b) Comparison of the SEA considered in the present work with the extant work.

Hangzhou, PR China 25-28 April, 2023

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral-Onsite

Numerical study on damage behavior of fiber-metal laminates subjected to combined blast and fragments loading

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Jiangsu University

Fiber metal laminates (FMLs) are widely used in a variety of protective structures due to their excellent impact resistance. In the present work, a nonlinear finite element (FE) model is developed to investigate the damage behavior of carbon fiber reinforced aluminum laminates (CRALLs) subjected to combined blast and fragments loadings. The strain rate effect of composite ply is involved and the intra-laminar damage is predicted based on 3D Hashin criteria; Johnson-cook model is employed to simulate the high velocity fragments impact response of aluminum layer; cohesive elements are introduced to describe the inter-laminar delamination phenomena. The proposed FE model is verified with the available experimental data in ballistic impact condition and then implemented to predict the fragments and blast impact behavior of FMLs. The dynamic response and damage mechanism of FMLs are analyzed and the effects of explosion distance, explosion mass and impact angle on the impact performance are discussed in detail.

Key words fiber metal laminates; blast and fragments loading; damage; delamination; FE modeling

Session: Optimization Design/ Modeling and Simulation

Presenting Type： Oral-Onsite

Numerical simulation of material strength of CMCs based on CT data reconstruction

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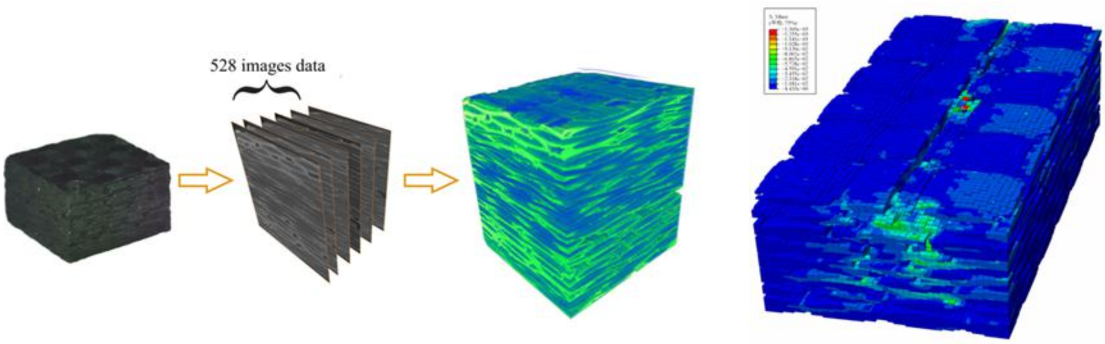
Ceramic Matrix Composites (CMCs) are the important material candidate for thermal structures in aero-engines. Strength failure analysis and prediction is the focus of service performance evaluation of CMCs. In this paper, a precise geometric model of the material was established by CT 3D reconstruction, and the strength prediction model of 2D-C/SiC composites was established according to the failure criterion of materials. Firstly, the volume fraction and location distribution of defects, the accurate geometric parameters of fiber bundles were obtained by μ-XCT 2D slice data reconstruction. Meanwhile, the hole-type defects were placed into the finite element model. The single-layer plain woven model and the structural model were established. And then, we defined the fiber bundle failure criterion and the matrix failure criterion respectively by writing the VUMAT subroutine, simulated the static tensile process of the material. The tensile strength of the material was simulated, the reliability of the finite element model was also verified by combining the experiment results at last. The simulation results showed that the damage of the material occurred firstly below the location of the coating cracks, and the cracks gradually propagated downward with the increasing load. After the first layer failure, the crack expansion path changed clearly from directly below the coating crack defect to the maximum bending position of the woven structure, which was more in line with the crack expansion law of CMCs material in the static tension process. The research could provide the effective data support for thermal structure design of CMCs in engineering application.

Key words 2D-C/SiC;CT;numerical simulation



Session: Optimization Design/ Modeling and Simulation

Presenting Type：Oral–Onsite

Enhancement of Cutout Composite Joint Characteristics via Continuous Carbon Fiber-Reinforced Thermoset Composite Printing

Yueke Ming[1,2,3,4]、Yugang Duan[1,2,3]、Ashraf Aboelenien[5]、Gerhard Ziegmann[5]、Zhibo Xin[1,2,3]、Xiao Hong[1,2,3]、Jin Zhou[1,2,3]、Ben Wang*[1,2,3,5]、Zafer Kazancı[4]

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A major concern in the design of aircraft fuselages made of fiber-reinforced composites is the inclusion of cutouts. These defects break the continuity of fiber paths, significantly increasing stress concentrations near perforation regions. To address these issues, the continuous and high fiber volume fractions of a composite were arranged in this study by a fiber-reinforced thermosetting resin printing technique. Standard open holes were created using a height-transition continuous printing path strategy, providing circular reinforcement around the hole peripheries. Compared to a sample prepared by conventional drilling, the as-prepared specimens displayed 75% and 17% improvement in open-hole and bolted-joint tensile strength, respectively. A potential reinforcement mechanism was illustrated by failure analysis. The region in the vicinity of the holes was strengthened through continuous and high-fraction fiber reinforcement that inhibited deformation and crack propagation under tensile load. The proposed method offers an automated manufacturing alternative for fabricating composite junction structures for application in aerospace engineering or other related industries.

Key words Polymer-matrix composites; Laminate mechanics; Joints/joining; Continuous fiber 3D printing

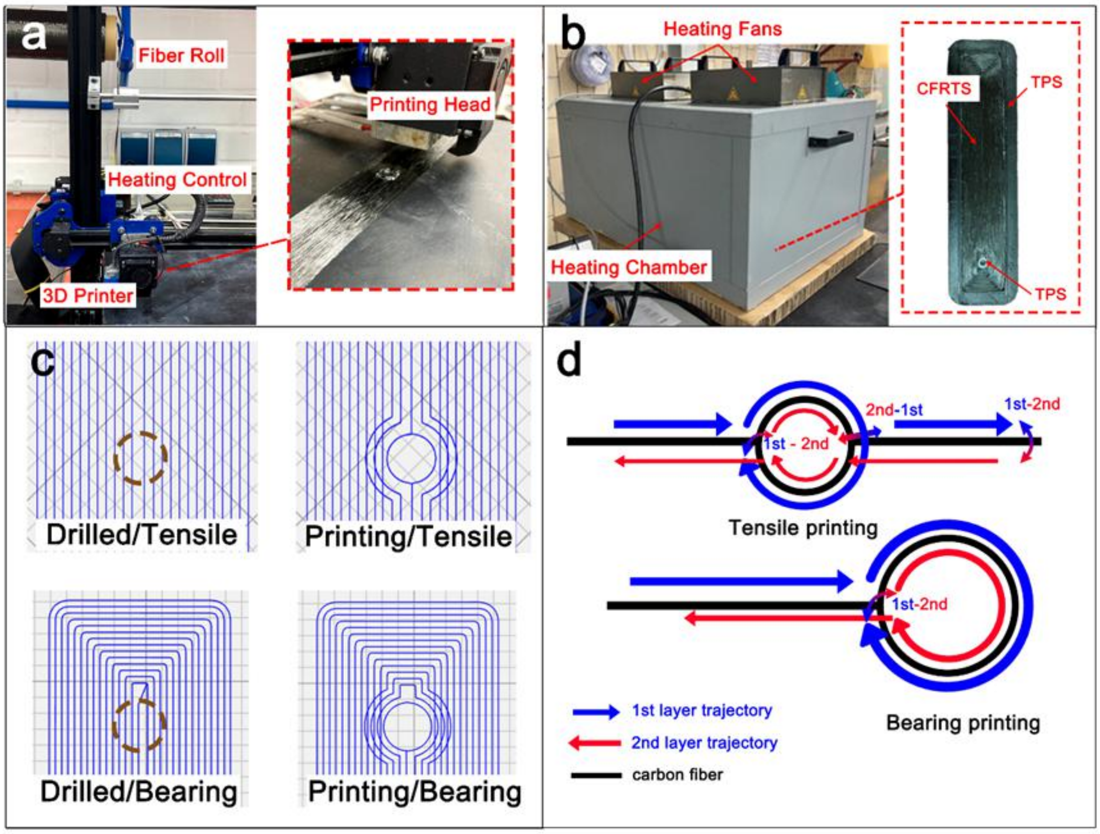

Fig. 1. (a) Printing process, (b) post-curing setup, (c) path planning strategy, and (d) height transition from the first layer to the second layer.

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Oral–Onsite

A CAE scripting editor targeting at GUI users

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2. WUOU (Chengdu) Technology Co., Ltd.

This work explores the possibility to perform CAE simulation before having a product design.

A conventional structural analysis has to initiate with a design in GUI, which works great on one design against multiple load cases. However, as simulation driven design pattern trending up, the one design should be filtered out from many possibilities for one complex load case, where the GUI narrative does not work conveniently.

A text editor, who communicates with the lowest level API of a solver exposing to end users, does all and beyond GUI’s capability. However, lacks of genearl usability for common users. To find out if it’s ever become a real competitor, A designated IDE support should be implemented first. The first supported solver will be ls-dyna.

The coding part is comparably settled, language server protocol standardlized the interaction between our software and the mainstream editor, which saves ton of codes, and exploiting Rust ecosystem should guarantee software efficiency and reliability. The real engineering effort could be spent on the real kink, namely, how to build the simulation narrative without clicking and dragging, but goto-definition, hover, and code-action etc. A pre-minimal viable production should be expected at conference.

Key words CAE scripting

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral-Onsite

Damage mechanism of bioinspired hybridization helical composite in lobster homarus americanus

Yanan Yuan*
Wuhan University

A typical twisted laminar structure was an essential feature for the exoskeleton of the lobster Homarus americanus to resist impact damage and penetration. In fact, two kinds of helical structures were observed in the exoskeleton with different pitch angles and ply thicknesses in the exocuticle and endocuticle. It is worth investigating the evolutionary mechanism of the hybrid helicoidal structure rather than a single helix. In this paper, two pitch angles and ply thickness were introduced to reproduce the hybridization helicoidal structures of crustacean ectoskeletons. Numerical investigations were carried out, including low-velocity impact and compression after impact (CAI). The results showed that the bionic architectures need to balance the protection function provided by the endocuticle and load-carrying performance provided by the exocuticle. In addition, the qualitative relationship between design parameters and performance was analysed. The decrease in angle and the increase in layer thickness will lead to an increase in energy dissipation during the impact process and a decrease in residual strength. In addition, the hybrid helicoidal microstructures were reconstructed and characterized experimentally using ultrathin laminate composites. The results show that compared with the single helix structure, the angle hybrid helix structure can not only fight head-on, but also protect the internal tissues and organs well because of its higher carrying capacity and larger prolonged residual loading. Therefore it is easy to understand or explain from mechanical mechanism and Darwinian evolution why the American lobster exoskeleton has evolved this interesting and unique characteristic morphology. The research results provide a reference for the design of hybrid bionic structures with multimechanism cooperation.

Key words lobster homarus americanus; hybridization helical; bio-inspired

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Oral-Onsite

An Explicit Optimization Strategy for Composite Overwrapped Structures Based on MMC Approach

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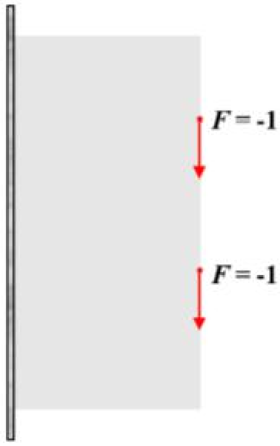
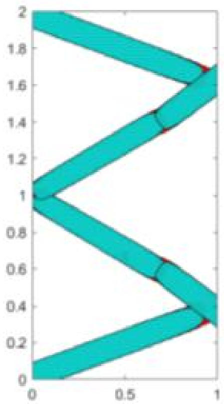
State Key Laboratory of Structural Analysis for Industrial Equipment, Department of Engineering Mechanics, International Research Center for Computational Mechanics, Dalian University of Technology

Composite overwrapped structures, performing excellent properties and full of designability, are progressively employed in a variety of fields for special requirements, which is to be a strong competitive part in the material field of the future. Despite the fact that more and more scholars and researchers pour their energy into composite overwrapped structures using optimization methods, its layout was and is still the course in engineering design. Furthermore, the majority of topology optimization frameworks applied to composite overwrapped structures are implicit, which is difficult to give precise control of the structural feature sizes. Considering the minimum compliance as the objective function, in this paper, we intend to optimize the composite overwrapped structures in an explicit way. Based on the moving morphable components (MMC) approach, we take the design variables as parameters to describe the materials distribution of the composite overwrapped structures and fiber orientation angle explicitly in the design domain that also alleviates the phenomena that gray medial elements and exceeding design variables. Compared with the traditional implicitly topology optimization methods employed in composite overwrapped structures, we take the advantage of reducing the total number of degrees of freedom (DOFs) of the MMC approach to improve computational efficiency and need no supererogatory work to attain the boundaries of the optimized structures. Incorporating the fiber orientation angle as a design variable to fulfill the whole optimization process, the presented strategy is also beneficial to seeking the most potential optimal structures. We verify the feasibility of the proposed approach by some two-dimensionally classic examples and simplified practical examples. This work may contribute a lot to guiding engineering applications.

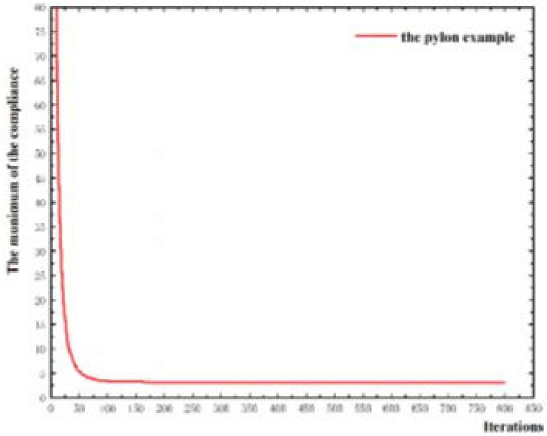
Key words Composite overwrapped structures; Moving morphable components (MMC) approach; Explicitly topology optimization method; Fiber orientation angle



The simplified pylon



The optimized results



The change history of the objective function

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral-Virtual Platform

Adaptive Multi-Fidelity (AMF) Modelling of Damage in Composites under Static Indentation

Karh Heng LEONG*、Jie ZHI、Vincent B. C. Tan、Heow Pueh LEE 、Tong Earn TAY
National University of Singapore

This presentation discusses an adaptive multi-fidelity (AMF) approach for progressive damage analysis of laminate composites subjected to static indentation. Compared to high-fidelity models, this approach is more computationally efficient because it uses a combination of low-fidelity shell elements and high-fidelity brick elements in a single concurrent model. Regions of shell and brick elements may be transitioned from one to the other and vice versa, depending on the need for enhanced or reduced fidelity, dictated by the mechanics of damage evolution. When damage in the form of matrix cracks or interfacial delamination initiates, shell elements transit to brick elements and discrete cracks are seeded using floating nodes. Discrete intralaminar matrix cracks and interlaminar cracks are described by inserted cohesive elements. Geometric non-linearity is considered in the finite element analysis. The AMF approach has previously been validated and verified for analysis of open hole tensile (OHT) and delamination migration experiments. In this paper, the AMF approach is extended to predict large deformation in specimens subjected to static transverse indentation. The numerical results are benchmarked with high-fidelity models and experimental data of cross-ply and quasi-isotropic laminates in literature. The predicted results show good agreement with experimental observation and high-fidelity models, and up to 41% improvement in computational efficiency is achievable.

Key words multi-fidelity modelling, progressive damage, static indentation

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral−Virtual Platform

Tapering Optimization of Double-Double (DD) Laminates

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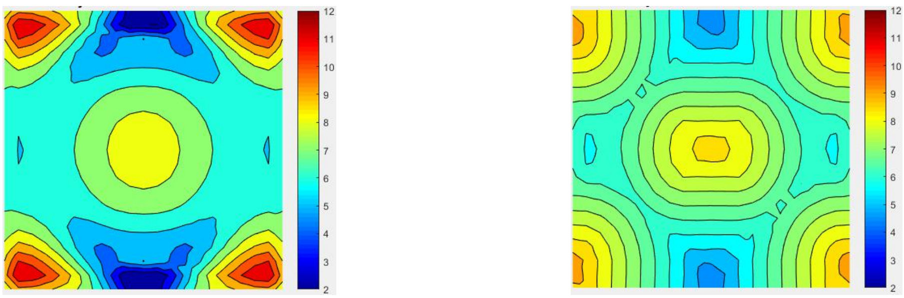
2. Stanford University

Double-Double (DD) laminates are novel layups made up of two groups of angle plies. The assembly of local sub-ply blocks provides homogenized material properties and can achieve the unique laminate layup for the whole structure with different sub-ply block repeats. However, the thickness thinning will bring buckling forward leading to structural failure. Here we work on searching the optimal thickness tapering strategy of DD laminates to achieve the highest buckling load with the given structure weight. The DD laminate is modelled as a shell with the thickness for each element defined as different repeats of the basic sub-laminate. Optimal thickness profiles will include sharp changes in the thickness, which may lead to thickness delamination. To overcome the problem, spacing constraints on thickness tapering are added to the optimization model. Numerical examples show that the added spacing constraints can help to yield a smooth thickness tapering at the cost of a reduced optimal effect.

Key words Structural Optimization, Double-Double Laminates, Buckling, Thickness Tapering



(a) Without spacing constraints (b) With spacing constraints

Fig. 1. Optimal thickness tapering results with the highest buckling load for DD laminates under uniaxial compression.

ACCM 12
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Session: Optimization Design/ Modeling and Simulation

Presenting Type: Oral-Virtual Platform

Failure analysis of fiber reinforced thermoplastic composite plate and conical metallic insert joints

Muhammad Ridha*[1]、Zhoucheng Su[1]、Le Quan Ngoc Tran[2]、Wei Ming Yek[2]、Stefanie Feih[2]、Sridhar Narayanaswamy[1]、 Tong Earn Tay[3]
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2. Singapore Institute of Manufacturing Technology (SIMTech), Agency for Science, Technology and Research (A*STAR), 73 Nanyang Drive, 138632, Singapore
3. Department of Mechanical Engineering, National University of Singapore, 9 Engineering Drive 1, 117575, Singapore

Most fiber reinforced composite materials used in load bearing structures such as aircraft, cars, or boats are made of thermoset plastics as the matrix. Thermoplastic composites may be used more widely in future as concerns on environmental friendliness and recyclability dominate. As with its thermoset counterparts, thermoplastic composite structures often need to be joined with other parts made of other composites or metals. Joining of parts can conventionally be achieved through mechanical means such as bolts, rivets or adhesives. However, mechanical joints of structures made of continuous fiber reinforced composites require drilling or water-jetting which disrupts the continuity of the fibers and hence degrade the load bearing capability. Furthermore, most thermoplastics are not easily bonded using thermoset adhesives because of their low reactivity, surface energy, and polarity.

This study presents an analysis of metallic inserts as an alternative solution for thermoplastic composite joints by the finite element (FE) method. A conical metallic part is embedded in the thermoplastic composite plate when the plate was moulded so that it can be used to transfer out-of-plane load. A new material model was created for the thermoplastic composite as existing material models were inadequate, especially in modelling the compressive failure of the composite. FE models were developed to analyse the response of the metal-composite structure under pull-out loads, and validated with experimental results. Geometrical parameters of the conical inserts and composite-to-metal adhesion were varied to investigate their influence on the failure load and mechanisms. The results show that adhesion between the metal insert and the composite surfaces plays an important role in load transfer. Insufficient or low adhesion toughness causes early delamination between the two, with load transfer mainly through mechanical locking, triggering premature failure of the joint.

Key words thermoplastic composites, finite element method, progressive damage

Hangzhou, PR China 25-28 April, 2023

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Poster

Three-dimensional progressive damage analysis of the tightening process of composite bolted joints considering the real thread structure

Qingyuan Lin*、Yong Zhao、Yuming Liu
Shanghai JiaoTong University

Bolted joints are the dominant connection method in assembling composite structures. Assembly quality of the bolted joint has an important effect on the mechanical properties of the whole composite structure. To investigate the stress, deformation and failure mechanism of composite bolted joints during the process of assembly, a three-dimensional progressive damage model for the real assembly process of composite bolted joints was developed and implemented using the subroutine VUMAT in Abaqus. This model takes into account the real thread structure in the composite bolted joint and simulates the real assembly process by tightening the nut during the calculation. In this model, the friction behavior of the thread contact surface is simulated by the penalty function, and the damage evolution analysis of the intra-face is realized based on the Hashin criterion. At the same time, the interface properties are characterized by cohesive model. The stress and strain field of composite bolted joint in the real assembly process was obtained by this method. The analysis results show that with the continuous of the tightening process, various damage modes will occur, including matrix compression damage, matrix tensile damage and interface damage. Among them, interface damage is the key damage type in the assembly process of composite bolted joints. The stress-strain field and damage obtained by this method can provide accurate initial state for subsequent analysis of the composite bolted joint.

Key words Composite bolted joints; Progressive damage analysis; Cohesive model; Tightening process; Real thread structure

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Poster

Mesoscopic Finite Element Simulation Analysis of Mechanical Properties of Air-entrained Bricks

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Fujian Agriculture and Forestry University

In this paper, by comparing the CT scan images of autoclaved aerated bricks (AAC), the random spherical coordinates of the pores of the air-entrained bricks are generated by MATLAB software, and the elastic-plastic damage model of the aerated bricks is established using the ABAQUS software. By comparing the porosity and pore size distribution of the finite element model and the air-entrained brick products, the corresponding Young's modulus was generated using finite element calculation to study the effect of porosity and pore size on the mechanical properties of AAC.

Key words air-entrained brick; spherical pores; porosity; finite element simulation; mechanical properties

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Poster

Damage Resistance of Helicoidal Laminates with Variable Rotation Angles

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Zhejiang University

The design of impact-resistant composite laminates could be inspired by a biologically Bouligand architecture, stacking unidirectional carbon fibre sheets helicoidally with constant rotation angles between each consecutive ply. Firstly, we chose the prepregs with a cured thickness of 0.141mm to fabricate original helicoidal laminates with constant rotation angles of 9°and 12°, respectively, as shown in Fig. A1. The energy level was determined according to the recommendation from the ASTM D7136 standard that the ratio of impact energy to thickness should be 6.7 J/mm (the calculated impact energies are up to 30J for DH12 and 40J for DH9, respectively). The experimental results indicate that the excessive diffusion of damage inside the original helicoidal configurations dissipates substantial amounts of energy, while the fibre failure is the dominant damage mechanism in the Cross-Ply controls, resulting in lower contact peak force. Then, we propose a cross-helicoidal design strategy by adjusting the relative position of the left-handed and the right-handed rotation units of the original helicoidal counterparts. These cross-helicoidal architectures alter the theoretical out-of-plane stiffness compared to the helicoidal counterparts, resulting in a rather different impact response. Experimental data confirm that the introduction of the cross-helicoidal design significantly improved the impact resistance of laminates, with larger impact peak forces and much smaller projected damage area (see Fig. A2), which is attributed to the fact that the initiation and propagation of matrix cracks are suppressed and delaminations are kept under controlled size. In addition, the cross-helicoidal design has a consistently positive effect on the impact resistance of DH configurations with different rotation angles. These findings demonstrate that the cross-helicoidal design can be a viable approach to improving the impact responses of helicoidal laminates.

Key words Bio-inspired helicoidal laminates; Impact behaviour; Damage resistance

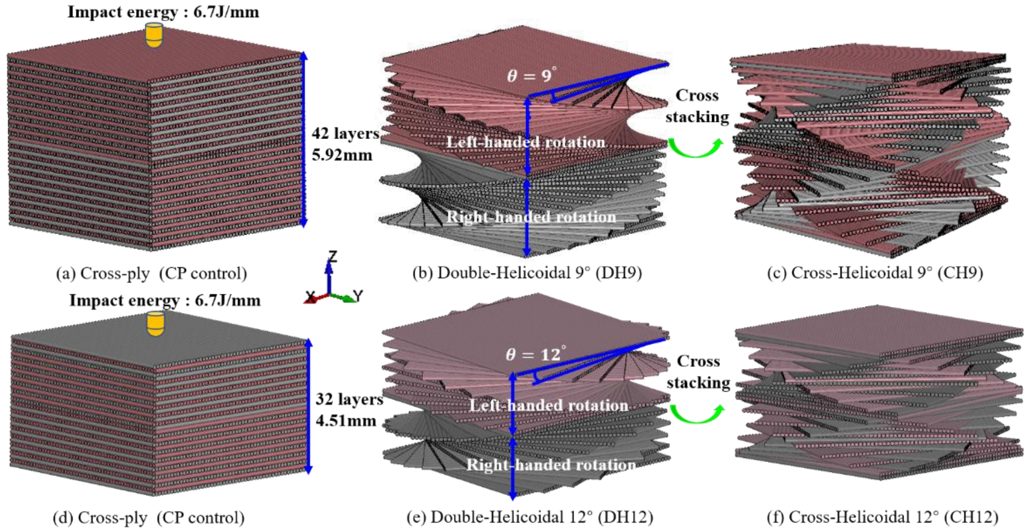

Fig. 1. Computer-generated visualization of six sets of composite lamination schemes.

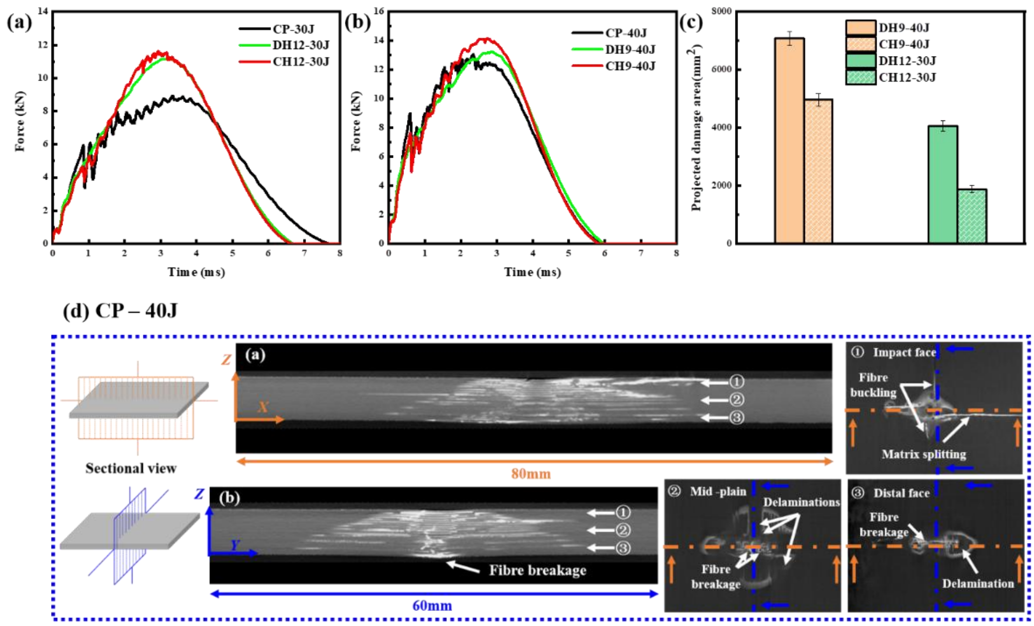

Fig. 2. LVI Force v.s. Time curves for helicoidal configurations and CP controls subjected to impact energy of (a) 30 J and (b) 40 J. Comparison of (c) projected damage area for CH configurations and their DH counterparts. (d) CT-scan image showing the through-the-thickness damage distribution related to the CP control under LVI impact energy of 40J.

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Poster

Buckling, Post-buckling, and Progressive Failure Analysis of Asymmetric Composite Sandwich Panels Under Shearing

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Considering the actual engineering applications, asymmetric sandwich panels with tapered and junction regions are widely used in aircraft structural components to carry in-plane compressive and shear loads. For structure safety, it is necessary to systematically investigate the stability and damage behavior of asymmetric sandwich panels under shearing. Quasi-static shearing tests and numerical modeling were implemented. The simulation results were compared with the experimental results, and a good agreement is achieved, which verifies the reliability and validity of the numerical simulation. Results show that the failure under shearing is initiated by buckling, and the failure mechanisms contains core-skin delamination, fiber breakage, matrix splitting and form core crushing and shearing. The initiation of damage occurs in the slope area of the tensile diagonal line and its vicinity. This is due to that stresses are redistributed after shear buckling, resulting in the high tensile stress on the working skin and an compressive stress on the stabilizing skin. As the shear load increases, the buckling deformation is intensified. The damage accumulates and spreads to panel edges. The progressive damage analysis shows that the matrix cracking occurs firstly, and fiber breakage is followed due to the loss of matrix support. In addition, the thickness of the foam core layer has a significant enhancement effect on the stability of the overall structure. This improves the shear stiffness and the load-bearing capacity of the asymmetric sandwich structure.

Key words asymmetric sandwich structure; buckling failure; progressive damage; shear failure

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Poster

Multi-objective optimization design of surface-conductive lightning strike protection system for CFRP composites

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A dual-layer lightning strike protection (LSP) system consisting of a conductive layer and an insulating layer has demonstrated effectiveness to protect carbon fiber reinforced polymer (CFRP) composites in aircraft against lightning strikes. This study established a design framework for a dual-layer LSP onto CFRP composites. First, an FE model was developed to predict the lightning strike damage on CFRP composites with a dual-layer LSP, and the FE results were validated by simulated lightning strike experiments. Then, the effects of the geometrical and electrical parameters of the dual-layer LSP system on the protective effectiveness were systematically examined. Finally, a multi-objective optimization (MOO) method was established to optimize the geometrical and electrical parameters of the dual-layer LSP system to achieve both high LSP effectiveness and light weight. This work provides understanding and guidance for designing a dual-layer LSP system for CFRP composites.

Key words Lightning strike protection (LSP), lightning strike damage, carbon fiber reinforced polymer (CFRP), multi-objective optimization (MOO)

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Poster

Micro-structure modeling and elastic properties prediction of 3D five-directional and full five-directional braided composites

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As a third-generation fiber-reinforced composite material,3D braided composites have become the preferred material for aircraft load-bearing components due to the fact that the fiber bundles in the reinforcement extend along multiple directions in space and interweave with each other to form an overall network structure,which overcomes the fatal shortcomings of low inter-laminar strength and low delamination resistance of conventional laminated composites.In this paper,based on the motion law of yarn carrier in four-step braiding process,the motion trajectory and spatial direction of yarn in each unit cell area were studied for 3D five-directional and full five-directional braided composites.The inner cell yarn topology of 3D five-directional and full five-directional braided composites were given,and the inner cell model was established based on CATIA platform.At the same time, based on the theory of three-cell model and the idea of homogenization averaging, the elastic constants of 3D five-directional and full five-directional braided composites with braiding angles from 10°to 45°were predicted by numerical analysis method, and the variation of elastic properties with braiding angle and fiber volume fraction were discussed.Static tensile experiments were also carried out.The experimental data agreed well with the simulation results, which verified the reliability of the model.It was found that the inner cell model of the 3D five-directional and full five-directional braided structure exhibits transversely isotropic characteristics, and the braiding angle and fiber volume fraction were the main parameters affecting the elastic properties of the braided structure.The 3D full five-directional braided structure has enhanced the axial tensile properties while maintaining the excellent mechanical properties of the 3D five-directional composite material due to the addition of the axial yarn in the resin-rich region.

Key words 3D five-directional braiding;3D full five-directional braiding;unit-cells model;composite materials;elastic properties

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Poster

Data-mining driven predictability for new materials with causal and correlative relationships

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Hangzhou, PR China 25-28 April, 2023

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Published only

Detailed Optimization design of Composite Laminates Considering the Constraints of Layers‘ Continuity

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An optimal design method for the ply details of composite laminates considering layers’ continuity constraints in different regions is proposed. Based on the autonomous structural analysis software SABRE, the optimization of the total thickness and proportion of the composite laminates based on the engineering criterion method was carried out. The rounding strategy was used to process the optimization results, and the total number of layers and each angle‘s layers of the optimized design were obtained. Considering the layers’ continuity in different regions and linear buckling, based on the Shared Layers Blending process, a ply sequence optimization method based on the SABRE’s composite ply engineering database is constructed, which effectively reduces the difficulty of the laminate ply sequence optimization caused by the introduction of ply continuity constraints. Compared with the traditional optimization technology of composite laminates based on finite element method or genetic algorithm, this paper transforms the complex discrete variable optimization problem into the priority problem based on engineering database. Using the built-in engineering method of SABRE software, the engineering of the layup is quickly realized, which has a certain reference value for the design of the layup of composite laminate structure.

Key words Layers‘ Continuity； Laminate； Layer up sequence； Buckling； SABRE； Engineering database

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Published only

Transverse shear failure behavior analysis of unidirectional FRP with fibre clustering

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National University of Defense Technology

Due to the high specific strength, specific stiffness, and designability, fibre reinforced plastics (FRPs) are widely used in contemporary industrial and aerospace area. From a systematic perspective, factors such as composition, process, manufacturing, and environment all introduce a large dispersion of the properties and have significant impacts on the engineering applications of the FRP, making the mechanical behaviour of FRP structures present a large and complex uncertainty during service. This leads to a conservative design and application of FRP structures, which have to choose the large design margins, severely limiting the efficient application of the FRP. In this study, we investigate the influence of fibre clusters on the transverse shear failure behaviour of FRPs by utilizing the finite element analysis method of computational micromechanics, building a multiscale modelling framework, and conducting virtual tests on the meso-model of FRPs containing different fibre clusters. First, using relevant algorithms, the non-uniform random distribution of fibres with different typical fibre clusters is simulated based on actual microscopic examination of FRP samples; Secondly, the representative volume element model is established through Abaqus and the linear Drucker-Prager plasticity model and the bilinear cohesion model are used to characterize the mechanical behavior of its matrix and interface respectively. To enable accurate model calculation and analysis, periodic boundary conditions are utilized to make the deformation between adjacent models continuous; Based on this, the transverse shear failure analysis was performed to clarify the impact of fibre clusters on the damage initiation and evolution in FRP, serving as a guide for structural analysis and design of FRP.

Key words Fibre clusters; FRP; Transverse shear failure; Damage initiation and evolution; structural analysis and design

Hangzhou, PR China 25-28 April, 2023

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Published only

Mechanism analysis of impact damage of typical reinforced composite panles by hail discrete source

Sicong Han*、Rui Hou、Shan Ren、Chen Zhao
Avic the First Aircraft Institute

To syudy the impact damage characteristics of composite laminates with hail from discrete source. Elastoplastic model were used to construct the constitutive models of hail respectively. Based on the B-K failure criterion of cohesive force interface element for the stiffened plate, the layered failure of the composite material was numerically simulated. By studying the response and damage propagation characteristics under different impact energy and impact angle,and comparing the impact test data of composite laminate hail discrete source impact,the numerical calculation method was compared and verified. The simulation analysis results show that the greater the impact energy of hail is, the closer the impact angle is to 90 degress,the greater the damage responseis. The prediction results of damage response and extension of the simulation method for the impact of hail are close to the experimental results,which can provide a basis for the study of impact damage introduction and impact resistance of composite materials.

Key words composite materials; hail discrete source impact; damage to introduce; impact resistance

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Published only

Research Study on the Buckling Analysis of Multi-spar Composite Structure

Jie Zheng*、Yang Zhao、Kai Du
AVIC thr First Aircraft Institute

In view of lacking the reliable stability analysis method for multi-spar composite box in engineering field, this paper carried out some research work for structural buckling analysis and the theoretical and numerical analysis method were build up separately. By comparing with the physical test results, the following conclusions could be obtained: 1) With the boundary conditions, i.e. simple supported at the two loading sides and fixed supported at the other two sides, or fixed supported at four sides, reasonable buckling loads are available for the multi-spar composite structure. 2) By using the built up finite element models with Buckling solving method in Patran and Abaqus, reliable buckling loads and modes which have a good agreement with the test results can be obtained. 3) The research work in this paper can provide some references for the designing of multi-spar composite structures.

Key words composite, multi-spar structures, buckling, finite element model, theoretical analysis

Session: Optimization Design/ Modeling and Simulation

Presenting Type：Published only

STUDY ON THE CONNECTION PERFORMANCE OF METAL SKIN/COMPOSITE STRINGER STRUCTURE

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Dalian University of Technology

At present, a large number of aircraft use metal skin stringer structure as the main load-bearing structure, and its overall or partial conversion into composite materials has become an important way to reduce the weight of aircraft segments. However, the connection process of composite components and metal components still draws a lot of reference from the mechanical connection form of metal structures, and the standardized design of the connection scheme of composite components and metal structures has not been formed. In order to study the influence of connection modes on the mechanical properties of metal skin/thermoplastic composite stringer structures, the finite element models of bolted, bonded, and hybrid joint structures are established to analyze the failure modes of joints with different connection modes and the load response curves at the loading points, based on which the nonlinear mechanical response of metal skin/thermoplastic composite stringer bearing cylinder is studied. The results show that when the structure is under load, the joint with hybrid connection mode has obvious segmental deformation mode, the adhesive surface failure occurs first, and finally the bolt shear failure occurs. The addition of adhesive technology in the traditional bolting technology can effectively improve the stiffness and ultimate bearing capacity of the structure. Meanwhile, for the metal skin/thermoplastic stringer bearing cylinder structure, the use of hybrid connection mode can suppress the phenomenon of structural instability caused by local buckling caused by single bolted connection, and the introduction of adhesive connection can reduce the use of metal bolts on the premise of maintaining the overall bearing capacity of the structure, and further realize the weight reduction of the structure.

Key words Thermoplastic composites; Connection modes; Finite element analysis; Structural optimization

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Published only

Optimal Design and Non-Parametric Optimization of Composite Reinforced Laminates using Continuous Fiber 3D Printing

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Huazhong University of Science and Technology

This study investigates the optimal ply orientation design of reinforced composite laminates using continuous fiber 3D printing and a parameter-free optimization algorithm. Compared with VAT/AFP processes, continuous fiber 3D printing avoids overlapping and void defects but introduces more variables, making the search for the optimal solution more complex. We apply various optimization algorithms, including self-improving JAYA algorithm, SCA algorithm, GA genetic algorithm, DE algorithm, and some improved JAYA algorithms to solve carbon fiber composite laminates. We use single-ply thickness, fiber trajectory, and rib trajectory as design variables and maximize the buckling load of reinforced composite laminates as the optimization objective. Multidimensional comparison results show that the self-developed JAYA algorithm can maximize the buckling capacity of reinforced composite laminates.

Key words 3D printing; reinforced composite laminates; JAYA algorithm; Maximum buckling load capacity

ACCM 12
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Session: Optimization Design/ Modeling and Simulation

Presenting Type: Published only

The failure study of post-buckled composite single-stringer panel

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1. aircraft strength research institute of china
2. Shanghai Aircraft Design and Research Institute

Non damage and with low-velocity impact damage specimens under uniaxial compression and tension of stiffened composite panel was conducted to study the failure load and failure modes. The interface de-bonding between stringer and skin was simulated by using the Cohesive Zone Model (CZM)in the commercial software ABAQUS. The numerical result is in good agreement with experimental one. The results indicate that: non damage specimen has comparatively large load capacity of the structure after buckling, and the interface de-bonding leads to damage evolution quickly ,the load of crack initial occurred equal to failure load Low-velocity impact damage has significant influence on the buckling load ,failure load,and failure mode. This study further shows that from 10°to 30°angles of stringer run-out the buckling load and failure load gradually increases.

Key words composite; cohesive zone model; post-buckling; panel-stiffener; interface de-bonding

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Published only

Multilevel Optimization Design of BCC Lattice Structure

Tianyi HUANG、Bowen LI、Feng ZHANG、Qihao ZHENG、Peng JIN*
Huazhong University of Science and Technology

The body-centered cubic (BCC) lattice structure, as a widely concerned lattice material configuration, has advantages such as simple topological type and strong designability, but also has the shortcoming of poor impact resistance. In order to explore a lightweight and impact-resistant lattice configuration, this paper proposes an enhanced multilayer body-centered cubic (MBCC) unit cell structure based on the traditional BCC structure, which designs the straight rods in the traditional BCC structure as arc rods described by trigonometric functions. First, the MBCC is parameterized and its equivalent mechanical properties are described by multilayer unit cell parameters including traditional BCC structure parameters and arc rod structure parameters. Then, taking the multilayer unit cell parameters as design variables, taking relative density as constraint, taking initial stiffness maximization and energy absorption efficiency maximization as design objectives, using ideal point method as optimization method, multi-objective optimization design of unit cell structure is carried out. The results show that compared with the traditional BCC structure, the new structure has larger initial stiffness and stronger impact resistance under the premise of keeping relative density consistent with the traditional structure.

Key words lattice structure；MBCC；parametric processing；multi-objective optimization

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Published only

Preliminary application of CAE visualization technology in virtual display of aircraft structure static strength test

Xiaohui WANG*、Xiangyan XU、Liang CHANG、Xiaohua NIE
Aircraft Strength Research Institute of China

As one of the main auxiliary means of aircraft physical test, the virtual test of aircraft strength can realize real-time monitoring and early warning of the test by displaying the test status and response in a high-fidelity virtual manner, and provide technical support for the test command and decision-making, thereby reducing the cost of the test risk. Driven by digital technology and the transformation of computer information technology, the rapid development of CAD/CAE/CAM technology is changing the traditional aircraft design process, and virtual test technology presents the development trend of intelligence, automation and integration. Among them, the deep integration of CAE/CAD technology into the virtual test process has become one of the most extensive technical practices in current engineering applications. Based on the independent CAE graphics engine SABRE-Prepost, the China Aircraft Strength Research Institute adopts the Qt-based multi-threading test data monitoring and processing technology, the OpenGL-based finite element model three-dimensional cloud map fast rendering technology and the Qt-based software graphic interface design based on the model test requirements Technology and advanced high-precision data difference processing algorithm have realized the research and development of the real-time display module of the three-dimensional strain cloud image of the static strength test of the aircraft structure, and applied it in the aviation model test site with remarkable effect, fully realizing the application of CAE technology in engineering deep fusion.

Key words virtual test; real-time display; SABRE-Prepost; Qt multithreading; UI Design

Hangzhou, PR China 25-28 April, 2023

Session: Optimization Design/ Modeling and Simulation

Presenting Type: Published only

A Rapid Prediction Method for Local Buckling of Fuselage Stiffened Panels in Composite Cylinder Sections

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A rapid prediction method for local buckling of stiffened panels of composite tubular fuselage is proposed. Based on the classical nonlinear thin shell theory, the Donnell equation for thin-walled stiffened curved plates with large out-of-plane deformation is given. Using the boundary conditions of the bay surrounded by the frame and the stringer, the displacement function for solving the Donnell equation is established. Based on The Rayleigh-Ritz method, a much more effective solution to deal with the Donnell equation is formulated. On the basis of the domestic independent software SABRE's pre-post processing platform, the procedure of the proposed method is realized. Taking a serial typical composite cylindrical fuselage reinforced wall plate as calculating examples, the method proposed in this paper and the commercial finite element software are used to calculate the local buckling load and buckling waveform of the wall plate. The results show that the method proposed in this paper and the commercial finite element software are well matched, which further verifies the effectiveness of the proposed method. The proposed method can provide a technical basis for the design of the stiffened panels of the composite fuselage.

Key words Composite；Fuselage；Stiffened panels；Local buckling；SABRE

Session: Testing and Evaluations

Presenting Type：Oral-Invited

Novel Testing of Composite and Sandwich Impact and Unique Evaluations Using Dynamic Fracture Mechanics

Luoyu XU*、Luoyu XU
Ningbo University

The present study develops an integrated numerical and experimental method for predicting interlaminar impact damage. A nanoindentation technique for measuring the stiffness properties of composites at a small length scale (nanometers) is leveraged to determine damage to composite laminates due to fast (microsecond) projectile impact. Specifically, nanoindentation is employed to measure the contact stiffness of an indenter and aerospace carbon/epoxy IM7/977-3 laminates with four different stacking sequences. Then, through a technique that combines nanoindentation and computational mechanics, an equivalent impact force approach is proposed to predict the upper-bound of interlaminar impact damage at impact energy levels of 5 and 10 Joules. Drop-weight impact experiments are conducted to validate the prediction results. In practical applications, estimating the upper-bound of damage is important for conservative and efficient damage tolerance designs, especially for thick composite laminates.

In order to provide an in-depth understanding of the basic impact mechanics of composite and sandwich structures, dynamic fracture experiments of bonded polymers to simulate composite interfaces using high-speed photography showed that different static sharp notches formed after the incident dynamic cracks met the composite material interfaces. In one scenario, a dynamic incident crack induced interfacial crack nucleation, and two convex notches formed after the interfacial crack propagated away. In another scenario, the dynamic incident crack kinked at the interface (interface-induced crack kinking), and a “head to tail” crack kinking pattern led to a concave notch with a singular stress field, which should be considered in mechanics modeling. On the contrary, load-induced crack kinking does not cause the above scenarios. A slightly curved/kinked dynamic crack only has a small local crack kinking angle, but its final crack direction was almost 90 degrees with respect to the initial crack direction over a long crack path. These findings partially explained the dynamic crack propagation during composite impact.

Key words interface, impact; dynamic fracture mechanics; nanoindentation, high-speed photography

Session: Testing and Evaluations

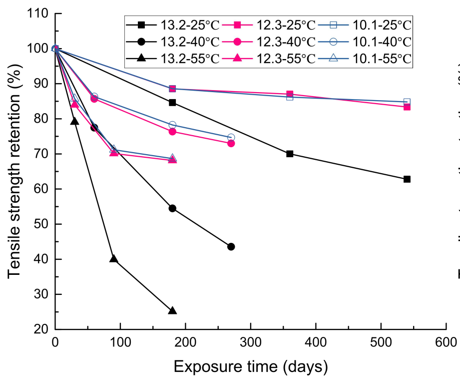
Presenting Type: Oral-Onsite

Tensile properties deterioration of BFRP bars in simulated pore solution and real seawater sea sand concrete environment with varying alkalinities

Deju Zhu*、Deju Zhu*、Yong Yi、Shuaicheng Guo
Hunan University

This study investigates the effectiveness of reducing alkalinity on the durability enhancement of basalt fiber reinforced polymer (BFRP) bars to address their durability in the alkaline environment of seawater sea sand concrete (SWSSC). After accelerated aging at different temperatures and durations, the tensile properties of BFRP bars immersed in simulated SWSSC pore solution and embedded in seawater sea sand mortar (SWSSM) with varying alkalinities were evaluated by tensile testing. In addition, the scanning electron microscopy, X-ray micro-computed tomography, and low-field nuclear magnetic resonance were used to examine the microstructure of embedded BFRP bars and SWSSMs. The experimental results indicate that reducing the pH of the solution and SWSSM to around 12 or below can significantly mitigate BFRP bar tensile strength loss. The maximum improvement of tensile strength retention for bare and embedded BFRP bars are 43.52% and 40.27%, respectively. Compared to BFRP bars wrapped in normal SWSSM, the degradation of resin, basalt fiber, and fiber-resin interface of embedded BFRP bars in the low-alkalinity SWSSMs is considerably mitigated due to the reduced alkalinity and porosity. According to the Arrhenius prediction, the tensile strength retention of BFRP bars embedded in normal SWSSM will decrease to 70% within 1.70-5.10 years, but it will be more than 85% for those embedded in low-alkalinity SWSSMs. Using low-alkalinity SWSSC is effective to mitigate the deterioration of BFRP bars by when BFRP bars are used as reinforcement in marine SWSSC structures. The low-alkalinity SWSSC could be developed by adding high content of silica fume in the cementitious materials.

Key words BFRP; Alkalinity; Tensile strength; Deterioration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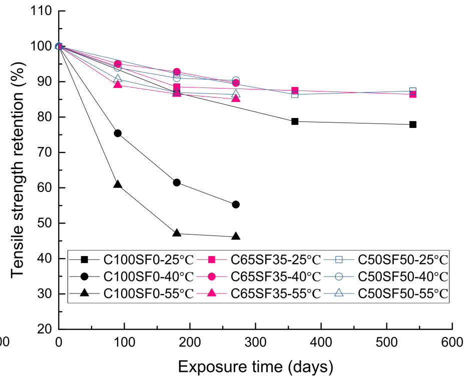
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Session: Testing and Evaluations

Presenting Type: Oral-Onsite

A novel testing method for composite-metal hybrid dihedral wing root spars joint structure

Tiren He*、Jifeng Xu、Jin Guo、Zhiyang Ma、Limin Gao
Beijing Aeronautical Science & Technology Research Institute

The purpose of this project was determining and providing a novel shear test method for composite-metal hybrid wing-root spars joint structure with 11 degrees of dihedral angle of wide-body civil aircraft. The test fixture consists of lateral support, clamping ends, load arm and deformation monitoring settings, which provides the capability to reproduce the loading conditions of the wing root structure in service. Firstly, a lateral support apparatus is installed in the middle of the test structure not only to simulate the real circumstances but also to prevent torsional instability. Secondly, the clamping end with multiple pin-shaft connection and stay bars has been used to eliminate pretentious stress concentration and torsional instability. Thirdly, the strain gauge layout is adequately arranged in a way to properly measure the deformations at joint locations for deducing bearing and bypass loads with high fidelity. In addition, a long cantilever is delicately designed to magnify the moment of force of actuating cylinder capacity. Meanwhile, a finite element model with geometric, material and contact non-linearity has been established to simulate the test process. The load distribution and the failure mode from the simulation agree well with the test results. It demonstrates that both the experimental test and the numerical simulation are cross-validated accordingly.

Key words composite-metal hybrid joint; dihedral angle

Session: Testing and Evaluations

Presenting Type：Oral-Onsite

Monitoring of Bolt Loosening Using Vibro-acoustic Modulation Method

Jianbin Li、Zhen Zhang*
Tongji University

Detection of bolt loosening is of great significance to ensuring the proper structural performance of engineering structures. Mechanisms of nonlinear acoustic breathing behaviors at the joining interfaces of bolted composite joints are analyzed to establish the relation between the remaining torque of the bolt and the acoustic characteristics of the harmonic generation. Moreover, two acoustic indices defined using vibro-acoustic modulation derived from theoretical analysis, are adopted to evaluate bolt loosening through finite element simulation and experiments. Results show that measurable high-order harmonics and sidebands are generated due to contact acoustic nonlinearity at the joining interfaces, and the two nonlinear indices increase with the decrease of remaining tightening force of the bolt.

Key words bolt loosening, stress evaluation, vibro-acoustic modulation, structural health monitoring

Session: Testing and Evaluations

Presenting Type: Oral-Onsite

Modern free-space facility for testing microwave scattering properties of composite materials

Azim Uddin、Faxiang Qin*
Zhejiang University

Automated measurement systems with remote access have become a trend in modern industry. However, the implementation of similar ideas in scientific laboratories still faces many difficulties associated with non-standard system architectures. Our experience in creating an automated microwave laboratory is likely to be of much interest for research groups wishing to implement modern measurement techniques. The free space measurement setup at InCSI of Zhejiang University was assembled in a room partitioned into two parts: an anechoic chamber, covered with conical broadband absorbers, and a control room. In the middle of the chamber is a massive frame for fixing composite samples. It can also accommodate a planar magnetic coil, heating chamber, and tension mechanism to apply external stimuli to the sample under test. The broadband horn antennas (0.5-20 GHz) were mounted on vertical plastic pillars resting on the rail carts. The carts are driven by belt actuators and Kollmorgen servo motors, allowing the distance to the frame to be changed with a maximum movement of around 2.5 m and a resolution of 100 mm. Two motor drivers and a controller have been integrated into the EtherCAT LAN. Rohde&Schwarz vector network analyzer (VNA) and other electronic devices were placed in the control room. A three-stage calibration has been implemented: (i) 2-port error correction of VNA and the short cables connecting it to the multiplexer with two SP6T microwave switches, (ii) de-embedding the six-meter cables connecting the multiplexer to SP4T switches inside of the antenna pillars, and (iii) Response&Isolation and Thru-Reflect-Line (TRL) error corrections for the antennas and free space. The first two stages are fully automatic with switches activated by an Arduino microcontroller, while the third one requires some manipulation of metal screens and absorbers. Also, during TRL precise movement of the antennas is required. The calibration and measurement algorithms, including the movement of the antennas, were implemented in Python with the Node-Red user interface. Using a VNC server and viewer, it became possible to carry out measurements with remote access. The functionality of the system has been demonstrated by measuring S-parameters from glass-fibre reinforced polymer composite samples with ferromagnetic wire inclusions of two types: (i) continuous parallel strings and (ii) short dipoles ordered in parallel. The samples were placed into a planar magnetic coil to tune their scattering properties by controlling the high-frequency surface impedance of the wires.

Key words VNA; Horn Antennas; Free Space Measurements; Multi-Stage Calibration; Lab Automation

Session: Testing and Evaluations

Presenting Type: Oral-Onsite

Ultrasonic Through Transmission Inspection and Identification of Mixed-type Defects in Composite Structures

Andong Cao、zhen zhang*
Tongji University

Carbon Fiber-reinforced Polymer are widely used in aerospace, military, automotive and other fields thanks to their excellent strength-to-weight properties. Due to load matching practical requirements, the applications of large-thickness composite structures with thickness-varying profile are gradually increasing. Such composite structures are prone to producing mixed defects including fiber waviness and porosity during processing, and traditional ultrasonic testing techniques using reflection show great limitations in the verification of the manufacturing quality of composite structures containing mixed defects. In this study, OnScale simulation and ultrasonic water immersion experiments are used to explore the interaction of ultrasonic waves with fiber waviness and porosity, and subsequently clarify the different time-frequency characteristics of ultrasonic waves after interacting with fiber waviness and porosity. A new method using transmission for identifying fiber waviness and porosity is proposed and demonstrate great potentials for industry application.

Key words CFRP; mixed-type defects; ultrasonic; transmission

Session: Testing and Evaluations

Presenting Type: Oral-Onsite

S180

Static strength test and numerical simulation of composite-metal hybrid bolted structure at aircraft wing-fuselage junction

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Complex composite-metal hybrid bolted structure especially that at aircraft wing-fuselage junction is definitely a hotspot for practicing structural optimization design, and their load-bearing performance is a key factor to ensure the safety and integrity of the aircraft. A test scheme is designed for experimental study of a specific hybrid bolted structure which is consisting of metal plates and composite ones jointing together by metal fasteners. To fulfill the large-scale and complicated test, a set of test fixtures is designed to incorporate the large size test specimen of configured panels with three stringers. Then the static strength test is conducted under axial tensile loading. Experimental results show that the static strength of the complex composite-metal hybrid bolted structure is controlled by the jointing metal plate, and the main failure mode is that fracture initiates around critical fasteners and leads to final structural failure in a blink with penetrating disconnection of all plates through the thickness. Meanwhile, a FEM model is established to simulate the test, and the analysis results of the FEM model correlate well with the test ones. Hence, the test method and the simulation model proposed here have demonstrated their suitability, consistency as well as high fidelity in optimization design of hybrid bolted structures.

Key words Static Strength Test; Finite Element Method; Hybrid bolted structure

Session: Testing and Evaluations

Presenting Type: Oral-Onsite

Defect detection system of Aircraft composite structure based on UAV

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2. Wuhu State-Owned Factory of Machining, No.99 Nanyang Road, Wuhu, 24100, China.

Nondestructive damage and defect detection is an important process in the daily maintenance of aircraft to ensure flight safety. The present non-destructive testing (NDT) methods are either complex and inflexible or time-consuming, which are difficult to achieve rapid and accurate testing of an aircraft. In this research, the deformation and defect detection method based on fast and high-precision 3D-reconstruction as well as the infrared-based NDT method are integrated onto the UAV platform. Through flexible and rapid photographic analysis, the near-surface internal defects and surface deformation defects of the aircraft composite structure can be detected accurately and in real time. First, a deep-learning-based high-precision speckle correlation algorithm is proposed to perform 3D reconstruction. The accurate pixel displacement calculation under large disparity is obtained through the proposed two-times interpolation method. In addition, an invisible speckle marking method is proposed to realize feature marking without affecting the appearance of the aircraft. Second, a micro-sized and low-power active thermal excitation system suitable for the UAV platform is designed, which is combined with the infrared camera as the thermal NDT system. Finally, the above two NDT systems are deployed on the UAV platform to achieve flexible, real-time and accurate non-destructive testing of aircraft composite structures.

Key words NDT; Aircraft composite structure; UAV platform; 3D reconstruction; Infrared

Session: Testing and Evaluations

Presenting Type: Oral-Onsite

Analysis of torsion failure behavior and its characterization of carbon fiber monofilament

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2. Research Institute for Frontier Science, Beihang University

Carbon fiber (CF) reinforced plastics are widely applied as structural materials. As CFRP is subjected to axial tension and compression load, it also faces a great challenge of the out-of-plane load. Therefore, the evaluation and failure analysis of torsion behaviors of CF are significant in practice. In this work, monofilament torsion test was used to characterize torsion properties of three types of CFs, i.e. normal-modulus CF300, middle-modulus CF800 and high-modulus CF40. The twisted fracture angle and the breakage elongation of CF300, CF800 and CF40 under torsion were 1.54, 3.60°, 2.15 and 0.36‰, 1.99‰, 0.71‰ respectively. According to the Raman peak analysis, AD/AG is referred as the degree of graphitization and the crystallite La is referred as the crystallite structure. The AD/AG and La of CF800 with the best tensile elongation showed great structure changes after torsion while the CF300 and CF40 changed little, which was corresponding to the torsion behavior. Furthermore, the failure mode was observed by the SEM images. The characterization indicates that torsion treatment on monofilament can evidently impact the crystalline structure of the middle-modulus and high-strength CFs, while polishing has more influence on the structure of normal-modulus and high-modulus CFs.

Key words carbon fiber; torsion properties; monofilament; Raman spectroscopy

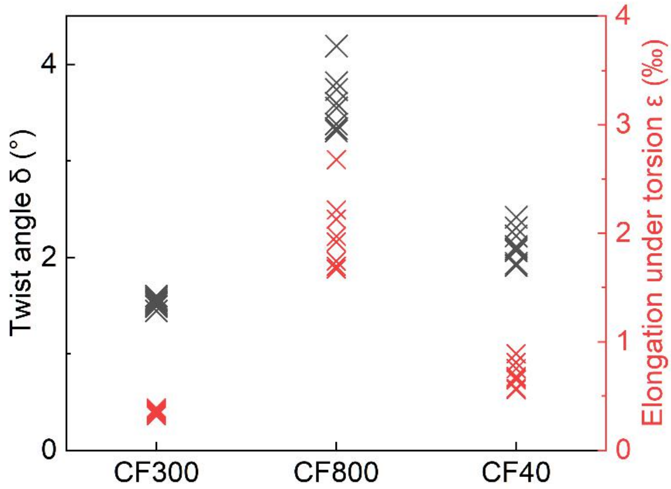

Fig. 1. The torsion properties of three kinds of carbon fibers

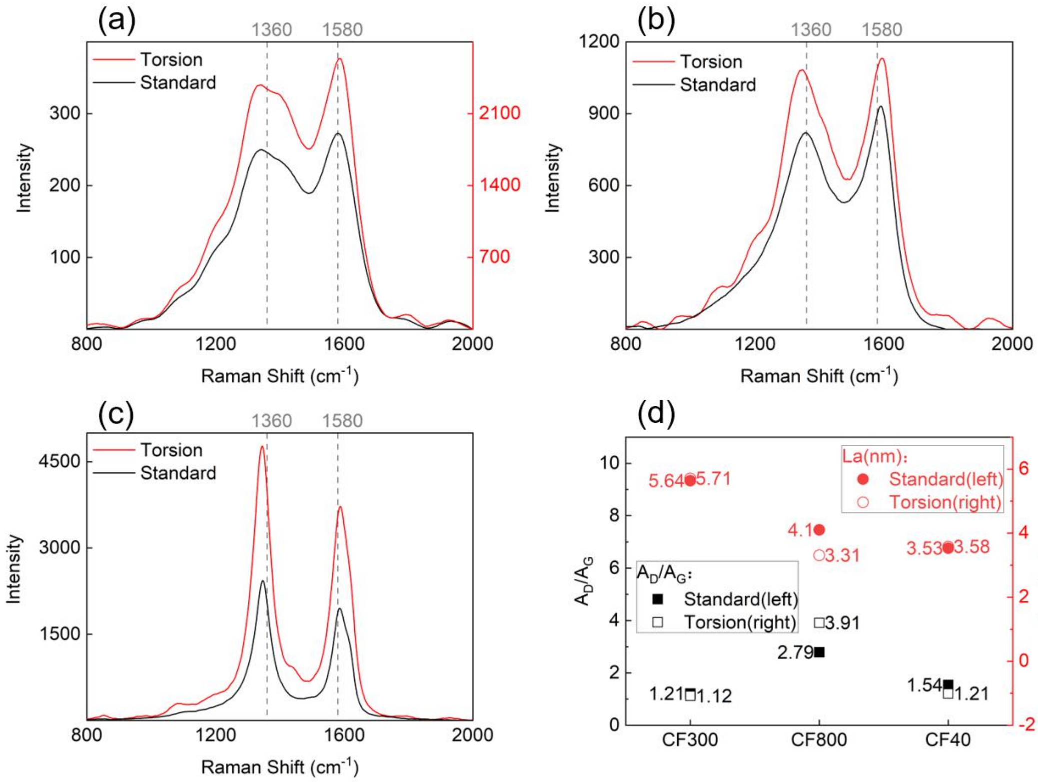

Fig. 2. The Raman spectra of (a)CF300, (b)CF800 and (c)CF40 in standard condition and after torsion and (d)the structure information probed from Raman spectra

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Session: Testing and Evaluations

Presenting Type: Oral-Onsite

Test methods for the interlaminar delamination properties of CFRP laminates

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2. Hebei University of Technology

Advanced carbon fiber composites are more and more widely used in aerospace and other fields. Composite laminated structure is one of the commonly used configurations, but due to the weak interlaminar properties, it is easy to produce delamination damage. The occurrence and propagation of delamination will seriously affect the load-bearing capacity and safety of the structure, and become the focus of attention in the design of laminated structures. Accurate characterization of delamination behavior of composite laminates is the basis of damage propagation behavior and strength analysis of composite structures with delamination damage. Interlaminar fracture toughness is usually used to characterize the delamination resistance of composite laminates. It is very important to develop effective testing methods for interlaminar mechanical properties to predict the delamination propagation behavior in composite structures. At present, the international standards for testing the delamination properties of unidirectional composite laminates have been established. However, multidirectional laminates are widely used in engineering structures, and the corresponding test methods should be extended to multidirectional laminates. The delamination mechanism of multidirectional laminates is much more complex than that of unidirectional laminates, which makes the establishment of corresponding standards face many challenges. Therefore, the recent research progress of our group in the testing methods of static and fatigue delamination properties of carbon fiber composite laminates are introduced here.

Key words Composite laminate; Delamination; Fracture toughness; Fatigue delamination growth.

Session: Testing and Evaluations

Presenting Type：Oral-Onsite

Ultrasonic Detection and Identification of Hybrid Defects in Complex-Shape Composite Structures

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Tongji University

To meet the aerodynamic-shape and load-matching requirements, aerospace composite structures usually adopt ply-drop layout to form a thickness-varying profile. The complex molding process makes it difficult to control the product quality, and ultrasound testing is usually adopted to inspect the defects such as pores, fiber waviness, and delamination generated after manufacturing. In this study, OnScale simulation and water immersion ultrasonic testing were used to explore propagation behaviors of ultrasonic waves in composites with complex microstructures, revealing the uncertainty of ultrasonic defect inspection caused by fiber waviness. Linear and nonlinear ultrasonic characteristics of various defects were subsequently clarified. Based on the finite element simulation and experimental results, novel methods for identifying delamination and fiber waviness using frequency-dependent reflections and ultrasound non-reciprocity were proposed. This study is expected to contribute to the detection and identification of mixed-type defects in large-thickness complex composite structures.

Key words Composite Structures; Fiber Waviness; Delamination; Porosity; Defect Identification

Session: Testing and Evaluations

Presenting Type: Oral-Onsite

Prediction of the crack behavior of CFRPs in Mode I tests based on GRU model

Xiaoying Cheng*、Jinghua Ying、Zhenyu Wu
Zhejiang Sci-Tech Univeristy

Non-destructive testing techniques have gained more attention in the application of damage prediction in fiber reinforced composites. In this work, a delamination prediction model based on Gated Recurrent Unit (GRU) with acoustic emission (AE) is proposed to monitor the degradation process of carbon fiber reinforced plastic (CFRP) composites. Firstly, 29 features of the raw AE signals captured in Mode I tests of CFRPs were extracted, including the time domain, frequency domain, and time-frequency domain, the time-frequency domain features are obtained by the wavelet packet to obtain the energy percentage of each node in the last layer, and the feature evaluation algorithm was used to filter out the insensitive features. Secondly, a GRU delamination prediction model was constructed and the effect of the AE signal length in the input sequence on the prediction accuracy was investigated. Finally, the proposed model was compared with the Recurrent Neural Network, Long Short-Term Memory, and Gradient Boost Regression, the results showed that the GRU model has higher prediction accuracy and requires less training time, which could provide a feasible way to quantify the performance degradation process of the CFRPs.

Key words Mode I test, acoustic emission, carbon fiber reinforced plastic, gated recurrent unit

Hangzhou, PR China 25-28 April, 2023

Session: Testing and Evaluations

Presenting Type: Oral-Onsite

Damage Evolution Analysis of C/SiC Composite under Biaxial Compression Based on Acoustic Emission

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Ceramic matrix composite are important candidate materials for the thermal structures of hypersonic aircrafts. The damage behavior under complex stress conditions is the key factor affecting the service performance of the structure. In the real service environment, damage modes of ceramic matrix composites are complex, and it is difficult to identify multiple damage modes under complex stress state by traditional monitoring methods. Acoustic emission (AE), as a monitoring method that can correlate the signals with the material damage mechanism, can realize the real-time online monitoring of ceramic matrix composites damage. In this study, AE technology is used to monitor the damage information of satin braided C/SiC in the biaxial compression test. Pattern recognition of the AE signals was realized by using the principal component analysis (PCA) and the fuzzy C-means clustering algorithm (FCM). Moreover, according to the AE feature parameters of the cluster centers, four classes of AE signals were mapped as matrix cracking, delamination damage, interfacial damage and fiber breakage. Then the evolution of various damage modes was described. The research shows the damage evolution includes 5 stages: (1) linear elastic stage with no damage occurs, (2) damage initiation with matrix cracking and delamination as main damage modes, (3) serious damage occurs with a large amount of delamination and fiber breakage events, (4) all kinds of damage develop stably except fiber breakage, (5) last failure stage with active fiber breakage events. AE pattern recognition technology helps to fully understand the failure process of C/SiC under biaxial compression. It also provides a potential failure warning method.

Key words acoustic emission; carbon/silicon carbide; biaxial compression; pattern recognition; damage evolution

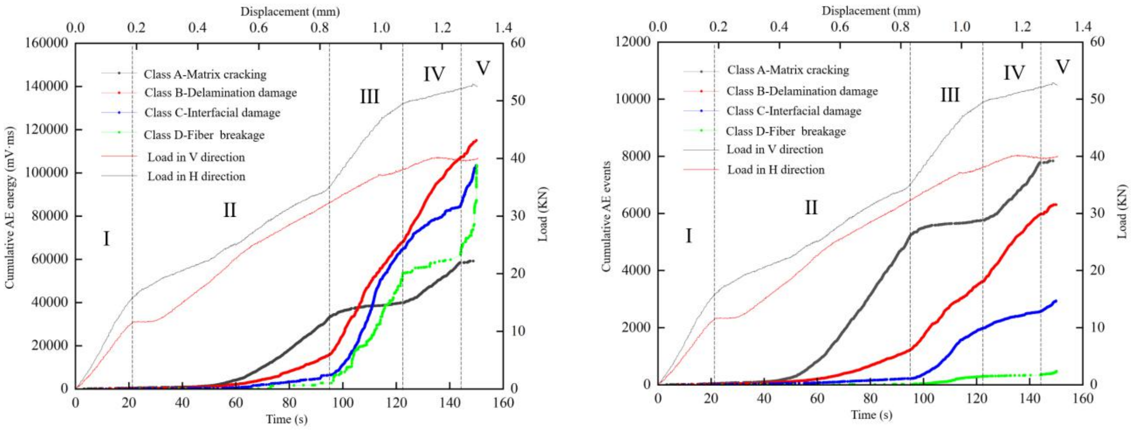

Fig.1. Cumulative AE energy and cumulative AE events with time

Session: Testing and Evaluations

Presenting Type：Oral-Onsite

Micromechanical Finite Element Analysis of the Transverse Mechanical Behaviour of Fibre-reinforced Thermoplastic Composites

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Northwestern Polytechnical University

In this study, transverse tension and compression tests of unidirectional AS4/PEEK composites were conducted. The fracture surfaces and failure micromechanisms were investigated using SEM method. Transverse tension failure was induced mainly by matrix plastic deformation, matrix cracking and interface debonding. Ductile fracture of the matrix was observed by matrix fractography study. Failure modes of transverse compression includes matrix shear and interface failure. A three-dimensional representative volume element (RVE) model containing randomly distributed fibres was developed based on the micro structural features of unidirectional AS4/PEEK composites. The fibre was considered as an isotropic material. The constitutive behaviour of the thermoplastic matrix was simulated by means of Gurson-Tvergaard-Needleman (GTN) model to represent the ductile fracture and micro-void nucleation and growth process. The interface between fibre and matrix was modelled by cohesive zone model (CZM) to express the progressive interface decohesion. Periodic boundary conditions were applied on the edges of the RVE. Simulations of transverse tension and compression were carried out with Abaqus. Results show good correlation with experimental stress-strain relationships.

Key words Thermoplastic composites, plastic deformation, ductile fracture, computational micromechanics, damage mechanics

Session: Testing and Evaluations

Presenting Type: Oral-Onsite

Experimental analysis of sealing leakage rate and tensile strength for wet-assembly hybrid bonded/bolted single-lap joints under fatigue conditions

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Northwestern Polytechnical University

Wet assembly hybrid bonded/bolted (HBB) joint as a newly designed connection method is gradually applied in composite integral fuel tank structures and as an important process parameter, bolt-hole clearance has been paid more and more attention by process designers. The mechanical and sealing performance for three kinds of bolt-hole clearance HBB joints was investigated by tensile test and helium mass spectrometer test using independent designed measuring fixture. Otherwise, in order to compare the fatigue resistance of HBB joints and interference-fit joints, tension fatigue test was conducted for the four kinds of specimens and the change tendency of leakage rates and microstructure damage modes were explored and analyzed in this paper. The results show that the load-displacement curve of HBB joint displayed a special form of double wave peak and among the three kinds of joints, 0.05mm bolt-hole clearance adhesive layer HBB joint presents the best tension and seal performance. The maximum load of 0.05mm adhesive layer is 12.6% and 6.3% higher than 0.0mm and 0.3mm adhesive layer, respectively. The initial leakage rates of 0.03mm and 0.05mm adhesive layer HBB joints are in the '-9' order of magnitude, while 0.0mm adhesive layer HBB joint and interference fit joint are in the '-6' and '-8' order of magnitude. After tension fatigue test, the leakage rate of 0.05mm adhesive layer HBB joint grows most slowly and the final result is 93.1% and 34.5% less than interference-fit joint and 0.03mm adhesive layer HBB joint, respectively. Compared with microstructures before tension fatigue test, the damage modes of HBB joints display a large area of adhesive layer failure after test, containing voids and unstick.

Key words Composite integral fuel tank, sealing leakage rate, hybrid bonded/bolted joint, clearance-fit adhesive layer, tension fatigue.

Session: Testing and Evaluations

Presenting Type: Oral-Onsite

The“cumulative”effect of second harmonic Lamb waves in composite plates for incipient damage monitoring

Shengbo Shan*[1]、Liaoliao Cheng[1]、Yang Song[2]、Li Cheng[2]、Pan Yongdong[1]
1. Tongji University
2. The Hong Kong Polytechnic University

Monitoring of incipient damage in composite structures before initiation of any macro defects is of paramount significance to facilitate their safety and maintainability. Structural health monitoring based on nonlinear guided waves shows great promise for incipient damage monitoring applications. Existing work shows that cumulative second harmonic Lamb waves can be generated subject to the non-zero power flux and phase matching conditions, which is conducive to damage monitoring in terms of wave measurement. However, due to the high damping of composites and Lamb wave beam divergence, the amplitude of primary Lamb waves attenuates during propagation, which significantly affects the cumulative effect of the second harmonic Lamb waves. This work proposes a theoretical model to characterize the cumulative effect of second harmonic Lamb waves in composite plates, which is further validated by finite element simulations. Specifically, the Kelvin-Voigt model is embedded in the material nonlinear stress-strain relation to simulate the material damping while the wave beam divergence is tuned by varying the size of the wave excitation zone. Results show that the amplitude of second harmonic Lamb waves generally increases first and then decreases with respect to wave propagating distance. This indicates the existence of a “sweet” position corresponding to the maximum second harmonic Lamb waves. Meanwhile, it is demonstrated that the proposed model enables precise prediction of the “sweet” position in cases with different material damping and wave beam divergence. Experiments are conducted to monitor thermal-aging-induced incipient damage in a composite plate based on the theoretically-predicted “sweet” position for nonlinear Lamb wave measurement. Through comparing the linear and nonlinear signals before and after the introduction of damage, it is confirmed that the second harmonic Lamb waves are indeed much more sensitive to incipient damage than their linear counterparts.

Key words Structural health monitoring, incipient damage, nonlinear Lamb waves, cumulative effect, wave attenuation

Hangzhou, PR China 25-28 April, 2023

Session: Testing and Evaluations

Presenting Type: Oral-Onsite

Real-time damage localization method for anisotropic composite materials based on acoustic emission technique

Jiayin Liu[1,2]、chao li[1]、zixi li[1]、xinxin yan[2]、wenduo chen[1]、dazhi jiang*[1]
1. Sun yat-sen university
2. Shenzhen Institute of Comprehensive Particle Facility

Carbon Fiber Reinforced Composites (CFRP) are composed of various components coupling with each other, causing complexity and unpredictability of the damages, for which a reliable monitoring method is necessary. Acoustic emission (AE) technology is developing rapidly, which has been widely applied to detect and localize damages in real time according to the acoustic velocity and the signal receiving time by the probes. Current 3-point localize techniques can only guarantee the damage localization accuracy in isotropic materials. However, composite materials exhibit obvious anisotropy, the acoustic velocity is influenced when propagating through anisotropic media, proposing great challenges to the localization technique. To solve the above problems, a new acoustic emission localization method was developed in this paper. Firstly, the elastic wave velocities in various orientations in two-dimensional CFRP were measured by two probes of AE, the data was then fitted by a function to form an anisotropic elastic wave velocity model. The multi-point localization method was designed to localize the damage source in two-dimensional anisotropic plates with plane surface by substituting the received signal data into the theoretical elastic wave velocity model, meanwhile, Monte Carlo method combined with mutual-correction method by multi-probe data was put forward to improve the localizing accuracy. The method was then extended to curved surface of a cylindrical shell structure, and the damage localizing accuracy was verified by lead pen breaking experiments. The results showed that the anisotropic multi-point acoustic emission localization technique greatly improved the localization accuracy with the error reduced by more than 60%, compared with the traditional ones. This method is expected to form a widely applicable engineering technique of real-time nondestructive testing in the future, which will provide a guarantee for the reliability of the composite structures.

Key words carbon fiber reinforced composites; real-time damage localization; anisotropy; acoustic emission technique

Session: Testing and Evaluations

Presenting Type: Oral-Onsite

Classification and Quantitative Evaluation of Pulsed Terahertz Based on Artificial Neural Network for Defects in Glass Fiber Reinforced Composites

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1. Northwestern Polytechnic University
2. Northwestern Polytechnical University

With the wide use of glass fiber reinforced polymer (GFRP) in aviation and space flight, it is important to detect the quality of the internal defects. In this work, we report a new method for classifying GFRP delamination and inclusion defects and predicting defect depth based on terahertz time-domain spectral signal analysis with neural network. Three machine learning algorithms were adopted to set up models to achieve this goal, including the classical back-propagation (BP) neural network algorithm, the novel extreme learning machine (ELM) algorithm and the one-dimension convolutional neural network algorithm. New set of features in time, frequency and wavelet domains is proposed and verified. By optimizing the terahertz detection feature set, the delamination and inclusion defects in samples were detected by using neural network intelligent recognition algorithm, thus realizing the intelligent recognition of internal defects in samples. Results show that in general the one-dimension convolutional neural network model outperforms the Bp neural network and the ELM. The corresponding recall rates are above 0.85 and can reach 0.98, and the macro F1 score is larger than 0.90. The automatic detection and classification of defects can effectively reconstruct the terahertz images showing the location and depths of internal defects. We forecast that this work will drive the development of automatic nondestructive defect detection based on terahertz technology and neural networks.

Key words Defect inspection; Non-destructive testing; Terahertz time-domain spectroscopy; Neural networks; GFRP

Hangzhou, PR China 25-28 April, 2023

Session: Testing and Evaluations

Presenting Type：Oral-Onsite

Numerical Analysis Method of Butt Connection Strength of Composite Stiffened Panels with Impact Damage

Jingchao WEI*、Tianjiao QU、Hui ZHANG、Linan CHENG、Xiangming CHEN
Aircraft Stength Research Institute of China

The aircraft fuselage structure contains a large number of wall panel butt connection designs. Due to the impact of foreign objects such as runway stones, hail, and maintenance tools, it is easy to cause different degrees of impact damage to the fuselage structure, thereby affecting the strength of the aircraft structure. In this paper, the structural strength test and numerical simulation analysis of the butt area of the composite panel with impact damage are carried out. Based on the assumption of material stiffness reduction in the delaminated region caused by impact damage, a finite element model analysis method is proposed. In the model, the Puck criterion is used to describe the failure of composite materials, and the failure of the adhesive layer between the skin and the girders is simulated based on the bilinear cohesion element model. In order to verify the validity of this method, a physical test verification study was carried out. The results show that the numerical analysis results proposed in the paper are consistent with the physical test results, and the error is less than 5%.

Key words Butt Connection Strength; Composite Stiffened Panel; Impact Damage; Numerical Analysis Method

Session: Testing and Evaluations

Presenting Type：Oral-Onsite

Novel Testing of Composite and Sandwich Impact and Unique Evaluations using Dynamic Fracture Mechanics

Yiwei Zhang、Weiling Zheng*、Jiangbo Dang
Power and Energy, Northwestern Polytechnic

Based on the feature that BP (Back propagation) neural networks can handle multivariate non-linear models, a neural network model was constructed to predict the fatigue life of composite unidirectional plates. Experimental values were used as the dataset and parameters related to the off-axis direction were calculated and considered as new features, enriching the variety of materials in the dataset to help improve the BP neural network model training. The number and number of nodes in the hidden layer of the network was determined using empirical methods, and four metrics were identified to assess the training effectiveness and accuracy of the BP neural network. The analysis of the training results shows that the use of BP neural networks to predict the fatigue life of composite unidirectional plates has good results, but the training accuracy has a certain relationship with the network structure, in order to ensure the training accuracy, the data in the training set should be made to contain a wider range. The use of BP neural network algorithm provides a way to study the fatigue life of unknown materials in engineering.

Key words Composite materials，Fatigue life，Off-axis performance，BP Neural Networks

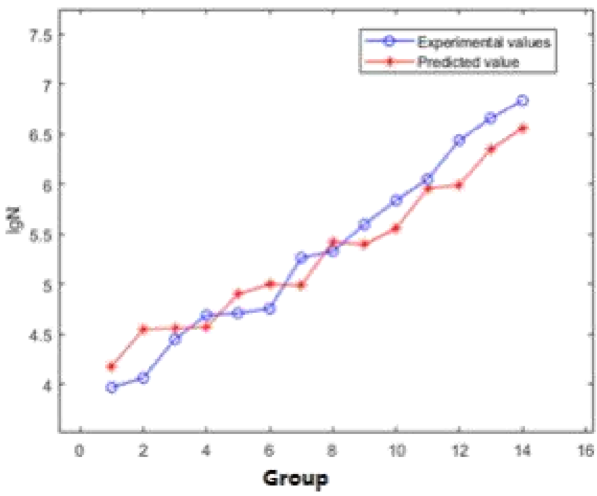

Fig. 1. Comparison of predicted and actual values forE1=66.52GPa material

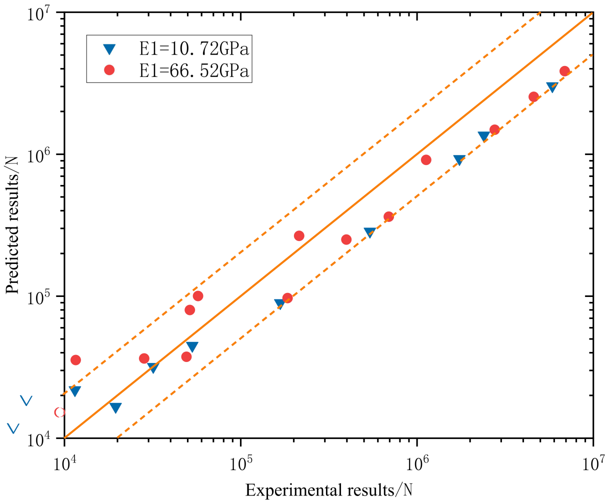

Fig. 2. Neural network training values and experimental values 2-fold dispersion band

Session: Testing and Evaluations

Presenting Type: Oral-Virtual Platform

The"cumulative"effect of second harmonic Lamb waves in composite plates for incipient damage monitoring

Wei Siang SUM*
PETRONAS Research

Ultrasonic testing (UT) is a non-destructive test often used on composite components or structures to detect defects or anomalies. However, the main challenge for UT of multi-layered, fibre-reinforced components are the high attenuation and scattering of ultrasonic waves, which cause difficulties in accurately identifying and measuring anomalies within the material.

This paper investigates the application of UT to detect embedded anomalies within multi-layered systems consisting of layers of polyethylene and fibre-reinforced polyethylene. This covers the method of producing the composite panels with embedded anomalies, the UT method and the design of experiment (DOE) analysis to optimise the settings.

A phased-array UT system is used to scan the panels, and the study covers a transducer frequency range of $2f_o$ to $4.5f_o$ MHz and E to $2E$ number of firing elements, which represents the aperture size. The DOE analysis covers multiple responses to the two main variables, focusing on the dimensional accuracy of the embedded defects in the panels. There are four responses, namely the differences between ultrasound measurements and mechanical measurements using a caliper for the x, y and z dimensions of the anomalies respectively, and the magnitude of noise factor, K, which represents the noise in the detected ultrasound signals.

The study shows the combination of UT variables that give the best accuracy in detecting the size of the anomalies and with minimal noise in its signal.

Key words non-destructive test, ultrasonic test, polymer, anomalies, defects

Session: Testing and Evaluations

Presenting Type: Poster

The research on the detection technology of a honeycomb sandwich panel structure

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Aircraft Strength Research Institute of China

According to the structural characteristics of a honeycomb sandwich panel and the types of defects easily produced by this kind of structure, the detection technology based on ultrasonic detection method and ray detection method is developed, which can accurately detect all kinds of defects of honeycomb sandwich panel structure, and is suitable for laboratory and field in-situ detection.

Key words honeycomb sandwich panel;detection technology

Session: Testing and Evaluations

Presenting Type: Poster

Compression shear test technique for flat panel of composite material

Chong Li*
AIRCRAFT STRENGTH RESEARCH INSTITUTE OF CHINA

The stability of fuselage panels under combined compression and shear loads has always been an important issue in fuselage strength research. In recent years, because of its high specific strength and good fatigue performance, composite materials are increasingly used in aircraft structures. In the selection stage of composite fuselage panels, the curved fuselage panels are usually simplified into flat panels for pressure shear tests. In the past, the box composed of flat plates were loaded by bending and torsion. In order to reduce costs and improve efficiency, now they are mostly tested by special pressure shear devices. The compression load and shear load are loaded separately. The two loads are applied independently and do not interfere with each other, One installation can realize the buckling load test with any compression shear ratio, and its superposition error is within 3%. It can also constrains the outer normal direction of the skin at the end of the frame, releases the degrees of freedom along the compression direction and shear direction, and simulates the support state under the whole frame, which is more realistic and effective than the previous support of simulating steel ribs in panel compression.

Key words compression and shear loads, composite materials, fuselage panels, flat panels, end of the frame, degrees of freedom

Hangzhou, PR China 25-28 April, 2023

Session: Testing and Evaluations

Presenting Type: Poster

Off-axis tensile properties of UHMWPE Fiber Composites

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Ultra-high molecular weight polyethylene (UHMWPE) composites are frequently used in ballistic impact applications, and the multi-axial stress conditions occurs during impact. This paper presents detailed experimental characterization of the off-axis tensile properties of UHMWPE fiber reinforced composites. Compared with the uniaxial test, the off-axis test data can be used to deduce the interaction term of Tsai-Wu strength criterion. The off-axis tensile coupon also possesses the potential for relatively inexpensive determination of biaxial strength properties of composite materials. This further can be used to predict the strength of composites under biaxial stress accurately and conveniently. The slipping failure often occurs firstly due to the low friction coefficient of the material in the test regarding the very low matrix volume fraction. Therefore, the dog-bone specimen is used in this paper and both ends are clamped. After measuring its basic mechanical properties, the off-axis tensile test is selected to determine the strength parameter F_{12} in the strength criterion. To obtain the specimen with high stress level in the test area and low stress concentration in the transition area, the shape design and parameter optimization of the specimen are carried out by numerical simulation, the strength parameter F_{12} calculated from the test data is used to fit the failure initiation envelope of the material stress plane. The results show that the Tsai-Wu strength envelope modified by the test data can reflect the strength characteristics of the material compared to experienced data regarding the specific UHMWPE Fiber Composites, which further fills the material database.

Key words failure criteria; off- axis tension; failure envelope; UHMWPE Fiber Composites

Session: Testing and Evaluations

Presenting Type: Poster

Ultrasonic guided wave-based fatigue damage pattern recognition of composite open-hole beam

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The fatigue damage modes of composite open-hole structures are diverse and complex, especially influenced by the angle of the layup. As a common method for damage pattern recognition of composite materials, acoustic emission (AE) technology has the limitations of passive monitoring and channel, and its damage clustering results are difficult to reflect the reverse problem of multiple damage patterns. In this paper, the evolution behaviors of fatigue damages in composite open-hole beams with different layers are studied using ultrasonic guided waves (UGW) in a way of real time and active monitoring. The UGW signal features mining method based on K-means unsupervised clustering and support vector machine (SVM) supervised learning is proposed to recognize the fatigue damage pattern. A multi-source sensing systems with AE, UGW and high-speed cameras were built to obtain damage evolution information in the tensile fatigue test. The acoustic emission method was used for verification, while the high-speed cameras were used to record the damage evolution process throughout the test. Then, the guided wave signals were collected as baseline signal before the test loading, and the damage signals of guided waves in the state of online load holding and off-line unloading were collected under several specific fatigue cycles. The damage sensitivity characteristics of guided wave and AE signals were analyzed respectively and K-means unsupervised damage clustering was performed. The clustering results show that the ultrasonic guided wave technology can be used to identify the fatigue damage pattern of composite open-hole beams. Furthermore, the proportion of damage modes under different fatigue cycles obtained by K-means clustering was used as the supervised learning label of SVM to establish the model. The test set prediction results show that the SVM supervised learning strategy based on K-means unsupervised clustering can truly recognize various damage patterns contained in specific damage sensing signals.

Key words Damage pattern recognition, ultrasonic guided waves, fatigue damage, composite open-hole beam, K-means unsupervised clustering, support vector machine

Session: Testing and Evaluations

Presenting Type: Poster

Post-impact static strength prediction of fiber metal hybrid composites based on digital image correlation

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Harbin Institute of Technology

Fiber metal hybrid composites integrating the merit of metal and fiber-reinforced plastic have high specific strength, excellent resistance to fatigue and impact. However, in engineering applications in the field of transportation such as aeronautics, the structures inevitably suffer from external damage, which leads to the deterioration of the mechanical properties of the material. Therefore, how to efficiently evaluate the damage tolerance and assess the effect of impact on the mechanical properties of fiber metal hybrid composites is an urgent issue. In this study, an isostrain elasto-plastic model considering internal thermal stress and impact dent geometry based on digital image correlation is proposed to predict the post-impact static strength of fiber metal hybrid composites. The predicted results of static strength and failure strain correspond well with the experimental data. In addition, the proposed model can also be employed for fiber metal hybrid composites with different fiber orientations, layup structures, and thicknesses of components to predict the post-impact tensile/compressive stress-strain relations, which can significantly reduce the experimental cost and provide guidance for structural design and engineering applications.

Key words Fiber metal hybrid composites; post-impact static strength; digital image correlation

Session: Testing and Evaluations

Presenting Type: Published only

Thermal/mechanical behaviors of fastened hybrid composite/metallic structure

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Aircraft Strength Research Institute of China

Extreme climatic conditions, such as high temperature, low temperature and hydrothermal environment, affect the bearing performance and life expectancy of composite and metal hybrid structural components in aircraft, which has a great impact on the flight performance and safety of aircraft. Due to the large coefficient of thermal expansion mismatch between the composite and metallic structures, the temperature change in the actual flight condition induces high thermal stresses in both the composite components and metallic components. This additional stress would alter load transfer and internal stress distribution in fastened hybrids of composite and metallic structure. Thermal/mechanical behavior of the large-scale, multi-joints hybrid composite/metal structure was investigated experimentally in different temperature conditions, as well as bearing axial load under different temperatures. The internal stress distribution of different components and fasteners in hybrid composite/metal structure under different temperature/load conditions was obtained by the strain gauge method.

Key words hybrid structure; temperature effect; thermal stress; experimental investigation

Session: Testing and Evaluations

Presenting Type: Published only

Study on nail load distribution ratio of composite - metal lap joint

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Multi-nail connections are a common connection method for aircraft composite structures to metal structures. These connection details are the weak points of aircraft structures and figuring out the load transfer ratio of each fastener is the key to structural strength calibration and weight reduction. The load distribution ratio of each row of nails is calculated using an empirical formula based on test strain data for the single shear structure with multi-row nail connection of composite thick plate and metal strip plate, and the results are compared with those obtained using an engineering calculation method. The findings demonstrate that the empirical formula, which is based on strain data, can calculate the load distribution ratio of multiple rows of nails. The empirical formula is easy to use and accurate enough to be used for preliminary strength analyses of composite material-metal lap joints in aircraft structures.

Key words aircraft structure, composite materials, lap joints,pin-load distribution, strain data

Session: Testing and Evaluations

Presenting Type: Published only

Study on Comprehensive Testing Technology of Composite Curved Plate

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The aircraft fuselage structure is composed of various forms of stiffened curved panels, and is the main load-bearing component of the fuselage structure, which accounts for a large proportion in the whole building block strength test process. In aircraft development, the stability, durability and damage tolerance of stiffened fuselage panels under single or combined tension/compression, bending, shear, airtight loads are usually considered, A large number of tests of wall panels under the combined action of multiple loads are required. For this reason, a series of technical research and device development work have been carried out. The self balanced loading system is adopted, and each load is relatively independent. The tension/compression, shear, and airtight loads of curved plates are single or combined, and each load is decoupled from each other without interference. The straight edge boundary of the curved plate is constrained by a V-shaped frame, which truly simulates the cylindrical boundary, and each joint is equipped with an anti instability device, which effectively prevents the instability of the free edge.

Key words curved panels，multiple loads

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Testing and Evaluations

Presenting Type: Published only

Experimental study on compressive strength of composite stiffened curved plate after repaired

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The proportion of composite materials in the airframe has become an important index to evaluate the progressiveness and market competitiveness of aircraft to some extent. In recent aircraft models of Boeing, Airbus and other companies, composite materials have been successfully introduced into main load-bearing structures such as fuselage and wings. The strength of these structures is closely related to flight safety. As the most widely used aeronautical composite structure, composite laminates are very sensitive to lateral impact loads due to their low interlaminar strength. However, in the process of production, operation and maintenance, composite structures are often subjected to impact loads such as bird impact, hail and tool fall, which will lead to matrix cracking and delamination damage of composite structures, resulting in structural strength and stiffness drop, It poses a great threat to the safety and reliability of aircraft in service.

In order to ensure the reliability and integrity of the composite structure during use and prolong its service life, the severely damaged structure or part must be repaired or replaced. Because the composite components are expensive, and the composite structure design is developing towards integration and integration, the replacement of damaged structures is not an economic choice, so the research on composite repair technology is becoming more and more important. The patching repair technology has become the mainstream composite structure repair method in the aviation field because it can restore the aerodynamic shape of components, produce small repair stress, and basically have no eccentric load and small weight gain. At present, there are a large number of patching repair studies on aircraft composite stiffened plates. However, the research and evaluation of the mechanical properties of composite structures after repair is still one of the key issues in the research of composite structure repair technology. Especially for the large-size composite fuselage stiffened curved plate of civil airliner, due to the cost, the failure behavior after repair has not been fully and deeply studied.

In this paper, the compressive strength of composite fuselage structure after repair is studied experimentally. Firstly, according to the structural characteristics of the fuselage, two kinds of composite stiffened curved plates, which are non-destructive and damaged and repaired by patching and gluing, are designed and processed. Then, according to the bearing characteristics of the

fuselage, the compression strength tests of the two kinds of composite stiffened curved plates under simply supported boundary conditions are designed and completed. Finally, the two test results are compared and analyzed from the aspects of initial buckling behavior, failure mode and failure load, The effectiveness of the patching repair of composite stiffened curved plates was evaluated. The results show that the designed repair scheme can meet the general requirements.

Key words Composite fuselage,Curved plate,Repair design, compressive strength

Session: Testing and Evaluations

Presenting Type: Published only

Static Test Technique for Large Curvature Composite Radome

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The radome is an important component that maintains the aerodynamic shape of the aircraft, makes the electrical property stable, and ensures flight safety. Composite is used in most aircraft radome in the world to reduce the weight of the aircraft. For the sake of safety, a static strength test was usually conducted on the radome to verify whether its strength and stiffness meet the requirements. In this paper, the load was treated equivalently, and a lever loading system of nonparallel force was put forward considering the characteristics of the large curvature of the radome structure and that it was difficult to apply load. All test cases were completed successfully, and the test results indicate that the test system works stably and reliably, and the strength and stiffness of the radome meet the design requirements.

Key words composite, radome, load, test

Session: Testing and Evaluations

Presenting Type: Published only

Static Test Technology of the Composite Leading Edge Considering Large Deformation of the Wing

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In the study of the application technology of the thermoplastic composite material structure, a structural static test was conducted, that can verify the correctness of the full-scale leading edge strength analysis method and inspect the manufacturing process. In order to ensure the leading edge structure of the composite wing suffering the same force as the real situation, the test needs to simulate the support stiffness of the wing main box segment on the front edge. The preliminary configuration and size of the support clamp were designed by theoretical methods, then the support clamp was optimized by finite element simulation. The test successfully simulated the support stiffness by applying the active load on the support clamp, and achieved the expected results.

Key words large deformation, thermoplastic, stiffness simulation, leading edge, test

Session: Testing and Evaluations

Presenting Type: Published only

Comprehensive Test Technology of Composite Curved Plate

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The aircraft fuselage structure is composed of various forms of composite curved panels, and is the main load-bearing component of the fuselage structure, which accounts for a large proportion in the whole building block strength test process. In aircraft development, the stability, durability and damage tolerance of stiffened fuselage panels under tension/compression, bending, shear, single or combined airtight loads are usually considered, A large number of tests of wall panels under the combined action of multiple loads are required. For this reason, a series of technical research and device development work have been carried out. The self balanced loading system is adopted, and each load is relatively independent. The tension/compression, shear, and airtight loads of curved plates are single or combined, and each load is decoupled from each other without interference. The straight edge boundary of the curved plate is constrained by a V-shaped frame, which truly simulates the cylindrical boundary, and each joint is equipped with an anti instability device, which effectively prevents the instability of the free edge.

Key words composite curved Plate, multiple loads, instability of the free edge

Hangzhou, PR China 25-28 April, 2023

Session: Testing and Evaluations

Presenting Type: Published only

Experimental investigation on multi-bolt single-lap and double-lap joints of composite/metal structures under compression load

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Due to the requirements of design, process and maintenance, bolted composite/metal joints are the most common forms of connections in aircraft structures. Because of the discontinued fiber, discontinued geometry and load concentration, the strength of multi-bolt composite/metal structures is very complex. Two kinds of composite-metal structure with bolted joints were tested under compressive load. Experimental results of single-lap and double-lap joints of composite/metal structures were analyzed. By comparing the damage evolution, load-strain curves and failure patterns during loading process, compressive properties and carrying capacity in different composite/metal structures were furnished.

Key words composite structure; single-lap joint; double-lap joint; experimental investigation

Session: Testing and Evaluations

Presenting Type: Published only

Study on interface debonding of reinforced composite panel based on seven-point bending test

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Aircraft strength research institute of China

The structural failure caused by out-of-plane bending load of reinforced composite panels under post-buckling load usually occurs at the interface or maximum bending moment. In this paper, the post buckling failure of the M-stiffened panel was simulated by seven-point bending test, and the interface detachment of the composite stiffened panel was analyzed by using the cohesive force element (CZM) technique based on the finite element analysis software ABAQUS. The analysis results are in good agreement with the test results, which proves the rationality and effectiveness of the method. The results show that the initial failure of the stiffened panel is interface debonding, and the loading distance has a great influence on debonding.

Key words M-stiffened panel, post-buckling, interface debonding, seven-point bending

Hangzhou, PR China 25-28 April, 2023

Session: Testing and Evaluations

Presenting Type: Published only

An imaging method for impact localization in aircraft composite structures using a correlation index

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The internal damage of aircraft composite structures caused by low-speed impact events is a critical problem. Impact monitoring is essential for the integrity and reliability of aircraft composite structures. This study presents a novel imaging method for impact localization in aircraft composite structures. Narrow-band lamb wave signals are extracted from impact response signals by the complex Morlet wavelet transform. A correlation index based on waveform is introduced to image the monitoring area for impact localization. The brightest location in the image represents the predicted impact location. The accuracy of the proposed imaging method is experimentally assessed by drop hammer impact tests in a complex aircraft composite structure with sparse array piezoelectric sensor networks. The results show that the proposed imaging method still has high localization accuracy and imaging resolution in the case of noise.

Key words Low-speed impact; Impact localization; The complex Morlet wavelet transform; Composite structures; Piezoelectric sensor

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Testing and Evaluations

Presenting Type: Published only

Research on Size Effect of Tensile Specimens of 3D Five-Directional Braided Composites

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3D five- directional braided composites have been widely used in recent years due to their special spatial network structure, which enables them to have excellent out-of-plane properties and good in-plane properties. However, there is a certain difference between the periodic boundary conditions imposed during the modeling and the size of the sample during the actual mechanical performance test, and the influence of the sample width on the mechanical performance testing process and results of the three-dimensional five-way braided composite material is not considered. . In this paper, based on the three-cell model analysis method, according to the proportion and stacking method consistent with the actual material, the warp unnotched tensile specimens and the weft unnotched tensile specimens of different widths are constructed, and the stress distribution and material of the specimens under different sizes are analyzed. The elastic properties and the influence of the size effect on the three-dimensional five-way braided composite material provide a theoretical basis for guiding the size design of the three-dimensional five-way braided composite material.

Key words 3D five-directional braided composite material, Geometry, Finite element modeling, Elastic properties, Size effect

Session: Testing and Evaluations

Presenting Type: Published only

Impact-induced damage localization algorithm of stiffened woven fabric composite plate based on optimized virtual time reversal

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Woven fabric composite structures play an important role in aerospace, ocean engineering, rail transit and other fields. However, due to their poor impact resistance, passive structure health monitoring (SHM) for barely invisible damage (BVID) has attracted more attention in the past. In this study, an optimized virtual time reversal algorithm has been developed to improve the efficiency and accuracy of locating the impact-induced damage on woven fabric composite structures. Firstly, the impact response signal is obtained by piezoelectric sensor network. Then, the narrow-band signals at multiple frequencies of impact response signals are extracted by wavelet transform in time-frequency domain. After that, the fitness function is constructed according to the time reversal theory. Finally, the intelligent optimization algorithm – whale algorithm is used to search the impact-induced damage position. The effectiveness of proposed method is verified by a lot of falling steel ball impact tests on a stiffened woven fabric composite plate. The results show that the proposed method has good accuracy and high efficiency to determine the position of impact-induced damage in the case of low signal-to-noise ratio. Moreover, there is not need to consider the propagation speed of the elastic wave on the structure, which is attractive to the passive monitoring system.

Key words Impact-induced damage; localization algorithm; Woven composite; Virtual time reversal; Piezoelectric sensor

Hangzhou, PR China 25-28 April, 2023

Session: Testing and Evaluations

Presenting Type: Published only

Study on Engineering Estimation Verification of Compression-Shear buckling of Composite T-stiffened panels

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A numerical approach was established to predict the buckling load of the composite panel stiffened by T-type stringers under compression and shear load. Analytic approaches were initially calibrated by experimental date to enable accurate predictions for the shear and compressive buckling load respectively. The buckling interaction equation was then employed to determine the buckling load for different shear-compression ratios, enabling envelopes for designers to rapidly estimate the buckling threshold for the T-stiffener panels under combined loading scenarios.

Key words Composite T-stiffened panels, Engineering algorithm, buckling load, compression and shear load

Session: Testing and Evaluations

Presenting Type: Published only

Compression shear test technique of flat panel of composite material

Guangqi Huang*
China Aircraft Strength Research Institute

The stability of fuselage panels under combined compression and shear loads has always been an important issue in fuselage strength research. In recent years, because of its high specific strength and good fatigue performance, composite materials are increasingly used in aircraft structures. In the selection stage of composite fuselage panels, the curved fuselage panels are usually simplified into flat panels for pressure shear tests. In the past, the box composed of flat plates were loaded by bending and torsion. In order to reduce costs and improve efficiency, now they are mostly tested by special pressure shear devices. The compression load and shear load are loaded separately. The two loads are applied independently and do not interfere with each other, One installation can realize the buckling load test with any compression shear ratio, and its superposition error is within 3%. It can also constrains the outer normal direction of the skin at the end of the frame, releases the degrees of freedom along the compression direction and shear direction, and simulates the support state under the whole frame, which is more realistic and effective than the previous support of simulating steel ribs in panel compression.

Key words compression and shear loads composite materials fuselage panels flat panels end of the frame degrees of freedom

Session: Failure Criteria and Verification

Presenting Type: Oral-Invited

Size-Dependent Strength of Micro/Nano Ceramic Particles Reinforced Polymer

Lihong Liang*、Rui Yuan、Xiuqing Ma
Beijing University of Chemical Technology

Particle reinforced polymer composites have wide application, and mechanical properties and damage criterion of composites affect their stability during service. Mechanical properties of the composites are dependent on the particle fraction, size, distribution, and interface interaction between two phases. In this paper, size and fraction dependent strength of polypropylenes (PP) with micro/nano silica particles is studied by tensile experiments and corresponding 3D finite element modelling based on interface cohesive model. The results indicate tensile strength of PP with 2% SiO2 nanoparticles of 50 nm is maximum in this study range, the microstructure mechanism related to smaller particle size and better interface bonding is revealed. Furthermore, particle size and interface coupling effect is considered, local interface damage evolution around a particle during tension of composites are demonstrated by the simulation, the simulation results agree with experimental results. The results are helpful to design polymer composites with nanoparticle inclusions.

Key words Nanoparticles; Mechanical properties; Size effect; Interface damage

Hangzhou, PR China 25-28 April, 2023

Session: Failure Criteria and Verification

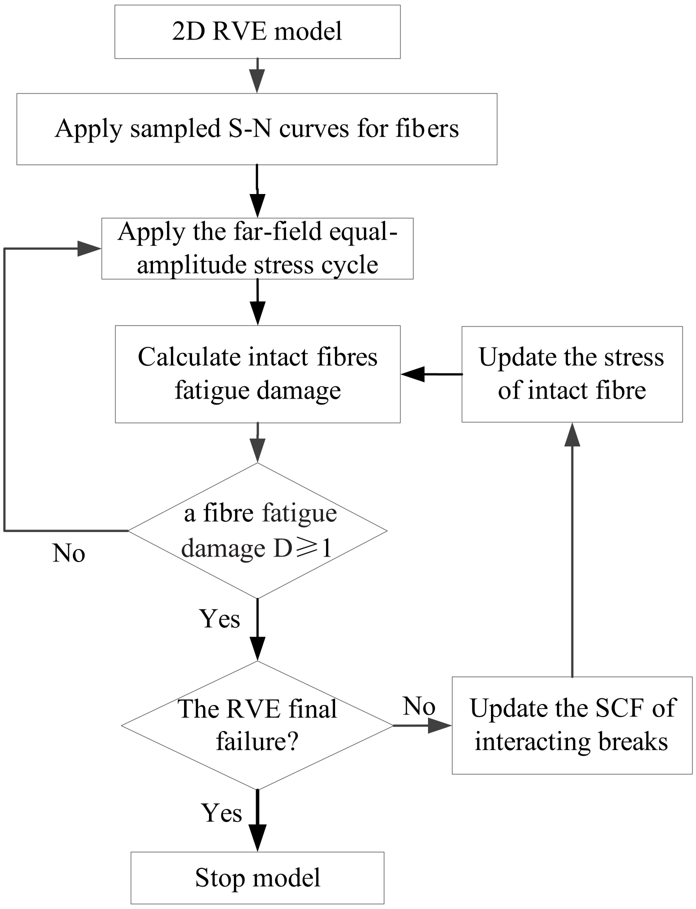
Presenting Type: Oral-Onsite

Stiffness degradation and fatigue life prediction of unidirectional CFRP under cyclic tensile load

Yuanqi CHENG、Fulei ZHU、Shufeng ZHANG*
National University of Defense Technology

In order to improve the reliability of composite structures, it is essential to have a comprehensive understanding of the fatigue mechanism of unidirectional (UD) carbon fiber reinforced plastic (CFRP). In this paper, the statistical fatigue strength of single fiber and the mesoscopic non-uniformity distribution of fibers in CFRP are comprehensively considered to evaluate the fiber break progressive evolution characteristics and fatigue life of CFRP. A method is proposed for predicting the fatigue life and stiffness degradation of CFRP under tension-tension fatigue load, in which the poor random of fiber distribution in UD CFRP including resin-rich region and fiber clusters region is taken into account. The stress of nearby intact fibers is redistributed based on the local fiber volume fraction (VF) within the influence of the break elements, and a new SCF (stress concentration factor) model is proposed. Based on the SCF model, a fatigue life of UD CFRP prediction flow chart is established. The SCF model predicts obvious defect points on the fiber break number and stiffness degradation curve. Comparison is conducted on the damage accumulation characteristics and fatigue life of unidirectional composite with regular and random fiber distribution, for the CFRP with the resin-rich regions, the SCF model predicts that large fiber clusters begin to appear in the resin-rich region, which is in good agreement with with experimental phenomena in available literatures. The prediction also shows that the uncertainty of fiber fatigue strength distribution has a significant influence on the tension-tension fatigue life of UD CFRP. This work shows that improving the uniformity of fiber distribution and reducing the uncertainty of fiber fatigue strength can enhance the tensile fatigue life of UD CFRP.

Key words A. UD composite B. Fatigue life prediction C. Fiber break evolution D. SCF model



Flowchart of fatigue prediction of UD CFRP

Session: Failure Criteria and Verification

Presenting Type: Oral-Onsite

Reinforcing efficiency of nanophases with various geometric shapes on interfacial bonding in multiscale composites

Kai He*、Huanchen Liao、Zhenyu Jiang
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Introduction of nanophases into the interface between fibers and matrix in fiber-reinforced polymer composites can form multiscale composites with significantly improved interfacial bonding. It was observed that the nanophases of various geometric shapes (e.g., nanotubes, nanoparticles or nanosheets) show quite different reinforcing efficiency. The nanophases with high aspect ratio can enhance the interfacial bonding of multiscale composites by bridging, deflecting and bifurcating cracks. It is generally believed that the reinforcing efficiency of nanophases with high aspect ratio (nanotubes and nanosheets) is better than that of nanophases with low aspect ratio (nanoparticles). However, our experimental study demonstrates that nanoparticles improve the macro-scale bonding strength more efficiently at same volume fraction. To elucidate the underlying mechanisms of this discrepancy, a multiscale mechanical model is proposed. The pull-out force of nanophases with different geometric shapes from the matrix is evaluated at micro-scale according to the van der Waals force-based interaction. The transverse tensile strength of multiscale composites at macro-scale is estimated combined the critical pull-out force with the distribution density of nanophases in the interface region. Three typical carbon-based nanophases are chosen for comparison, i.e., fibrous carbon nanotubes, granular buckminsterfullerene nanoparticles, and lamellar graphene oxide nanosheets. The study indicates that the critical pull-out force and the distribution density of nanophases are almost equally important in improvement of interfacial bonding of multiscale composites. The high aspect ratio nanophases have the superior enhancing effect as individual, but the advantage could be counteracted by the relatively low distribution density in the interfacial region due to their geometric features. The two factors need to be carefully balanced to achieve the desired ultimate performance of multiscale composites.

Key words Multiscale composites; Nanophase; Interfacial bonding; Multiscale mechanical model

Session: Failure Criteria and Verification

Presenting Type: Oral-Onsite

True stress theory of matrix in a composite

Zhengming Huang*
Tongji University

Whereas mechanics theories for isotropic materials are almost matured, those for anisotropic or composite materials are matured only within linear elasticity. All of the other mechanical properties of a composite outside linear elastic range are overall not able to be analyzed satisfactorily. A fundamental reason is in that only homogenized or approximated stresses are obtainable for the composite by the current theories, from which the internal stresses in its constituent fiber and matrix are homogenized values as well. Its mechanical properties must be estimated on a true stress level. The true stresses of the fiber are either the same as its homogenized counterparts, if the fiber is continuous, or immaterial, if the fiber is discontinuous. The true stress theory for the matrix has been systematically established by the author, and is reported in this presentation. As almost all composite failures are caused by matrix failures, the true stress theory plays a predominant role in estimating the composite properties outside linear elastic range. A number of challenging problems in composite failures have been resolved based on the true stress theory, and are highlighted in the presentation.

Key words True stress; constitutive relation; interface debonding; kinking; strength prediction

Session: Failure Criteria and Verification

Presenting Type: Oral-Onsite

Validation and improvement of failure criteria for carbon fiber reinforced polymer composites in the cryogenic regime

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Carbon fiber reinforced polymer (CFRP) composites are ideal materials for lightweight cryogenic pressure vessels of future launch vehicles, and reliable failure criteria are required for their structural evaluation in the cryogenic regime. This paper outlines an ongoing research on the validation and improvement of CFRP failure criteria under cryogenic conditions. Mechanical tests on unidirectional (UD) CFRP composites under various loading conditions were initially performed at room temperature and cryogenic temperatures, and the cryogenic failure characteristics of CFRP composites were investigated. Then, a mesoscopic numerical model based on representative volume elements (RVE) was developed to predict the failure envelope of UD CFRP composites at different temperatures. Finally, the predicted failure envelope is compared with the classical failure criterion, the applicability of which at cryogenic temperature is investigated, and a new set of homogeneous failure criteria is proposed. According to computational and experimental results, the proposed failure criterion shows some improvement in the prediction of the cryogenic failure behavior of CFRP composites.

Key words Carbon fiber reinforced polymer composites; Failure criteria; Cryogenic temperatures; Damage and failure

Session: Failure Criteria and Verification

Presenting Type: Oral−Onsite

Micromechanical predictions on anisotropic elastic moduli of a short fiber composite with arbitrary geometric combination

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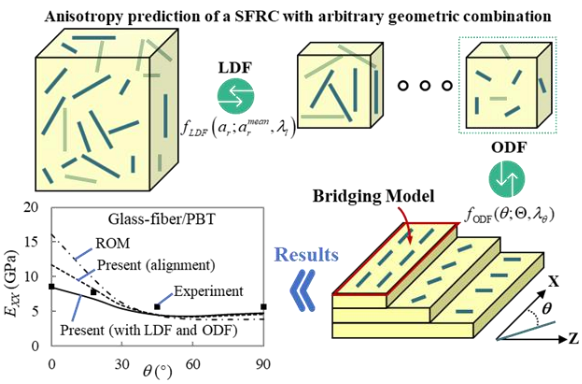
This paper is concerned with the anisotropic elastic properties of a short fiber reinforced composite (SFRC). The anisotropy comes from the different intrinsic properties between the fiber and matrix and arbitrary geometric combination of the reinforcing fibers. The micromechanical Bridging Model is employed, where the RVE (representative volume element) is a concentric cylinder, while the inner fiber cylinder has a shorter length than the outer matrix cylinder. To validate the accuracy of Bridging Model on the elastic moduli predictions, the influences of misaligned and nonequal-length fibers must be eliminated, so an aligned SFRC is invited first. The second issue is to predict the elastic moduli of a SFRC with arbitrary geometric combination. Such geometrical features include fiber length distribution and fiber orientation distribution, they are respectively described by Erlang-2 (LDF) and Weibull (ODF) probability density functions. Since the probability density in conjunction with the Bridging Model is cumbersome to integrate, a numerical treatment is used for both iso-strain and iso-stress assemblages. A third issue is determination of the shape parameters of LDF and ODF. Taking an injection molded SFRC as an example, the fibers might be shortened during injecting process due to the screw shear force and fibers collision. On the other hand, it was observed that longer fibers are more prone to be aligned along the flow direction. Consequently, a linear relation of these parameters to the fiber volume fraction is assumed so that to minimize the fitting parameters. The present method is validated by available experimental data of different SFRC systems, good agreement is found.

Key words short fiber composite; elastic moduli; micromechanics



Session: Failure Criteria and Verification

Presenting Type: Oral−Virtual Platform

Failure mechanisms of fluted-core sandwich composite panels under uniaxial compression

Xinyu Li*、Haiyang Yang、Zhong Zhang、Yuanchen Li、Panding Wang、Hongshuai Lei
Beijing Institute of Technology

The Fluted-core sandwich composite structure has attracted growing attention in the fields of aerospace due to its high strength-to weight ratio and high load-bearing capability. In the present study, the fluted-core sandwich panels exhibited multi-failure modes under uniaxial compression, including global buckling, local buckling, and material failure. Analytical models were established to predict the failure behaviors of structures based on the classical Rayleigh–Ritz method and failure criterion. Furthermore, failure mode maps were generated on the basis of the geometric parameters of the unite cell. Integrated fluted-core sandwich composite panels were then fabricated from carbon fiber reinforced plastics (CFRP) by adopting the integrated forming process and co-curing method. The uniaxial compression tests and finite element simulation were carried out on composite sandwich structures with trapezoidal and triangular cores, rendering excellent consistency and demonstrating the reliability of the proposed analytical method. The effects of the geometric variable on both load-bearing capacity and failure modes were systematically explored. The results revealed that the global buckling was prone to occur with thinner core. For structures with trapezoidal core, the buckling half waves appeared at the face sheets segments between two webs. However, the decrease in width of short span or increase in thickness of face sheets enable the structures more prone to material failure, so as to inhibit the occurrence of local-buckling behavior. Overall, the parametric analysis provided novel insights into preliminary structural design, promising for the future engineering applications.

Key words Sandwich composite panel; Analytical modeling; Failure mode; Finite element method; Uniaxial compression test.

Session: Engineering Applications

Presenting Type: Oral-Invited

Research on Tensile Failure Mechanism of Unidirectional CFRP Tendons Under High Temperatures Based on Fractal Characteristics of AE Signals

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In view of the problem that the mechanical properties of Unidirectional (UD) carbon fiber-reinforced polymer (CFRP) tendons at high temperature deteriorates significantly and it is difficult to give timely damage warning, this paper carried out four groups of acoustic emission (AE) monitoring tests for tensile failure process of UD CFRP tendons under different temperature conditions (i.e. 20 °C, 300 °C, 450 °C and 500 °C). By analyzing the time domain characteristics and fractal characteristics of AE signal sequences at different temperatures, it was found that the AE count and cumulative energy sequence can be better used to describe the whole failure process of UD CFRP tendons. The Hurst index of AE count sequence could reflect the meso-damage evolution law of UD CFRP tendons, which provided a theoretical basis for establishing the advanced warning mechanism for structural health monitoring (SHM). In addition, the multi-fractal spectrum could help us to understand the tensile failure mechanism of UD CFRP tendons at different temperatures from microscopic perspective. Finally, the reliability of the analysis based on multi-fractal spectrum was verified by using scanning electron microscopy (SEM).

Key words Unidirectional CFRP tendon; Acoustic emission; High temperature; Multi-fractal; Hurst index; Failure mechanism

Session: Engineering Applications

Presenting Type: Oral-Invited

Preparation and Sizing Method of Polyetheretherketone Homologous Sizing Agent

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School of Materials Science and Engineering, Wuhan University of Technology

Compared with carbon fiber reinforced thermosetting composites, carbon fiber reinforced thermoplastic composites (CFRTP) have the advantages of high molding efficiency, good impact resistance and recycling. However, there are still many problems in the high-quality preparation and industrialization of high-performance C-CFRTP. To realize the preparation and application of high-performance C-CFRTP, the interface construction of C-CFRTP must be solved. In this paper, a preparation and sizing method of polyetheretherketone homologous sizing agent is provided. A new sizing agent and sizing method with good compatibility with high-performance resins such as polyetheretherketone are developed, which solves the interface construction of thermoplastic composites and the inner impregnation technology of fiber bundles. The polyetheretherketone resin can be combined with fiber more tightly by grafting amino group to polyetheretherketone and carboxyl group to carbon fiber respectively. In the infrared spectrum ranging from 3500 to 3300 cm-1, it can be seen that polyetheretherketone resin has been successfully aminated. And the aminated resin powder can be dissolved in N,N-dimethylformamide. When the volume ratio of N,N- dimethylformamide to deionized water is (2.3-4):1, the aminated polyetheretherketone can be precipitated and adsorbed on the acidified carbon fiber surface. Thanks to electrostatic adsorption, aminated polyetheretherketone has better binding ability with acidified carbon fiber. The homologous sizing agent prepared in this paper not only has a high similarity of molecular structure with polyetheretherketone resin, but also has a good bonding performance with carbon fiber. And the sizing process is simple and easy. The preparation method and sizing process are also suitable for other thermoplastic engineering resins, such as polyether ketone ketone, polyphenylene sulfide, etc., so it has a broad application prospect.

Key words Polyetheretherketone, Thermoplastic composite, Sizing agent composite, Interface

Session: Engineering Applications

Presenting Type: Oral-Onsite

Synthesis and Curing Behaviors of SiBCN Ceramic Precursor via Polymer-Derived Ceramics Route

Zhe PENG、Xiaoxiao Chai、Longfei Gao、Nan An、Song Li*
Beijing Composite Materials Co., Ltd.

SiBCN ceramic matrix composites have been gradually become the preferred materials for key thermal structural components such as nose cone and wing leading edge of ultra-high speed aircraft with it's excellent properties of oxidation resistance, high temperature stability, ablation resistance. SiBCN ceramic precursor plays an important role in the manufacturing process, characteristics, applications for SiBCN ceramic matrix composites. Therefore, the design and synthesis of high-performance SiBCN ceramic precursor and the study of its ceramic process are of great significance for the preparation of high-performance SiBCN ceramic matrix composites. In this paper, polysilazane was used as the main chain of the polymer and borazine was acted as the branch chain of the boron source. Four SiBCN ceramic precursors compounds were synthesized by dehydrogenation of polysilazane and borazine. Their molecular structures were characterized by FT-IR, DSC, XPS, XRD, TG and other methods, and their curing kinetics and ceramic process were studied. The synthetic mechanism of SiBCN ceramic precursors was proved to be the linking between N-H bond of polysilazane and B-H bond of borazine to form new B-N bond. The kinetic parameters of precursors were calculated by Kissinger and Crane equations, where the results were summarized as follows: apparent activation energy is 266.17 kJ/mol with reaction order of 0.943. One of SiBCN precursors with viscosity lower than 300mpas and ceramic yield higher than 80% showed the content of B in the ceramic product was 4.67% and decomposition temperature was higher than 1650 °C. This study lays a foundation for the research and application of high-performance SiBCN ceramic matrix composites in aerospace engineering field of thermal protection smaterials.

Key words SiBCN ceramic, precursor, high temperature stability, thermal protection materials

Session: Engineering Applications

Presenting Type：Oral-Onsite

The Theory of Compressive Strength of Solid Buoyant Materials in the Depth of the Whole Sea and the Improvement Method of Water Separation

Jingze Wang*、Jingze Wang
West Lake University

Full-sea deep manned diving is the ultimate goal of the second generation of deep manned submersibles, and the requirements for solid buoyancy materials are also more stringent. However, after decades of development and optimization, the existing preparation process and methods have reached the limit and are difficult to be further improved, which hinders the development of the deep-sea manned diving industry. This paper create the theory of compressive strength of solid buoyant materials in the deep sea, make full use of the characteristics of skewed distribution of compressive strength of hollow glass beads, and propose to use the "water separation method" to screen hollow glass beads, eliminate hollow glass beads with low compressive strength, and then improve the compressive strength and safety reserves of solid buoyant materials in the deep sea. The test results show that the compressive strength of the buoyancy material after water separation can withstand the hydrostatic pressure of 175 MPa, the water absorption rate of 48 hours is 0.07%, and the density increases by 7.67%. It meets the requirement of 1.5 times of safety factor for solid buoyant materials at sea depth. It is of great significance to the exploration and development of deep-sea resources.

Key words solid buoyancy materials, Full-sea deep, theory of compressive strength

Session: Engineering Applications

Presenting Type: Oral-Onsite

UV-Thermal Curing 3D Printing of Continuous Carbon Fiber-Reinforced Thermoset Composites towards Low-Cost, High-Performance UAV Manufacturing

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Thermoset based composites have been widely used in UAV industry because of their low density, high specific strength and modulus, fatigue performance and corrosion resistance. Currently, composite materials used in advanced UAVs have exceeded 90%, moreover, the dramatic increase of composite materials will arrive in company with the enlarged UAV application market in both civil and military fields. To significantly reduce composite manufacturing costs and enhance the competitiveness in the UAV market, it is necessary to develop the composite structure manufacturing technology towards high-efficient and low-cost in response of such a large usage and potential future demand. In addition, future next UAVs needs to be geared towards large-scale, integrated, high-performance composite structure to satisfy the innovative composite lightweight design, which requires multi-degree-of-freedom automated composite manufacturing methods to realize the integrated process of complex composite configurations.

Conquering the future demands of UAV composites, this paper proposes an UV-thermal curing 3D printing technology of continuous fiber-reinforced thermoset composites. Specifically, the printing ability of modified epoxy-based composite is achieved by in-situ UV light, and subsequent thermal curing is conducted to complete curing degree of composite. The printed continuous T300-grade carbon fiber-reinforced epoxy resin matrix composite possesses a dense structure with the fiber content of 45% and the porosity of <4%, consequently attaining a competitive result with the tensile strength above 900 MPa, the bending strength above 600 MPa, and the interlayer shear strength above 50 MPa. A frame of quadrotor UAV was selected as the manufacturing verification to demonstrate the manufacturing feasibility for the complex structure of thermoset based composites. The results clarify that molding efficiency can exceed 700 mm/min, and the molding accuracy surpasses ±1.5mm/1000mm, besides that the post-curing without mold support reduces costs significantly, which is expected to meet the demand for future UAV composite applications.

Key words 3D printing; Continuous carbon fiber; Thermoset composites; UV-thermal curing

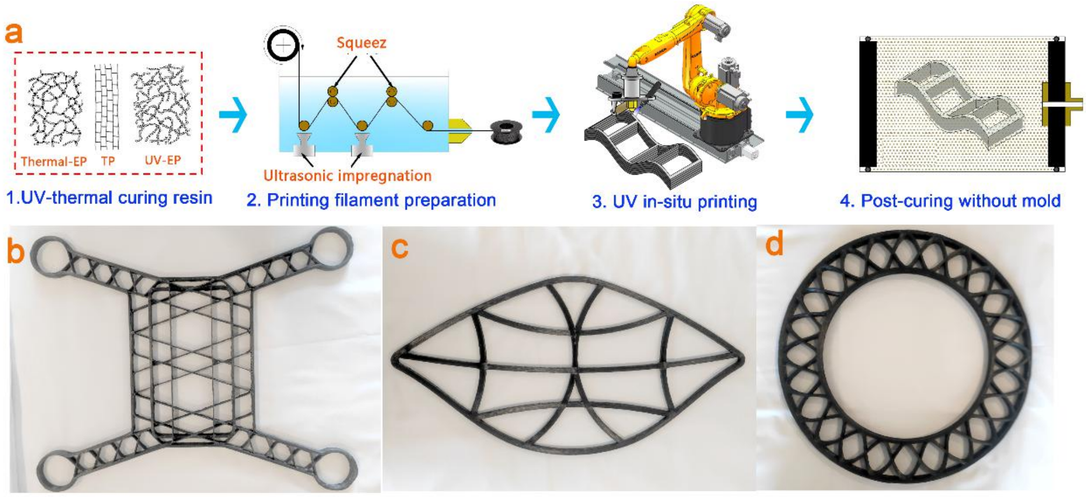

Fig. 1. a）illustrations of UV-thermal curing 3D printing process, (b) printed quadrotor UAV frame, (c) web frame, (d) circular frame

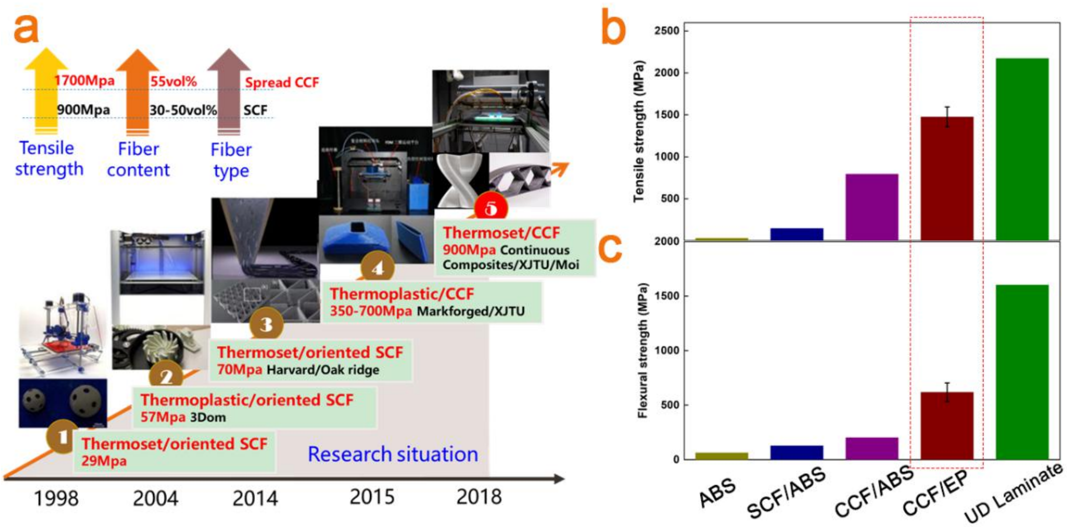

Fig. 2. (a) histrionic development of composite 3D printing, comparisons of (b) tensile strength and (c) bending strength of composite 3D printing

Session: Engineering Applications

Presenting Type: Oral-Onsite

The Interlayer Toughening of Aerospace Composites Using Thermoplastic Veils

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2. Shandong University
3. Delft University of Technology

This work presents the results of our recent studies on the adhesive bonding of aerospace carbon fibre reinforced poly-phenylene-sulfide (PPS) and poly-etherether-ketone (PEEK) composites. A high-power UV-irradiation technique was proposed to rapidly treat the surfaces of the PPS and PEEK composites, that significantly improved the surface activities of the laminates. Upon the UV-treatment, the adhesion between the aerospace epoxy adhesives and the PEEK/PPS composites had been significantly improved to a level that was sufficient to prevent the interface failure. Consequently, adhesive joints of thermoplastic-to-thermoplastic, thermoplastic-to-thermoset and thermoplastic-to-metal with excellent structural integrity had been obtained. For example, the lap-shear strength of the thermoplastic-to-thermoplastic joints increased from 11.8 MPa to 31.7 MPa upon UV-irradiating the PPS composites for 3 s, and from 8.3 MPa to 37.3 MPa by applying a 5 s UV-irradiation to the PEEK composites. Moreover, the mode-I and mode- II fracture energies of the thermoplastic-to-thermoplastic joints significantly increased from ~50 J/m^2 to ~1500 J/m^2 and from <300 J/m^2 to ~7000 J/m^2, respectively for both of the adhesively bonded PEEK and PPS composite joints.

Key words Adhesive bonding; Aerospace applications; thermoplastic composites

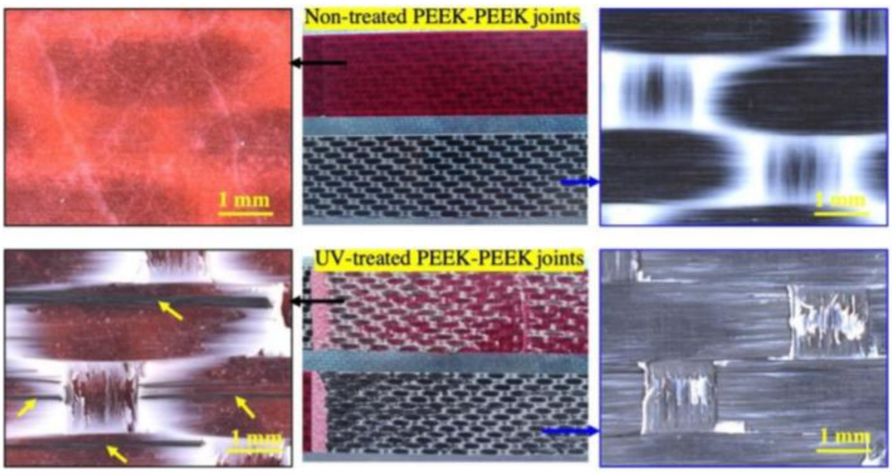

Fig. 1. Typical mode-I fracture surfaces of the PEEK-PEEK composite adhesive joints with

the substrates being non-treated and UV-treated. The red color film is the aerospace adhesive.

Session: Engineering Applications

Presenting Type: Oral-Onsite

Discontinuous Impact Fatigue Failure Model and Microscopic Mechanism of Pure Titanium Under High Strain Rate Loading

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Northwestern Polytechnical University

The fatigue failure behavior of structural materials under repeated impact loads has always attracted much attention. Mastering its damage accumulation process and evolution mechanism at the micro scale is the fundamental way to understand the impact fatigue failure mechanism. Due to the complexity of the impact fatigue load itself and the limitations of the current experimental equipment, there are still major problems in the study of impact fatigue failure of materials. Therefore, in this study, pure titanium was used as the research object. Based on the traditional split Hopkinson tension bar system, a strain-controlled impact fatigue life test experiment was designed to study the microscopic evolution mechanism of impact fatigue and its effect on the macroscopic mechanical behavior of materials. The quasi-static mechanical properties of the samples at different impact fatigue test stages were tested. The microstructure of the samples at different stages and the fracture morphology after impact fatigue failure were characterized by scanning electron microscopy (SEM) and electron backscatter diffraction (EBSD). The cyclic hardening / softening law and its microscopic evolution mechanism of pure titanium during impact fatigue failure were studied. The results show that the strain-controlled impact fatigue life test can be realized by changing the striker length. Manson-Coffin fatigue life model can better reflect the relationship between impact fatigue life and strain amplitude of pure titanium. Moreover, pure titanium exhibits cyclic hardening during impact fatigue failure, which is mainly due to the combined effect of fine grain strengthening caused by twin deformation and strain hardening caused by plastic deformation during fatigue. Finally, the impact fatigue damage of pure titanium is mainly manifested as the loss of deformation ability.

Key words impact fatigue; pure titanium; Manson-coffin model; microstructure

Session: Engineering Applications

Presenting Type: Oral-Onsite

Design and Application of Deep-Sea Composite Pressure Hull

Meng WANG*、Pengfei WANG、Xue LU、Jiang SONG、Yuzhe WANG
Beijing Composite Materials Co., Ltd.

Submersible is an important tool for carrying out ocean missions and is of strategic significance for safeguarding national marine security and developing marine economy. The pressure hull is the core structure of submersible. With the increase of submersible diving depth, the advantages of composite pressure hull become more prominent. In foreign countries, the composite pressure hull has been commercialized and industrialized. In China, the development of deep-sea composite pressure hull is still in the trial production stage. Our company started earlier, and has the ability to design and prepare the full sea depth pressure hull of composite material, and has the successful experience of sea test of typical models. Thanks to the support of many parties, we will devote more efforts to serve the development of China's marine industry.

Key words deep-sea, composite, pressure hull

Session: Engineering Applications

Presenting Type: Oral-Onsite

Application of Graphene Glass Fibre Fabric in the Deicing Solution for Wind Turbine Blades

Zhengrong Yu*、Hui Zhang、Hongyu Su、Yanbo Xu、Xinyu Guo、Xuan Gao、Li Xu
Beijing Graphene Institute Co., Ltd.

At present, not only most wind farms in the central, eastern and southern China are facing severe winter freezing disasters, but also with the climate change that China's precipitation line has moved northward in recent years, some wind farms in northern China have also begun to consider the icing prevention and deicing solutions of wind farms in winter. By 2022, the annual power loss due to icing will be as high as 20%-50% in regions with severe icing conditions, and the total loss of a single 2 MW wind turbine during its service period will be 4.8-12 million yuan. The total domestic loss can reach as high as 144-360 billion yuan. Currently the domestic anti-icing solutions mainly based on hydrophobic coatings, gas-blowing thermal methods and electric-thermal methods. They all have various drawbacks. A new fibrous material that integrates light-weight, flexibility, long-term stability and unique electro-thermal performance was developed by the core members of Fuxi Glass Carbon Team and Beijing Graphene Institute. This material, namely Graphene glass fibre fabric (GGFF) is known for its unique mechanical, thermal and electrical properties that will help airfoil structures like wind turbine blades to ensure the stability and safety of the structure's operation under the conditions of low temperature and high humidity prone to icing. GGFF material is soft and relatively easy to process, with high heat conversion efficiency and extremely fast heating rate, providing a new solution for wind power icing prevention and deicing problems.

Key words graphene, glass fibre fabrics, composites, wind turbine blades, deicing

Session: Engineering Applications

Presenting Type: Oral-Onsite

An Advanced Ice Protection System Based on CNT Webs

Xudan YAO*[1,2]、Stephen Hawkins[2,3]、Brian Falzon[2]
1. Northwestern Polytechnical University
2. Queen's University Belfast
3. Monash University

Owing to its superior specific strength and stiffness, carbon fibre reinforced polymer (CFRP) composites are increasingly being used in diverse sectors, such as marine, automotive, sports and, in particular, aerospace, where they comprise around half the weight of the primary structure of the latest generation wide-body passenger aircraft such as the Boeing 787 and A350 XWB. This revolution in materials and fabrication, together with ever increasing pressure to reduce fuel consumption has provided the impetus for the development of multifunctional structures incorporating such functionality as structural health monitoring, lightning strike protection and improved ice protection systems.

Directly drawable carbon nanotube (CNT) web is a uniquely adaptable and useful material composed of highly aligned, small multiwalled CNTs, produced by chemical vapour deposition (CVD). It is electrically conductive, particularly in the draw direction, extremely light (areal density: 0.019 g/m2) and flexible, and highly compatible with composite materials. By controlling the aspect ratio of these CNTs and the number of stacked web layers, a tailored resistance can be achieved.

In this work, a CNT web-based electrothermal anti-icing/de-icing (AI/DI) system has been created for aerospace applications. Compared with the state-of-the-art heating systems, the highly aligned CNT-web based system possesses negligible weight, rapid and uniform heating, efficient energy consumption and tunable electro-thermal behaviour, with both anti-icing and de-icing performance verified. Such an AI/DI element would be located on critical aircraft wing and nacelle lip leading edges, which are also the areas most susceptible to impact. Hence, the AI/DI elements would be the first to suffer impact damage, necessitating a mechanism to detect damaged areas and to repair them. The mechanism for detection of damage to the AI/DI element also facilitates the localisation of potential damage to the underlying CFRP composite, further enhancing the multifunctional value of CNT web. The flexibility of the CNT web-based electrothermal system was demonstrated by applying it to the leading-edge surface of a representative composite wing section provided by Spirit Aerosystems Belfast.

Key words carbon nanotube web; anti-icing/de-icing; electro-thermal system; composite

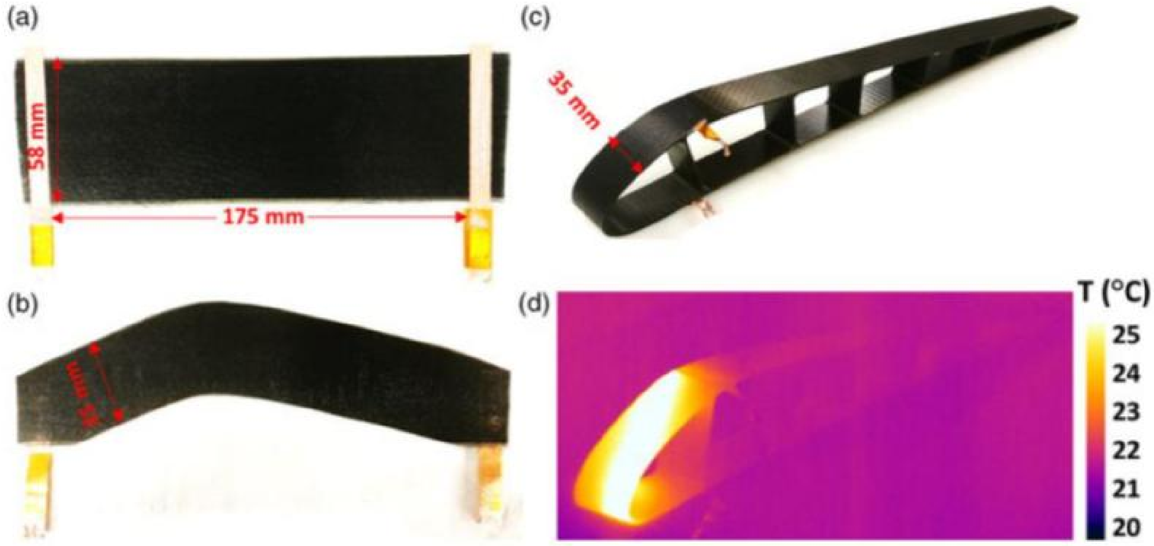

Fig. 1. CNT web/glass fabric composite heater (a) original sample, (b) after being cut into a conformal shape, then (c) applied onto the aircraft wing section and (d) heating performance viewed by IR camera.

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Engineering Applications

Presenting Type: Oral-Onsite

Aeroelastic Effect on Thermo-Acoustic Response and Fatigue Life of Braided Composite Panels

Yiwei Duan、Duoqi Shi、Changqi Liu*、Xiaoguang Yang
Beihang University

In this paper, a novel aerodynamic-acoustic coupling model to investigate the influence of aeroelastic effects on the thermo-acoustic response of three-dimensional, four-directional braided composite panel is proposed, and the fatigue life under the combined aerodynamic load and acoustic load is discussed by using a rainflow cycle counting method. Assuming that the fibers are transversely isotropic and the matrix is isotropic, the fiber inclination model was used to predict the effective stiffness matrices of the composite panels. The piston theory and Gaussian random acoustic excitation were used to simulate the aerodynamic load and acoustic load, the thermal load is assumed to be a uniform distribution in steady state, and the material properties are assumed to be independent of temperature. Based on the von-Karman strain-displacement relation, the governing equations of the panel were formulated, and the response solutions of the four sides simply supported panel were obtained using Galerkin method and Runge-Kutta method. The aeroelastic effect on the thermos-acoustic response of the braided composite panel was investigated in time and frequency domains, and the life of different load conditions was predicted. The results show that the aeroelastic not only transforms the movement form, but also affects fatigue life of the panel. An increase in both SPL and flow dynamic pressure leads to a decrease in panels' life, and there is a counterbalance mechanism between the two influence mechanisms. To accurately predict the fatigue life of the braided composite panel, the geometric nonlinearity effect of the panel is required to be considered especially in the high SPL conditions.

Key words braided composites, nonlinear vibration, aeroelastic effect, dynamic response, fatigue life

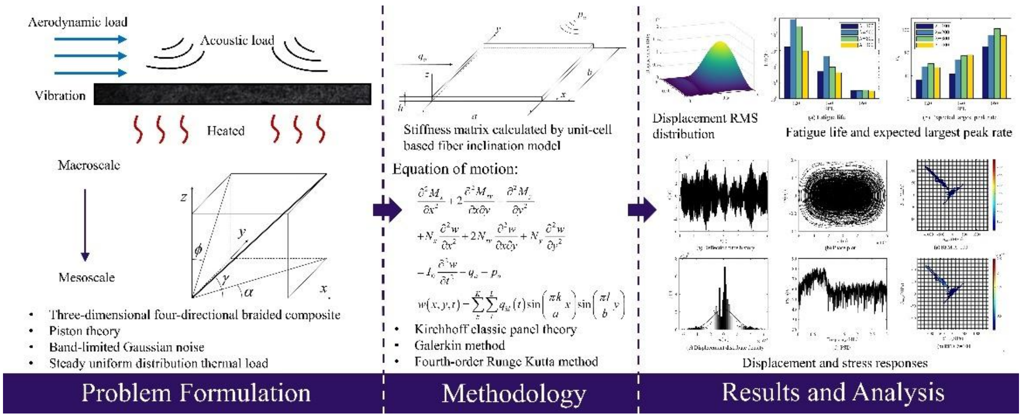

Fig. 1. The main research content and methods of this paper.

Session: Engineering Applications

Presenting Type: Oral-Onsite

Static and Dynamic Tensile Behaviors of BFRP Bars Embedded in Seawater Sea Sand Concrete Under Marine Environment

Deju ZHU*、Sheng Li、Yong Yi、Shuaicheng Guo
Hunan University

This study investigates the static and dynamic tensile behaviors of BFRP bars after exposure to the seawater sea sand concrete (SWSSC) under marine environment. Accelerated corrosion tests were conducted under various exposure periods (60, 90, and 120 days) and temperatures (25, 40, and 55°C). Results show that the tensile properties of BFRP bars are sensitive to strain rate. Both the tensile strength and the elastic modulus of BFRP bars increase with increasing strain rate, but the failure strain drops. The tensile strength and failure strain reduce with increasing exposure temperature and duration, whereas the elastic modulus does not change significantly. Accelerated corrosion also increases the strain-rate sensitivity on the tensile strength of BFRP bars. The degradation of the BFRP bars can lead to adverse effects on stress transfer from the resin to the fiber. Microstructure analysis clearly reveals that failures of BFRP bars occur due to fiber breakage, matrix cracking, and interface debonding. Strain rate and exposure to the SWSSC under marine environment affect the failure patterns of BFRP bars. The specimens fail in the form of bundles under quasi-static conditions. When the strain rate increases, the size of fiber bundles reduces, and interface debonding becomes more severe. The basalt fibers always exhibit brittle fracture, but the fracture surfaces change from relatively flat to rough when the strain rate increases. Moreover, the deterioration of BFRP bars is caused by resin hydrolysis, fiber-resin interfaces debonding and fiber damage after corrosion. These results can provide some insights to promote the application of BFRP composites in coastal and marine structures.

Key words BFRP bar; Seawater sea sand concrete; tensile properties; Strain rate

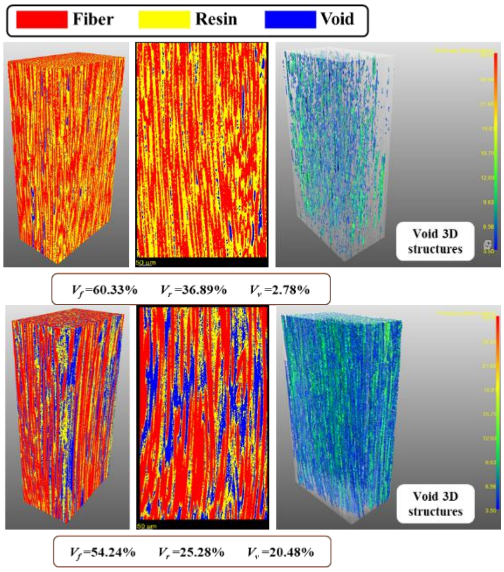

Fig.1. Micro-CT images of BFRP bars

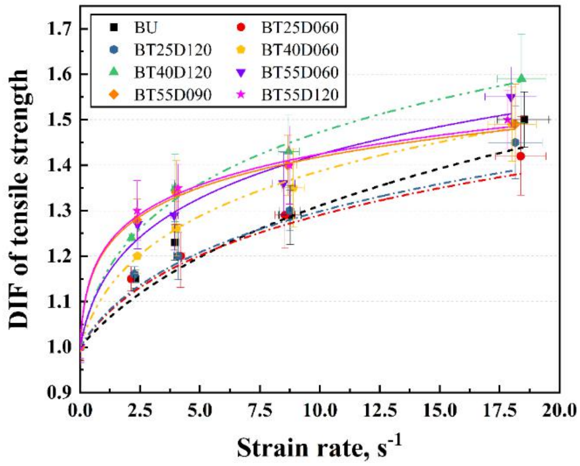

Fig.2. DIF of tensile strengths

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Session: Engineering Applications

Presenting Type: Oral-Onsite

Curing Design and Analysis of Damage Repair for Honeycomb Sandwich Structure

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Honeycomb sandwich composite structure has excellent characteristics of light weight, high specific strength, high specific stiffness and impact resistance. It has been widely used in aerospace, navigation, civil engineering, rail transit, energy, wind power and other fields. However, various damages are inevitable in manufacturing, service and maintenance, which directly affect its strength, stiffness and reliability. Therefore, the repair process is of great significance for restoring the mechanical properties of damaged honeycomb sandwich structures and reducing the life-cycle cost.

Firstly, the macro and micro geometric model, curing dynamics model, heat conduction model and residual stress model of the repair process of honeycomb sandwich structure (panel: carbon fiber / epoxy resin; Core: aluminum honeycomb) panel damage and core damage are established; Secondly, the macro and micro scale finite element model of panel damage and core layer damage repair and curing of honeycomb sandwich structure is established to realize the parametric analysis of curing process parameters and geometric parameters on curing temperature, heat conduction, curing deformation and residual stress. Finally, the corresponding relationship between the damage repair process parameters and repair efficiency of honeycomb sandwich structure is established to realize the engineering design and theoretical guidance of damage repair of honeycomb sandwich structure.

Key words honeycomb sandwich structure; damage repair; curing process; residual stress; repair efficiency

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Session: Engineering Applications

Presenting Type: Oral-Onsite

An Automated Workflow for Composites Part Manufacturability Prediction and Tooling Optimisation

YI WANG*[1]、Siyuan Chen[1]、Jonathan Belnoue[1,2]、Stephen Hallett[1]
1. University of Bristol
2. National Composites Centre, UK

Advanced composites, i.e. carbon-fibre reinforced polymer (CFRP), have become the main structural material in the aerospace industry and renewable energy fields such as wind and hydrogen energy. A central question for industrial applications is the manufacturability of anisotropic and viscoelastic advanced composite materials. This has been a challenge ever since the beginning of large scale use of composites and still remains a challenge today. As a result, the development times of the manufacturing process are usually long, requiring costly demonstrator programmes, resulting in large number of parts having to be scrapped, reworked or redesigned.

In the present study, an automated digital workflow for the manufacturability prediction of composite parts made via autoclave moulding is proposed. Several specific challenges in composites manufacturing digitalization have been addressed: robust models to describe the material behaviour under processing conditions, the high computational cost of simulation (previously taking weeks for thick composites parts) and the non-automated transition between the different phases of the manufacturing process. The workflow consists of three main modules: virtual layup, virtual autoclave and virtual inspection enabling a fully automated end-to-end process simulation. The performance of the workflow was accessed by an industrial-level complex, thick composite part (L-shape geometry with part thickness up to 25.4 mm). Good agreement in part quality prediction was observed when compared with the physically manufactured part with a simulation time of a few hours compared with traditional techniques often taking weeks. A machine learning-based algorithm was then used to optimize the part manufacturability and tooling geometry. This enables to effectively improve part quality and production rate and will greatly benefit the manufacture and design of composite products such as aircraft fuselage, liquid hydrogen tanks and jet engine fan blades, etc.

Key words Advanced composites manufacturing; Tooling Design; Digital manufacturing; Machine learning optimisation

Session: Engineering Applications

Presenting Type: Oral−Virtual Platform

Study on the Interface Adhesion and Mechanical Properties of Elastomeric Composites Reinforced with NiTi Shape Memory Alloy

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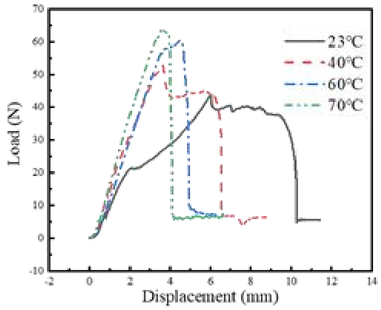
1. Hubei Key Laboratory of Theory and Application of Advanced Materials Mechanics, Wuhan University of Technology, China

2. Department of Engineering Structure and Mechanics, Wuhan University of Technology, China

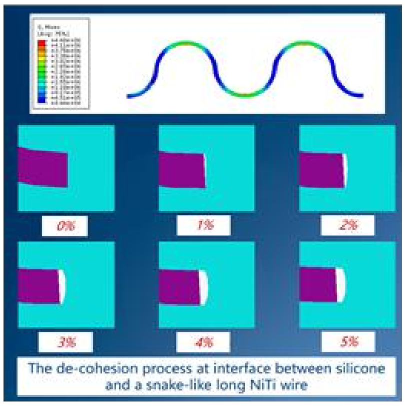
In order to investigate the interfacial mechanical behavior a novel composite made of shape memory alloy (SMA) and rubber elastomer under the temperature effect, a series of pull-out experiments on NiTi SMA wires within rubber matrix were carried out. As a result, the relationship between adhesion force and sample displacement of SMA/rubber composites at different temperatures were obtained, and the influence of environmental temperature in combination with pre-strain of SMA wire on its interfacial bonding performance with rubber matrix were analyzed. The experimental observations reveal that the phase transformation induced by temperature variation plays a significant role for the enhancement of mechanical and interfacial properties, mainly due to the recovery stress if the SMA wire was pre-strained. On the other hand, simulations employing finite element software have been developed, in which the constitutive equations of hyper-elastic elastomer and SMA were introduced and the cohesive damage law was taken into account. The large deformation and adhesion response in tensile loading of a snake-like NiTi wires textile, silicone elastomer matrix and their interface zone are studied numerically. From these computational results, it can be concluded that to better utilize the intrinsic properties of SMA reinforced elastomer, more effective improvements on its interface strength is necessary.

Key words SMA wire; rubber elastomer; interface behavior; temperature effect; finite element simulation



with 2.2% strain pre-stretch

Pull-out Test Results of Composite



Session: Engineering Applications

Presenting Type: Oral-Virtual Platform

Energy-Absorbing Mechanisms of Thick CFRP Structures for Railway Vehicles

Dongdong CHEN*、Xiaoyu Sun、Shoune Xiao
Southwest Jiaotong University

Thin-walled structures show excellent advantages such as high mechanical performance, ease of forming, and high lightweight efficiency. One of their typical applications is the energy-absorbing components, which can convert the collision energy during a crash event into internal energy in a controllable mode. Compared to their metallic counterparts, the composite structures, especially the ones made from plain woven carbon fiber reinforced polymer (CFRP), are often of higher energy absorption efficiency and have attracted extensive attention in the past few decades. However, most existing studies focus on the crashworthiness of CFRP structures with a thickness of less than 5 mm and a maximum mean crushing force of less than 100 kN. In practice, the requirement for CFRP energy-absorbing structures with a larger thickness and load-carrying capability exists in railway transportation. In this study, an experimental and numerical investigation was carried out to explore the crushing response of circular composite tubes reinforced by plain woven CFRP. Quasi-static and dynamic axial crushing tests were carried out for CFRP tubes with an inner diameter of 100 mm and a wall thickness of 12.4 mm. Experimental results show that increasing loading velocity leads to a 21.8% reduction of specific energy absorption (from 99.7 kJ/kg to 78.7 kJ/kg) but has a negligible influence on collapse failure modes. Finite element models are also established and validated against the experimental results via ABAQUS/Explicit software. The influences of several different parameters on the simulated results, such as the number of shell layers, frictional coefficient, and interfacial properties, were also investigated and analyzed.

Key words CFRP, Impact test, Energy-absorbing mechanisms, Numerical simulation, Crashworthiness design

Session: Engineering Applications

Presenting Type: Oral−Virtual Platform

Design and Verification of Multi-Layer Mechanical and Thermal Integrated Composite Plane Structure

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Beijing Institute of Spacecraft System Engineering

With the increasingly stringent requirements for thermal load-bearing and lightweight of structures in complex space missions, the mechanical & thermal integrated structure has attracted extensive attention. In this paper, a multi-level thermal integrated planar structure with a kind of "sandwich" structure composed of resin based carbon fiber composites panel and aluminum alloy honeycomb as the matrix, besides polyimide foam material as the main thermal bearing material is proposed. A mechanical and thermological coupling design method was adopted, which can meet the heat bearing boundary of -170 ~ + 135 °C and achieve the vacuum thermal conductivity of the plane structure normal up to less than 1.0 w/ (m · K). Meanwhile the first-order frequency of the structure was not less than 70Hz. The method has been verified by thermal vacuum and vibration tests. The test piece had no deformation before and after the thermal vacuum test, and the normal vacuum thermal conductivity of the structure is 0.52~0.88w/ (m · K); The structure had no damage before and after the vibration test, and the first-order frequency of the structure is 111hz. The test results showed that this integrated structural design method can realize the mechanical and thermal integrated design, furthermore the designed structure had process realizability, which has been applied to a spacecraft structural product.

Key words sandwich structure； resin based carbon fiber composites； polyimide foam； vacuum thermal conductivity.

Session: Engineering Applications

Presenting Type: Poster

Achieving High Cryogenic Absorption Energy in Nanocrystalline NiTiFe Alloy

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Materials with high energy absorption capacity have been demanded for numerous engineering applications. Particularly, cryogenic energy absorption is highly desirable for aerospace exploration applications. Meanwhile, increasing needs call for SMA-made components that function at cryogenic temperatures and over a wide temperature range while possessing high superelastic stress (σ_{Ms}). In this study, nanocrystalline NiTiFe alloy wire was fabricated. B2↔R reversible martensitic transformation was observed during cooling and heating. Superelasticity with a recoverable strain of ~8% was achieved at low temperatures from -196 °C to -50 °C. The stress hysteresis and absorption energy gradually increase with decreasing tensile temperature. The stress hysteresis increases to 702 MPa at liquid nitrogen temperature, and correspondingly, the absorption energy increases up to 35.9 (maximum) MJ/m^3. These functional properties are caused by B2+R↔B19' martensitic transformation. Moreover, it is found that the temperature dependence of the lower plateau stress ($d\sigma_{As}/dT$) is 3.8 MPa/°C, which is consistent with that in R→M transformation published before, while the temperature dependence of the upper plateau stress ($d\sigma_{Ms}/dT$) abnormally decreases with decreasing temperature and tends to be zero in cryogenic region. Such counterintuitive phenomena can probably be ascribed to stored elastic energy in B2 parent phase and R phase before loading. It is suggested that the stress coupling, pre-existing elastic energy, which hinders the forward transformation, can increase the upper stress plateau (σ_{Ms}), and decrease the lower stress plateau (σ_{As}), thus exhibiting large stress hysteresis and large absorption energy, which could be useful to design shape memory alloys for low temperatures and high energy absorption applications.

Key words NiTiFe; martensitic transformation; superelasticity

Session: Engineering Applications

Presenting Type: Poster

Grain size effect on thermoelastic martensitic transformations of NiTiNb alloy

Youyi YANG、Lishan Cui*、Daqiang Jiang
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Based on the thermoelastic transition from the parent phase (B2) to martensite (B19'), NiTi-based shape memory alloys have been widely used in many fields (such as aviation, medical, etc.). Further, grain size has a strong influence on the properties of materials (such as strength). The grain size effect on single B2 → B19' transformation in NiTi alloys has been reported. In recently years, some anomalous phenomena before transform, namely pre-martensitic transformation, have been found in NiTi matrix that rich in Ni or doped with the third element (such as Fe, Co, etc.). Some interesting phenomena, such as large thermal/stress hysteresis, have been reported in NiTi alloys due to the pre-martensitic transformation. Hence, the pre-martensitic transformation has received extensive attention. Nevertheless, the grain size effect of B2 → B19' transformation with pre-martensitic transformation has not been reported. In this study, the grain size effect on thermoelastic martensitic transformation of NiTiNb alloy was investigated. It was found that the B2 phase undergoes pre-martensitic transformation (forming a dual-phase composed of the parent phase and nano-domain) and B19' martensitic transformation two-step transformation, instead of the B2 → B19' transformation which is suppressed, during the cooling process with the decrease of grain size more than 45 nm. Then, the forward/reverse martensitic transformation temperature decreases (the former decreases with a higher degree) and the thermal hysteresis increases. With decreasing grain size an increasing energy barrier arises, the B19' martensitic transformation is completely suppressed and the pre-martensitic transformation only is observed in grains smaller than 45 nm.

Key words thermoelastic martensitic transformations, pre-martensitic transformation, energy barrier

Hangzhou, PR China 25-28 April, 2023

Session: Engineering Applications

Presenting Type: Poster

A damage localization and size quantification algorithm for CFRP composite structures using Lamb waves-based structural health monitoring

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School of Aerospace Engineering, Xiamen University

Carbon fiber reinforced plastic (CFRP) composite materials have captured extensive attention in aerospace and other industrial fields due to their extraordinary mechanical and in-service peculiarities. Accurately and quantitatively monitoring the damages in composite structures is very challenging, but important for assessing their integrity. In this paper, a damage location identification and size quantification method based on Lamb wave is proposed for CFRP composite laminates. A continuous hidden Markov model (CHMM)-based damage scaling factor together with a weighted average imaging algorithm is introduced to identify the damage location. To quantify the degree of structural deviation from the healthy state, the inconspicuous change of Lamb wave signal is converted to a CHMM-based damage scaling factor with significant change. Based on the damage scaling factors of all sensing paths, a weighted average imaging algorithm is performed to identify the most probable damage location. Besides, simultaneous interpreting the position of wave scattering sources from different sensing paths, the damage size can be estimated quantitatively. For the damage with an unknown shape, the damage size can be estimated by a damage contour algorithm using convex envelope of damage reflection points. Whereas for the damage with known shape, the accuracy of size quantification can be further improved by calculating the maximum inscribed n-polygon. Since the signals captured are usually contaminated with noise, a singular loci removal scheme based on an automatically updated boundary region constraint and points clustering, is adopted to eliminate noise reflection points away from the damage estimation center. Experiments on two CFRP structures (i.e. an ordinary flat plate and a curved stiffened panel) with multiple damage cases are conducted to substantiate the proposed technique. Results demonstrate that the proposed algorithm is capable of pinpointing both location and size of the damage in composite structures.

Key words CFRP composite structure, damage identification, Lamb wave signal, damage size quantification

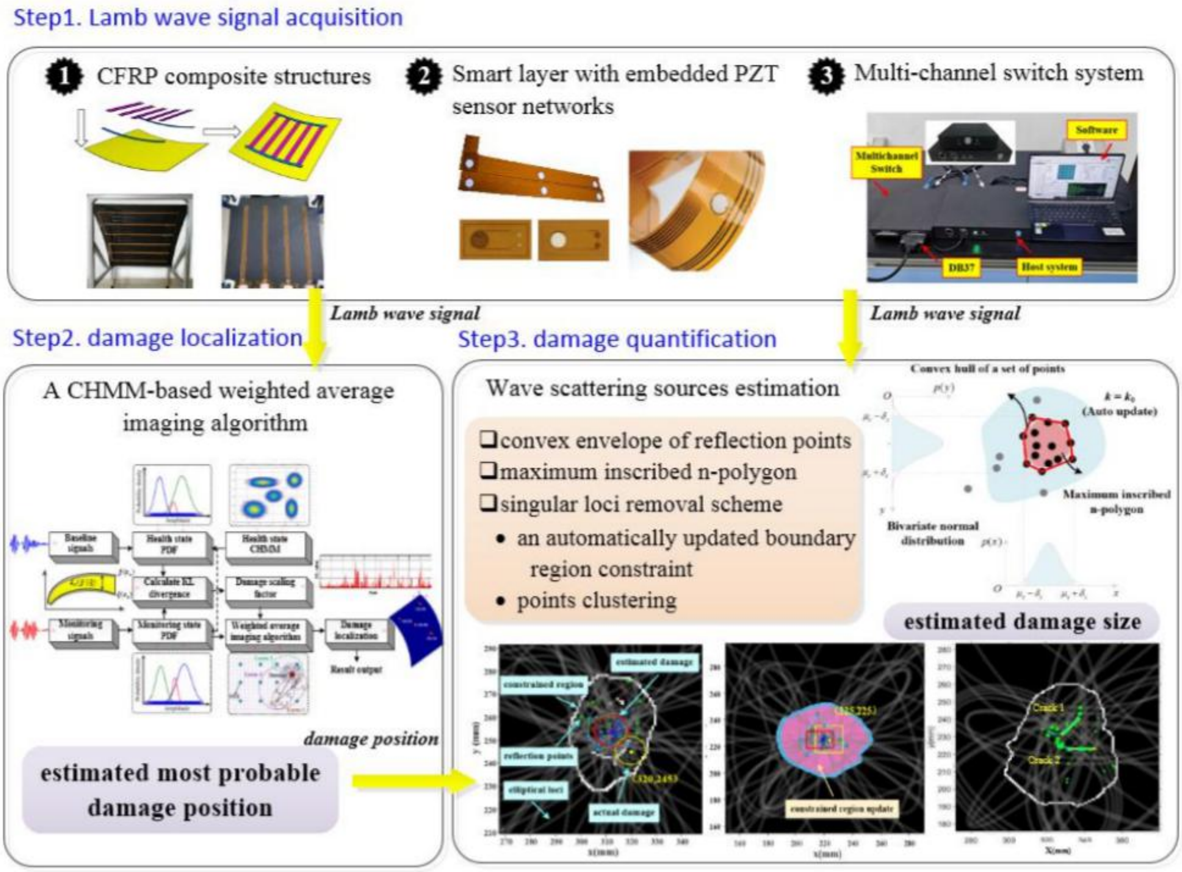

Fig. 1. The flowchart of Lamb wave-based damage localization and size quantification scheme.

Session: Engineering Applications

Presenting Type: Poster

Based on SrAl2O4:Eu2+, Dy3+ long afterglow luminescent composites, component optimization and performance evaluation

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With the continuous deterioration of energy consumption and environmental pollution, the development of new energy-saving and environmentally friendly materials and the improvement of existing material properties have become the focus of scientific and technological development. Long afterglow materials generally refer to a type of material that relies on excitation to store energy after the light excitation stops, and delays the luminescence phenomenon in a long time, and has been widely used in signage, switch signs, luminous coatings, etc., and has broad application prospects in transportation, fire protection, construction and other fields.At present, the study of long afterglow luminescent materials is still in the early stages, and the mechanism of light emitting is not yet clear, but there is sufficient evidence that the long afterglow phenomenon is closely related to defects in materials. Electrons emit light through thermal motion and hole compounding, and the afterglow follows the power law attenuation (I(t)~t-m)[2]. Therefore, the afterglow intensity of long afterglow materials decays rapidly, and the luminous intensity is difficult to maintain a high level over a long period of time, which greatly limits its application in areas such as luminous lighting. How to give full play to the lighting advantages of long afterglow materials, especially the long-term maintenance of large luminous intensity, is a necessary way to develop long afterglow materials.
$SrAl_2O_4:Eu^{2+}$, Dy^{3+} is one of the most widely used long afterglow materials, emitting a green afterglow sensitive to the human eye and a luminous time of more than 12h. Wiese et al. mixed $SrAl_2O_4$ with cement to prepare luminescent concrete for road marking and explored the relationship between afterglow intensity and excitation time. Studies have shown that when the excitation duration is 1min, the luminous intensity of the material reaches its maximum and no longer continues to vary with the increase of the excitation duration (excitation light source: 150 W xenon lamp). This shows that under a certain excitation strength, $SrAl_2O_4$ in the mixed material can be fully excited in a short period of time.
In this paper, $SrAl_2O_4:Eu^{2+}$, Dy^{3+} was selected as long afterglow luminescent materials, and PMMA with excellent optical properties was used as the matrix, and $SrAl_2O_4$/PMMA composite materials were prepared, and $SrAl_2O_4$/PMMA composites could maintain a large luminous intensity for a long time by means

of LED light source timing filling. Among them, timed light is not only used to re-excite long afterglow materials, but also plays a role in illumination. The LED light source with short-term light filling and the long afterglow material of long-term illumination alternate illumination can give full play to the advantages of long afterglow materials to achieve the purpose of energy saving, and have great application prospects in various lighting scenarios.

Key words $SrAl_2O_4$; Eu^{2+}，Dy^{3+}; long afterglow; PMMA

Session: Engineering Applications

Presenting Type: Poster

A Convolutional Neural Network for damage localization and quantitative characterization of composite materials .

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Composite materials have the advantages of high specific strength , fatigue resistance , light weight and so on . With the increasing use of composite materials in modern structure , the damage detection for carbon fiber plastics is always a hot topic , Structural health monitoring (SHM) have great significance to ensure the structural safety , reduce the maintenance cost ,and extend the service life , lamb wave-based damage detection is one of the most promising structural health monitoring technologies . Since the location and size of the damage will change the amplitude and phase of the damage signal , in this paper , a new method is proposed to transform damage signal into picture datasets containing signal pathway-amplitude and time information , according to the arrangement of the sensor network , the whole detection area is divided into several smaller sub-area , the signal is collected without damage and recorded as the baseline signal , then the absorbing adhesive of different sizes is pasted at different position in each area ,and the damage signal is obtained by the signal ,and the difference signal is obtained by subtraction with the previously collected healthy baseline signal . When the location and size of the damage changed , the picture change accordingly . A change in phase corresponds to a change in the location of the damage , and the change in color depth represents the change in amplitude which corresponds to the change of damage size . Using Convolutional Neural Network (CNN) can identify the change in these images , and use its powerful image classification ability to classify the damage images ,and achieve the purpose of damage location and quantification .

Key words Structural health monitoring; Convolutional Neural Network; damage location; damage quantification

Hangzhou, PR China 25-28 April, 2023

Session: Engineering Applications

Presenting Type: Published only

Research on test and simulation analysis of blunt trailing edge bonded structural components of wind turbine blades

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In the structural design of wind turbine blades, the structural design of the trailing edge is very critical.Especially for blunt trailing edge blades, it is more and more common for wind turbine blades to fail during operation or test verification due to unreasonable structural design.Because the structure of the trailing edge is relatively complex, its bearing capacity has a great relationship with the geometry and structural design. Therefore, the detailed analysis of the structure of the trailing edge is very important.In order to obtain the strain distribution and failure characteristics of the blunt trailing edge bonded structure during loading, we carried out component-level testing and simulation analysis.In this paper, the blunt trailing edge structure of the 60m-class blade is selected and designed as an L-shaped sample including the bonding area.In the simulation analysis, the details of the blunt trailing edge structure are built into the two-dimensional model, and the strain response of the blunt trailing edge under specific load conditions is analyzed and compared with the test to prove the accuracy of the model.Through the analysis of simulation and test, the strain response characteristics of each area of the blunt trailing edge bonded parts under load and the failure mode of the trailing edge are clarified. At the same time, the structural design suggestions for the blunt trailing edge are also given in this paper.The research results in this paper provide basic data for the structural design of wind turbine blades.

Key words blunt trailing edge, component-level testing, simulation analysis

Session: Engineering Applications

Presenting Type: Published only

Research on the application of high performance fiber-glass pultrusion girgder in wind turbine blade

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Sinoma Wind Power Blade Co., Ltd

Large blades, high towers and customized design of wind farms" has become a typical development trend of wind power in the era of parity. As the core component of wind turbine to capture wind energy, the performance and cost of blades have a decisive impact on the cost of electricity in the whole life cycle of wind turbine. The development of large-scale, lightweight and low-cost blades has brought severe challenges to materials, processes, design and verification. The conventional glass fiber pouring technology can not meet the requirements of improving structural performance. Based on the development of high modulus glass fiber and the application of pultrusion process, a high-performance glass fiber pultrusion plate with a tensile modulus greater than 62Gpa was developed, which can provide higher rigidity for the blade and reduce the blade weight by more than 500kg. The width and thickness of different plates have a great influence on the structural efficiency of the blade; The integrated infusion of pultruded fiberglass girder and skin greatly improves production efficiency. Combined with the "building block" test verification, it is pointed out that the pultruded glass fiber main beam blade is an effective means to solve the lightweight and highstrength design of large blades.

Key words pultrusion girgder, lightweight, highstrength

Session: Engineering Applications

Presenting Type: Published only

Application of Impulse-cyclone Airflow Drying in Wood-based Composites

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2. Universiti Malaysia Kelantan

Wood fiber/wood flour drying is an important pretreatment process of wood-based composites. The current drying methods are characterized by long drying time and high energy consumption, which do not conform to the strategic decision of developing low-carbon economy and sustainable industrialization in China. In this paper, the new features of the development of impulse-cyclone airflow drying equipment were discussed. The feasibility of using this technology as a new type of heat treatment energy-saving and environmental-friendly equipment was outlined in the industry, and case studies were conducted. The artificial neural network model was used to predict the drying water content of wood flour, and the CFD model was used to continue the optimization of the equipment to improve the drying efficiency. Finally, the future research directions are prospected and discussed.

Key words Impulse-cyclone Airflow Drying; Wood-based Composites; Wood flour; Moisture Content; Optimization

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Engineering Applications

Presenting Type: Published only

Synergistic effect of magnesium oxysulfate whisker and intumescent flame retardant on flame retardancy and mechanical properties of glass fibre reinforced polyethylene composites

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The intumescent flame retardant (IFR) contained ammonium polyphosphate (APP) and poly(1,3-diaminopropane-1,3,5-triazine-o-bicyclic pentaerythritol phosphate) (PDTBP), and organic modified magnesium oxysulfate whisker (OMOSw) synergist formed synergistic flame-retardant system (IFR/OMOSw), which could improve the flame retardancy and mechanical properties of the continuous glass fibre reinforced polyethylene (GFPE) composites. The flame retardancy of GFPE/IFR/OMOSw composites increased first and then decreased with the increase of OMOSw synergist loading. The synergistic flame-retardant system (IFR/OMOSw) could produce intumescent char layer covered on glass fibre surface, which reduce the wicking actions of glass fibre. The mechanical properties (tensile strength and Mode I interlaminar fracture toughness) were improved after adding OMOSw synergist, except for the flexural strength with no obvious change. The GFPE/IFR/OMOSw composite had the best comprehensive performance when the matrix contains 24 wt% IFR/6 wt% OMOSw compared to GFPE composite containing 30 wt% IFR.

Key words Polymer-matrix composites, Fracture toughness; Intumescent flame retardant, Synergist, Flame retardancy

Session: Biomedical Applications

Presenting Type: Oral-Invited

Novel Functional Bacterial Cellulose composites used for Tissue Regenaration and Repair

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University of Science and Technology Beijing

Bacterial cellulose, with unique structural features, physicochemical properties and impressive biological characteristics, is widely used in biomedical fields. In our recent studies, a set of technologies, including self-crosslinking, in-situ composite, in-situ template-growth method, were used to introduce active chemical groups, bioactive molecules, nanoparticles and conductive polymers to BC matrix, so as to achieve its applications in wound healing, nerve repair and urethral repair. (1) A novel composite was prepared by introducing polyethylene glycol and polyhexamethylene biguanidine into BC matrix. The composite exhibited high transparency, water retention ability, flexibility as well as good anti-adhesion property. Moreover, it displayed excellent biocompatibility and strong and sustained antibacterial effect. And it could efficiently promote skin wound healing and regeneration in a rat model. A bifunctional group modified bacterial cellulose was prepared by carboxymethylation and selective oxidation. Further, the chitosan was compounded in the network of DCBC by self-crosslinking to form dialdehyde carboxymethyl bacterial cellulose/chitosan composite. The composite exhibited excellent antibacterial activity and promoted proliferation and migration of HUVEC. Moreover, it could accelerate healing of deep II degree scald wounds of Bama miniature pig through epidermal growth and collagen production.(2) A multiblock conductive nerve scaffold with self-powered electrical stimulation was prepared by in situ polymerization of polypyrrole (PPy) on the nanofibers of BC. Platinum nanoparticles were electrodeposited on the anode side for glucose oxidation, while nitrogen-doped carbon nanotubes (N-CNTs) were loaded on the cathode side for oxygen reduction. The scaffold showed good mechanical property, flexibility and conductivity. Dorsal root ganglions cultured on the scaffold showed significantly longer neurite outgrowth than those on the BC/PPy group. And the scaffold promotes nerve regeneration of rats. BC/poly(3,4-ethylenedioxythiophene)-sulfonated nanofibers composite was prepared through the in-situ polymerization of PEDOT and the doping of SNFs in BC matrix. The polymerization of PEDOT endowed BC with conductivity, making the membranes conducive to the adhesion and proliferation of adipose-derived stem cells. The membrane exhibited great biocompatibility, high conductivity , and greatly improved the peripheral nerve repair of rats. strength. (3) A double-modified bacterial cellulose/soybean protein isolate (DMBC/SPI) using as urethral tissue engineering scaffold was prepared. The scaffold displayed good biocompatibility and biodegradability. In vitro, DMBC/SPI promoted cell adhesion, cell proliferation, and guided directional growth of stem cells. In vivo, it enhanced the urethra tissue repair and did not cause a inflammatory response. These studies show the functional diversity of BC composites and the bright prospect of clinical application in human body.

Key words Bacterial cellulose, Tissue Regenaration, composites, functional, modified

Session: Biomedical Applications

Presenting Type: Oral-Onsite

3D Printing of MXene-Encapsulated Nanocomposites

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Vat polymerization-based 3D printing is often applied to fabricate objects with porcelain structures using photosensitive resins (PSR). Currently, the applicability of 3D printing depends on the raw material selection, while the current 3D-printed workpieces based on vat polymerization often suffer from inherent shortcomings in practical applications, such as mechanical properties, thermal stability, and functionality, requiring improved material performance. The introduction of nano-fillers is an effective way to improve the performance of the printed object. We prepared nanocomposites by incorporating Ti_3C_2 MXene nanosheets to enhance the overall characteristics of a PSR, including mechanical properties and thermal resistance. The mechanical properties of the designed nanocomposites confirmed the enhanced ultimate tensile and flexural strengths and modulus. Moreover, the incorporated MXene presented no substantial influence on the toughness of the PSR. The glass transition and thermal degradation temperatures increased as well, resulting predominantly from the hydrogen bonding between the PSR and MXene. In addition, the elastomer based on encapsulating 3-(trimethoxysilyl)propyl methacrylate-modified MXene nanosheets in a photocurable polyurethane acrylate resin (PAR) matrix was fabricated by digital light processing 3D printing. The mechanical properties of the elastomers could be tuned by varying the MXene amount in the PAR. Piezoresistive sensors and wearable finger guard sensors, with long-term working stability, were fabricated by coating a MXene-based hydrogel on the surface of the 3D-printed structural parts. Together, our findings provide a new paradigm for the overall design of 3D-printed nanocomposites with excellent performances, which are anticipated to expand the scope of 3D printing.

Key words 3D printing; Vat polymerization; Nanocomposite; MXene

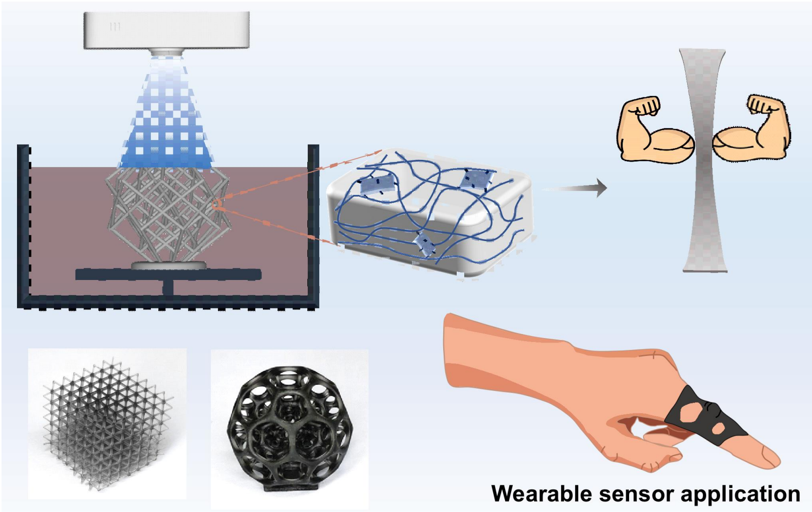

Fig. 1. Schematic illustration of the MXene-encapsulated Nanocomposites from vat polymerization.

Session: Biomedical Applications

Presenting Type：Oral-Onsite

Biomimetic Elastomers, Their Composites and 3D Printing for Diverse Medical Applications

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Aiming at the bottleneck problems that the widely used biomedical elastomers are difficult to mimic the mechanical and self-healing properties of natural tissues, and difficult to be processed, we have carried out systematic studies. A multi-bond interaction molecular mechanism of synergistic strong bonds and weak bonds has been proposed. Synergistic three mechanisms of "mechanically invisible" weak bonds and forming copper coordination bonds for strengthening and catalyzing the recombination of dynamic covalent bonds constructs a multi-bond hybrid cross-linking molecular network, which solves the conflict that high mechanical strength, low modulus, and self-healing are difficult to balance. This work provides a universal molecular design for the development of soft, strong, and self-healing bionic elastomers. A general processing strategy of "creating strength from weakness" in synergetic multi-bond systems is proposed. Utilization of the weak non-covalent interaction between food materials and polymers forms a strong covalently cross-linked network, which overcomes the difficulty of thermoset elastomers processing. Accordingly, a series of new medical devices based on elastic composites with outstanding performance for tissue engineering and biomedical flexible electronics have been fabricated.

Key words elastomers, dynamic bonds, self-healing, 3D printing, tissue repairing

Session: Biomedical Applications

Presenting Type: Oral-Onsite

Laser Induced Gradient Hydrophobic Surface with Lower Flow Resistance for Improved Hemocompatibility

Quanchao ZHANG*、Honglin Luo、Yizao Wan、Quanchao Zhang
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Blood contacting materials with anti-thrombotic surfaces are highly demanded in clinics [1, 2]. Despite considerable research on surface modifications, limited progress has been made on effective prevention of thrombosis for artificial implants such as mechanical valve prosthesis. Herein, wettability gradient surface, which can ideally exhibit low flow resistance and good hemocompatibility was developed for potential reduction of thrombosis. In this work, the gradient hydrophobic surfaces on both nickel-titanium (NiTi) alloy and pyrolytic carbon (PyC) were prepared by the combination of laser etching technology and low surface energy molecules self-assembly approach, respectively. Scanning electron microscopy (SEM) observation confirms that the gradient hydrophobic surfaces are composed of different microstructures (regular pores or parallel ridges). The two gradient hydrophobic surfaces show spontaneous droplet motion and much lower flow resistance than their bare materials, respectively. Compared to their bare materials (NiTi and PyC), the two gradient hydrophobic surfaces show the corresponding better blood compatibility and anti-adhesion performance. The results presented in this paper confirm that creating a gradient hydrophobic surface with lower flow resistance is an effective way of achieving the improved hemocompatibility.

Key words Gradient hydrophobic surface; Laser etching; Flow resistance; Blood compatibility

Session: Biomedical Applications

Presenting Type: Oral-Onsite

Electroconductive and Instant Bioadhesive Janus Hydrogels for Bioelectronics

Huiqi SUN、Rongguo Wang*
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Bioadhesives such as tissue adhesives have potential advantages over sutures and staples for wound closure. Still, the low conductivity, the typical double-sided adhesives fail to severe as electrical conductors, which can transmit real-time physiological signals, thus severely limiting their applications in bioelectronics. Despite significant advances, flexible bioadhesives with transparency, high conductivity, low toxicity, high mechanical match with tissue, and quick adhesion formation in wet environments are uncommon. Herein, based on one side dipping method, a facile but efficient strategy, novel biocompatible and instant adhesion Janus adhesives are prepared. The dipping side of the surface is low adhesion due to the neutralization of carboxyls. Interestingly, adjusting the one side dipping time can regulate the conductivity of hydrogel without affecting the other side's adhesion behavior. Furthermore, the Janus hydrogel exhibits excellent adhesion properties, which possess a conformal and seamless hydrogel-tissue interface, leading to interfacial toughness values over 600 J/m2.The Janus hydrogel's mechanical properties are similar to living tissue, which can minimize the foreign body sensation or damage between electronics and tissue. Excellent biocompatibility of the Janus hydrogel is confirmed through a cell cytotoxicity test using NIH3T3 cells. The relative cell viability was almost 100%. The Janus hydrogel has demonstrated that it is helpful for internal tissue/organ repair and improves tissue-electronic sensibility. It is promising to serve as next-generation human-electronic interface materials bioelectronics.

Key words bioadhesives, Janus, tissue-electrode interface, conductive hydrogels, wet adhesion

Session: Biomedical Applications

Presenting Type：Oral−Onsite

Zwitterionic Materials for Bone Tissue Engineering

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Zwitterionic mateirals is a new type of well-recognized synthetic antifouling materials. During the past two decades, numerous zwitternic surfaces & interfaces have been developed for improving the antifouling ability of diverse substrates. However, the antifouling is still the focus of the exploitation of zwitterionic materials for biomedical applications. From the chemical structure point of view, we find that zwitterionic polymers (equal amount of oppositely charged residues in each repeat unit) is a high-efficieny biomineralization ligands. In addition, the ionic nature of the zwitterionic materials can enable hih-efficiency delievery of BMP-2.

Key words zwitteironic materials, bone tissue engineering, controlled release, biomineralization.

Session: Biomedical Applications

Presenting Type：Oral-Onsite

Research on mechanical properties of multilayer micro-lattice biomaterials for skull repair

Yang Zhao、qianqian Wu*、linzhi Wu
Harbin Institute of Technology

Developing skull repair biomaterials are crucial for clinical biomedical applications. To overcome problems of current skull repair biomaterials, the novel method with micro-lattice design is proposed based on skull structural characteristics for skull repair and its feasibility is implemented by designing the multilayer micro-lattice skull repair biomaterials (MBs) combining both suitable mechanical properties and biocompatibility. The quasi-static compressive and flexural mechanical properties of MBs are studied experimentally, numerically and theoretically. The compressive strength and modulus of the above MBs specimens are in the range of 86.72 ± 0.84 to 197.73 ± 0.74 MPa and 2.99 ± 0.13 to 7.56 ± 0.54 GPa, respectively. The flexural strength, stiffness and fracture toughness of MBs are in the range of 251.56 to 437.91 MPa, 6.63 to 10.63 GPa and 0.262 to 0.416 MPa m1/2, respectively. Comparing with human skull specimens, the MBs match well in the quasi-static mechanical properties. Since the designed MBs have mechanical properties and density comparable to that of skull and suitable biological space for cell growth, it can be implanted into the human body to matched surrounding skull tissue well. The insight of MBs combining with design constraints of biomaterials provides a novel method for designing/tuning skull repair biomaterials that might result in the optimized clinical skull surgery effect.

Key words Biomaterial, Mechanical property, Multilayer micro-lattice, Theoretical analysis, Simulation

Session: Biomedical Applications

Presenting Type: Oral-Onsite

Respiration monitoring for infant health utilizing flexible pressure sensor with high stability achieved via nanostructure interlock

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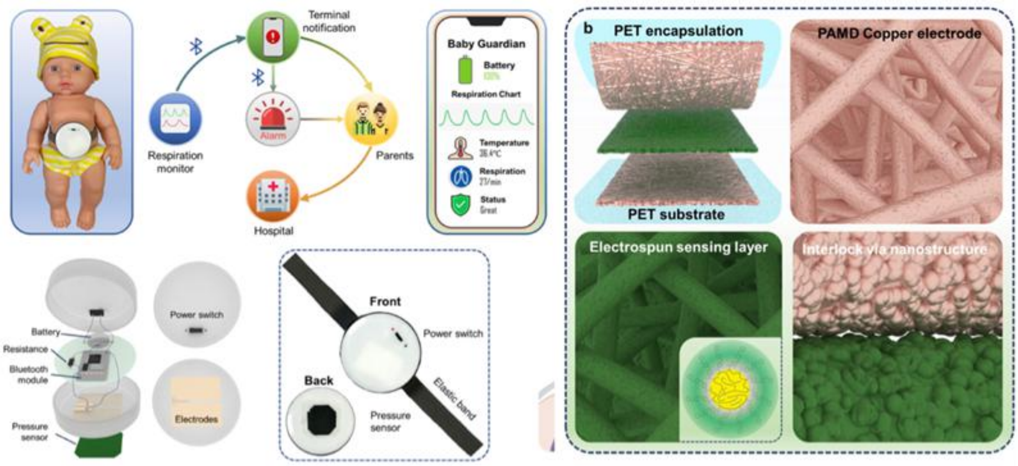
The monitoring of respiration has been a significant assistive maneuver for the health care of infants to avoid sudden death. Herein, continuous monitoring of infant respiration is demonstrated using high-performance flexible pressure sensors enabled by fibrous PANI@(PLA-PBAT) composites. The flexible pressure sensor presented high sensitivity (45.5 kPa-1), outstanding recoverability and static/dynamic stability (30000 s/10000 cycles). The signal drift was further suppressed utilizing fibrous copper electrodes via the nanostructure interlocking mechanism between PANI@(PLA-PBAT) fibers and Cu@PAI fibers. The prototype of respiration monitoring system was developed with integrated body-temperature measurement and wireless communication. Instant feedbacks including buzzle alarms and phone notifications are implemented when abnormal status is detected such as respiratory arrest and tachypnea.

Key words Infant sudden death syndrome, health monitoring, respiration monitor, flexible pressure sensor



Session: Biomedical Applications

Presenting Type: Oral-Onsite

Supercritical Antisolvent Technology Assisted Fabrication of ICG-Based Composite Nanoparticles and Their Biomedical Applications

Peiyao XU、ranjith kumar Kankala、shi bin Wang、ai zheng Chen*
Institute of Biomaterials and Tissue Engineering, Huaqiao University

Indocyanine green (ICG) is a commonly near infrared (NIR) imaging agent in clinical, with outstanding phototherapy performance for tumor diagnosis treatment and therapy, as well as bacterial infection. However, ICG suffers from multiple shortcomings of poor aqueous instability in the physiological environment, short half-life and rapid body clearance, which often hinder its clinical biomedical application. Although impressive progresses in nanocarrier were made toward a joint goal that improved outcomes of ICG, the low drug loading efficacy and sophisticated construction process remain significant challenges in the production of nanoplatform.

According to the unique advantages of supercritical antisolvent process (SAS) and solution casting method, we firstly developed a novel approach to obtain ICG-loaded nanoparticles (ICG-PLO NPs), which was fabricated via coating of SAS produced-ICG nanoparticles (ICG NPs) by polypeptide poly-L-ornithine (PLO). This unique nanoplatform with ultra-high drug encapsulation efficiency exhibited remarkably improved aqueous and photothermal stability of ICG. Notably, the coating of PLO could improve the internalization level in cells and anticancer effect *in vivo*, which has comprehensively augmented the cancer phototherapy effect of ICG.

Based on the simple, fast, and low-cost fabrication process, a versatile nanoplatform based on chitosan coated ICG and luteolin (ICG/LUT-CS) was also developed for the chemotherapy-photothermal treatment of *S. aureus*-infected skin wounds. Under NIR excitation, ICG/LUT-CS performed excellent hyperthermia activity for damaging cell integrity and reducing drug tolerance of bacterial biofilms. Moreover, the photothermal effect significantly accelerated LUT release, damaging the intercellular protection system of bacteria and facilitating LUT delivery into biofilms. This synergistic chemotherapy-photothermal eradication of bacterial and biofilm strategy displayed outstanding potential in reinforcing the therapeutic efficacy *in vivo* and *in vitro* and diminishing the side effects. Overall, this novel particle formation integrated strategy broadened the applications of SAS technology, which enlighten the design of nano-formulations containing ICG for clinical translation.

Key words Indocyanine green; Supercritical fluid; Composite nanoparticles；Phototherapy

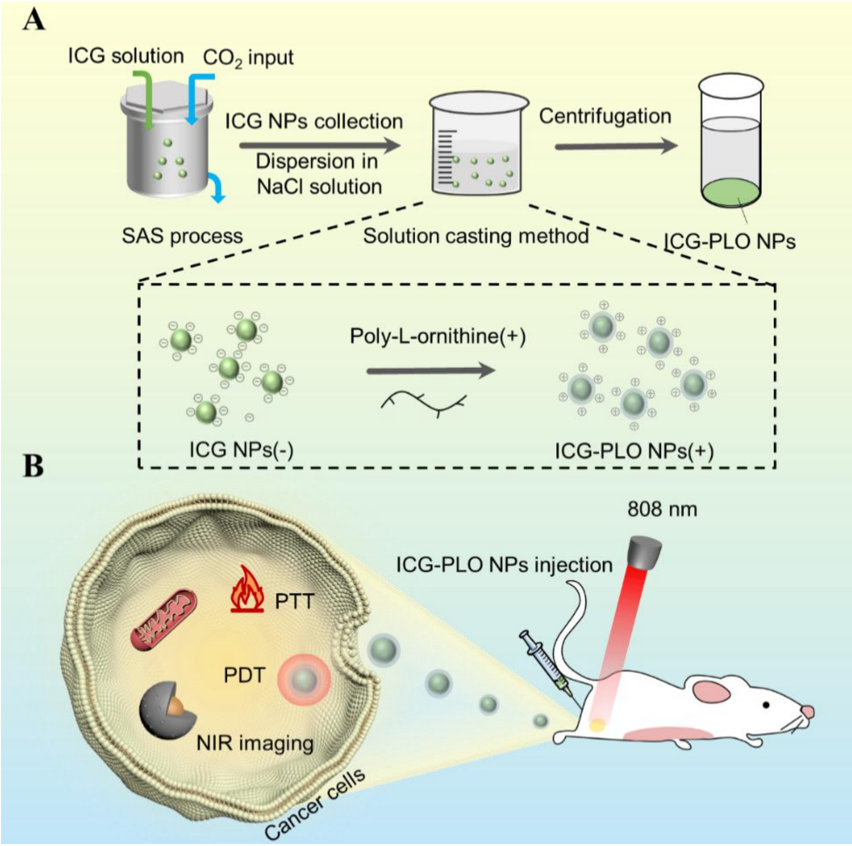


Fig. 1. (A) The fabrication process of ICG-PLO NPs and (B) the photothermal and photodynamic therapy for cancer cells.

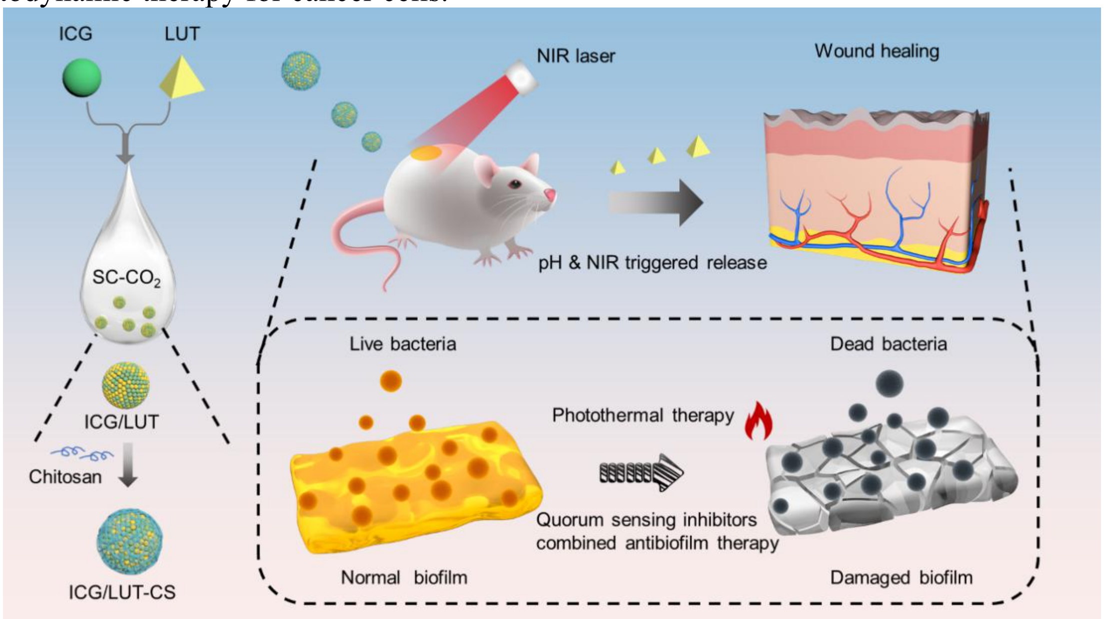


Fig. 2. Schematic illustration of the development process of ICG/LUT-CS and synergistic chemo-/photothermal-therapy for antibiofilm and antibacterial treatments.

Session: Biomedical Applications

Presenting Type: Oral-Onsite

In Vivo Degradation Behavior of Magnesium and Its Alloys Under Controlled Loading Conditions for Orthopedic Implants

Xuanbin Zhang、Long Guo、Zhixiu Hao*
Tsinghua University

Magnesium and its alloys have been identified as a promising material for repairing large segmental bone defects due to their mechanical properties similar to those of bone tissue. However, the in vivo degradation behavior of magnesium under controlled loading conditions has not been fully understood. In this study, animal experiments were conducted to validate existing degradation models and analyze the correlation between changes in surface morphology and degradability. New Zealand White rabbits were used as animal subjects, and a loading device was designed and mounted on the rabbits for controlled loading conditions. Samples were obtained under both cyclic and constant loading conditions, and surface morphology analysis was performed using Micro-CT, field scanning electron microscopy, and energy spectroscopy. The results showed that the rate of degradation of the magnesium block under cyclic loading was significantly higher than under constant loading in the in vivo environment. The appearance of surface morphological structures in vivo differed from those degraded in vitro. The application of load accelerated the formation of pores and crevices on the surface of magnesium materials, increasing the material's susceptibility to corrosion of internal substances and accelerating the rate of degradation. These findings provide valuable insights for the design and development of new generation magnesium-based orthopedic implants.

Key words animal experiments; magnesium materials; magnesium degradation model; surface appearance

Session: Biomedical Applications

Presenting Type: Oral-Virtual Platform

Evaluation of Surgical Treatment of Spinal Deformity using Pedicle Screw Fixation System with Carbon/PEEK Composite Rods

Heoung Jae CHUN*、Min Jong Lee、Hye-Sung Seo
Yonsei University

The number of spinal disease patients is growing. However, biomechanical researches on some spinal diseases and their treatments are scarce. Nowadays, finite element method is applied in a variety field of biomedical applications such as evaluation of surgical treatment and design of suitable prosthesis. Since the advent of the pedicle screw fixation system, posterior lumbar fusion has become a very popular procedure for the treatment especially of spinal deformities, because pedicle screws can provide robust initial stability and lead to higher lumbar fusion rates when compared to those of uninstrumented lumbar fusions. However, even though many previous studies have reported excellent surgical results with instrumented lumbar fusion for spinal deformation diseases, the robust stiffness of titanium rods might lead to an increase in the stress concentration at the adjacent segment and stress shielding effect after fusion, which could be a candidate risk factor for adjacent segment degeneration and fusion. Even though fusion affects the motion and disc stress of the adjacent segment, there are significant questions that remain. In this presentation, the positive influence of stiffness of the carbon/PEEK composite rod of pedicle screw fixation system was investigated in the view of biomechanical behaviours. The finite element method and statistical analysis were adopted for the patient specific study. It was concluded that the proposed patient specific approach for the evaluation is very useful for the research and treatment of lumbar diseases.

Key words Biomechanics, Finite element method, Computer-aided engineering, Lumbar kyphosis

Session: Biomedical Applications

Presenting Type: Oral-Virtual Platform

Poly (Amino Acid) Based Injectable and Self-Biodegradable Hydrogel

Kuan YANG、Xinyi Zhao、Yongmei Chen*
Shaanxi University of Science and Technology

As semi-synthetic polymers combined both the advantages of natural macromolecules and synthetic polymers, poly(aspartic acid) is a protein derivative dangling amide bonds. Herein, we report a semi-synthetic hydrogel based on poly(aspartic acid) via in-situ gelation. The hydrogel is composed of aspartic acid molecules attached by peptide bonds, providing remarkable biodegradability and biocompatibility. The degraded small molecules of amino acids from the poly(aspartic acid) based hydrogels are non-immunogenic, and can finally be excreted or absorbed in physiological processes by the human body. This work highlights competitive candidate and great potential of the hydrogel in a minimally invasive approach for biomedical applications.

Key words Injectable；Self-biodegradable；Hydrogel

Session: Biomedical Applications

Presenting Type：Oral–Virtual Platform

Fabrication of A Modified Bacterial Cellulose with Different Alkyl Chains and Its Prevention of Abdominal Adhesion

Yajie Xie*、Yajie XIE*、Huiyi Yang、Wenbo Liu、Miaojie Shi、Junfei Li、Yudong Zheng
University of Science and Technology Beijing

Abdominal hernia mesh is a common product which is used for prevention of abdominal adhesion and repairing abdominal wall defect. Currently, designing and preparing a novel bio-mesh material with prevention of adhesion, promoting repair and good biocompatibility simultaneously remain a great bottleneck. In this study, siloxane with different alkyl chain length was grafted to regulate the surface properties of BC by a direct, simple and convenient method, and then the cell adhesion and proliferation of BC surface were regulated, which plays a vital role in anti-adhesion of BC on a tissue patch. The hydrophilic and hydrophobic properties and cell adhesion behavior of the surface of the siloxane-modified BC can be regulated by grafting siloxane with alkyl chains of different lengths. The microstructure, mechanical properties, surface roughness and hydrophilicity of the siloxane-modified BC were characterized, and cell behaviors were studied with normal human dermal fibroblasts (NHDF). The cell cytoskeleton and expression of Collagen-I in NHDF have also been analyzed by immunofluorescence assay. The intraperitoneal mesh model and abdominal wall muscle hierarchy defect model in rats was used to evaluate the histocompatibility of this biomaterial, and its potential application as hernia repair material. To our knowledge, this is the first example to adopt a novel silylation method to grafted siloxane with alkyl chains of different length on BC surface and to explore the effects on cell adhesion, proliferation and prevention of abdominal adhesion systematically. By observing cell proliferation and morphology, the grafted siloxane can reduce the adhesion of cells greatly, and less and less cells attached on the surface of the siloxane-modified BC when the alkyl chains of siloxane increased. BC-C16 sample showed the most obvious anti-adhesion effect. For the total area of cell adhesion, the value of BC-C16 sample can be reduced to up to 76 times comparing to BC. Moreover, the cell immunofluorescence staining indicated that the grafted siloxane won't influence the expression of Collagen-I. The BC-C16 exhibits excellent anti-adhesion and biocompatibility in the intraperitoneal mesh model and abdominal wall muscle hierarchy defect model in rats. Our study highlights the importance of the siloxane-modified BC in regulating material surface properties, cell adhesion, cell proliferation and abdominal anti-adhesion.

Key words Bacterial cellulose, Silylation, Fibroblasts, Anti-adhesion, Abdominal cavity

Session: Biomedical Applications

Presenting Type: Poster

Heat-stimuli shape memory effect of poly (ε-caprolactone)-cellulose acetate composite tubular scaffolds

Hao Wang[1]、Hong Xia[1]、Zhenzhen Xu[2]、Baoji Hu[1]、Toshiaki Natsuki[1]、QingQing Ni*[1]
1. Shinshu University
2. Anhui Polytechnic University

Small-diameter artery disease is the most common clinical occurrence, necessitating the development of small-diameter artificial blood vessel. PCL-CA (poly(-caprolactone)-cellulose acetate) composite nanofiber membranes were prepared with PCL and CA（The ratio of PCL to CA is 3:1). A smooth stainless-steel mandrel with a diameter of 4 mm was used to roll up the prepared nanofiber membranes to produce the tubular scaffold with 50°C hot water. The tubular scaffolds were subjected to axial and circumferential tensile tests. The mechanical performance of the PCL-CA tubular scaffold could be improved by increasing the layers. In addition, the burst pressure of the tubular scaffolds was increased with the layers, and the burst pressure of 6-layers (2380 ± 36.8 mmHg) and 8-layers (3720 ± 80.5 mmHg) tubular scaffold were much higher than the human saphenous vein(2000 mmHg). The compression shape memory performance of the PCL-CA tubular scaffold with different layers was also investigated to simulate and analyze the contraction and expansion of tubular scaffolds. The experimental results showed that the compression strain of the tubular scaffold in the diameter direction reached 35%, and the ultimate shape recovery rate reached 87%. However the shape fixity rate and shape recovery rate increased, demonstrating that the optimum number of layers can improve the compression shape memory performance of the tubular scaffold. The tubular scaffold had the auto-recovery property during the recovery process, meeting the contraction and dilation requirement of the vessel. What is more, the tubular scaffolds could be recovered by the temperature stimulation, which can be used in repairing the vessel or improving the thrombus.The results of this study, including comprehensive morphological, mechanical properties, and shape memory properties, indicated the potential applicability of PCL-CA tubular scaffolds as tissue engineering grafts.

Key words electrospinning; small-diameter; tubular scaffold; shape memory

Session: Biomedical Applications

Presenting Type: Poster

Surface porous poly-ether-ether-ketone based on three-dimensional printing for load-bearing orthopedic implant

Shuai Li、Bing Wang*
Harbin Institute of Technology

Poly-ether-ether-ketone (PEEK) possesses excellent biocompatibility and similar elastic modulus as bones but yet suffers from poor osseointegration. In order to balance PEEK's mechanical and osseointegration properties, a novel surface porous PEEK (SP-PEEK) is successfully fabricated by fused deposition modelling three-dimensional printing (FDM 3DP) and characterized by mechanical and osteogenesis in vitro tests. Moreover, the effects of pore diameter and pore layer number on the mechanical behaviors of SP-PEEK are investigated by theoretical model and numerical simulation. Comparison among experimental, theoretical and simulation results show good agreement. As pore diameter decreases, the equivalent strength and modulus become more sensitive to the decrease of pore layer number. In addition, the SP-PEEK exhibits the mechanical properties within the range of human trabecular bone and cortical bone, and thus can be tailored to mimic human bone by adjusting the pore diameter and pore layer number, which is benefit to mitigate stress shielding. The effects of pore diameter on the cell proliferation and osteogenic differentiation of SP-PEEK are tested by the co-culture of osteoblast precursor cells (MC3T3-E1) and SP-PEEK round discs. Results showcase that porous surface improves the osteogenesis in vitro, and the SP-PEEK group that the pore diameter is 0.6 mm exhibits optimal-performance osteogenesis in vitro.

Key words surface porous; poly-ether-ether-ketone; three-dimensional printing; load-bearing orthopedic implant.

Session: Biomedical Applications

Presenting Type: Poster

Synthesis of fluorinated urchin-like serried hydroxyapatite with improved water sorption-solubility and bioactivity for dental composites

Hongyan Chen, **Junjun Wang**, Ruili Wang, Meifang Zhu

Donghua University

Abstract： Light-curable resin composites have been widely applied as dental restorative materials due to their excellent physicochemical property and attractive clinical properties over amalgam alloys. However, the restoration fracture and secondary caries are still the main causes for repair failure. Previous work confirmed that inorganic fillers play a pivotal role on improving the physicochemical properties of dental composites. Based on our previous studies, the urchin-like serried hydroxyapatite (UHA) presented excellent bioactive properties and reinforcing effect, which attracts wide attention in dental materials. However, the synthesized UHA particles contain hydroxyl groups, making them easy to absorb water molecules and decrease the mechanical properties of dental composites in the oral environment. Fluorine is present in the hydroxyapatite mineral in natural tooth enamel, which plays a key role in the prevention of dental caries. The aim of this study is to synthetize the fluorinated urchin-like serried hydroxyapatite (FnUHA) particles with different degree of fluorine substitution and explore the effect of the fluorine element on the water absorption-solubility, mechanical strength, and biological activity of dental composites. The obtained FnUHA particles were further modified with 3-methacryloxypropyl trimethoxysilane (γ-MPS) to get the silanized FnUHA (SFnUHA) particles, which were then used as the reinforcement for dental composites. The morphology, compositional elements, and structure of the

FnUHA were characterized by FE-SEM, TEM, XPS, XRD, and FTIR, respectively. The mechanical properties of the SFnUHA reinforced dental composites with different filler loadings were measured with a universal testing machine. The results demonstrated that the 50 wt% SF5UHA filled dental composite exhibited the acceptable flexural strength and compressive strength, giving the respective improvements of 56% and 31% compared with those of the 50 wt% UHA filled composite. In addition, this composite also presented the lower water absorption-solubility and the better in vitro bioactivity. Therefore, fluorinated hydroxyapatite is a promising filler to improve the mechanical properties and functionality of dental composites.

Session: Emerging Applications

Presenting Type: Oral−Invited

Preparation and Performance of One Dimensional Sensor

Xiangyu Jiang*
Beihang University

The author used the principle of wettability to construct micro-nanoscale one-dimensional structures of inorganic particles, small organic molecules, polymers and other substances. Especially by studying the special structure of organism and changing the nature of material itself by means of synthesis, the one-dimensional structure constructed can be transformed into detector elements by using the change of property produced by the composite structure, so as to realize chemical or physical detection, and form high-sensitivity and small-volume sensor components.

1. The assembly of inorganic particles: The linear assembly of superparamagnetic particles is realized for the first time through the design of substrate structure and directional contraction of aqueous solution film.

2. Polymer assembly: Polymer and aggregation-induced luminescence (AIE) nanowires were prepared by directional evaporation of organic solvents. Based on the swelling characteristics of polymers and the changes of fluorescence intensity caused by the interaction of polymer swelling with internal AIE molecules, a new method for detecting volatile organic gases was developed.

Key words Wettability; One Dimensional; Vapor Sensor; Polymer Swelling

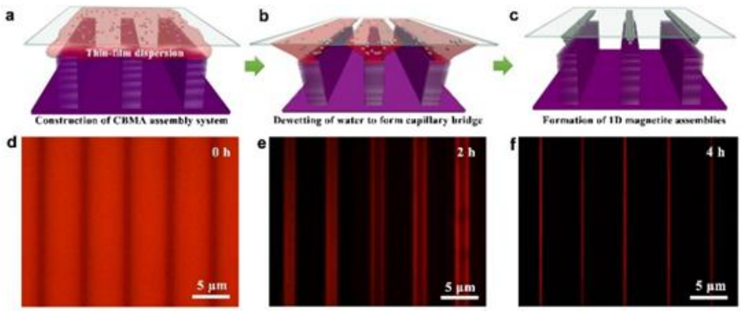


Fig. 1. The assembly of nano particles

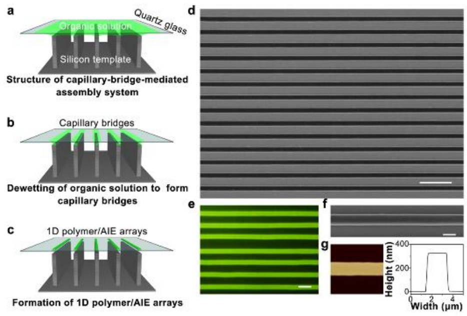


Fig. 2. The assembly of polymer

Session: Emerging Applications

Presenting Type: Oral-Invited

Two-dimensional Inorganic Molecular Crystals

Tianyou Di*
Huazhong University of Science and Technology

Two-dimensional (2D) materials have attracted tremendous research interests for their unique and rich properties. Typical 2D atomic crystals such as graphene and MoS2 possess the layered structure. The layers stack together via van der Waals (vdW) interaction. Within the layers, however, the atoms are interconnected via robust chemical bonds. The 2D inorganic molecular crystals (IMCs) we report here exhibit a totally different structure. These IMCs constitutes building blocks of inorganic molecules, which are bonded together all around via vdW interaction. Here, we mainly introduce the concept of IMCs and our recent progresses in this field. We firstly developed the passivation-assisted method in vapor deposition process to preferentially suppress the vertical growth of IMCs and realized the 2D growth of typical IMCs Sb2O3 with thickness down to monolayer. As the molecular structure allows the combination of multiple molecules within layers, we demonstrated the synthesis of 2D bimolecular IMCs consisting of SbI3 and S8 molecules. Taking advantage of the molecular structure, we realized the fabrication of wafer-scale IMC vdW film through the thermal evaporation deposition. Thanks to its compatibility with complementary-metal-oxide-semiconductor manufacturing processes, the vdW film of IMC can be precisely controlled and integrated with other materials to fabricate devices in a scalable way. The vdW dielectric film can also be used to fabricate high-performance 2D devices. Used as substrate in the MoS2-based field effect transistors, the Sb2O3 film can lead to higher mobility and higher stability of device performance for less charge scattering centres and trap states as compared with conventional dielectrics. More importantly, this vdW dielectric can be directly integrated onto 2D materials to form a dense and uniform film and used as the gate dielectric material. In addition, we used our vdW film as a vdW encapsulation layer to improve the stability of 2D materials (for instance BP). We show that such a scalable encapsulation layer not only maintains the intrinsic properties of typical air-susceptible 2D materials due to their vdW interactions but also remarkably improves their environmental stability.

Key words 2D materials, inorganic molecular crystals, dielectrics, field effect transistors

Session: Emerging Applications

Presenting Type：Oral-Invited

Anisotropic Metasurface for Wavefront Manipulation and Broadband Microwave Absorption

Yi Huang*
Nankai University

Electromagnetic wave absorption materials are playing a significant role in information safety， electronic reliability, healthcare. Furthermore, microwave absorption materials could protect the projects from exposure to radar detection, which is very important for national defense security. In this report, carbon based light weight high performance microwave absorbing/shielding materials were demonstrated. By adjusting the electromagnetic parameter, ultra-broadband and highly efficient absorption properties in both microwave and terahertz bands was obtained. For the first time, a VO2/reduced graphene oxide composite aerogel with excellent off/on switchable MA performance were constructed. Given these intelligent electromagnetic performance, Carbon-based electromagnetic functional materials may open new vistas for important applications in civil and military fields.

Key words Intelligent, broadband, electromagnetic wave absorption, Carbon-based materials

Session: Emerging Applications

Presenting Type: Oral-Invited

Dielectric Nanocomposites for Energy Storage Applications

jiangyu Li*
Southern University of Science and Technology

High energy density capacitors are highly desirable for numerous applications including power electronic systems, hybrid electric vehicles and wearable electronics. Commercial capacitors are largely built on polymeric dielectrics, which enjoy high breakdown strength and can be easily rolled for large scale manufacturing, though their dielectric constant is low, limiting their energy density. Inorganic oxides have large dielectric constant, yet they suffer from low breakdown strength, resulting in inferior energy storage performance. To overcome these limitations of single-phase materials, tremendous efforts have been devoted to developing hybrid dielectrics, and nanostructured composites are found to be most promising to balance the tradeoff between the dielectric constant and breakdown strength. In this talk, we will present our work in theory, development, as well as characterization of dielectric nanocomposites, with particular emphasis on understanding breakdown failure to guide the energy storage applications.

Key words Dielectric nanocomposites; energy storage applications； breakdown strength； capacitors

Session: Emerging Applications

Presenting Type: Oral-Invited

Electrocatalytic CO_2 Reduction toward C2+ Alcohols

Gengfeng Zheng*
Fudan university, China

The fast and continuous accumulation of greenhouse gases such as carbon dioxide and methane has been bringing a series of irreversible effects on the environment. Using renewable energy sources, the electrochemical conversion of CO2 and other carbon-based small molecules into value-added products represents a unique and important strategy for realizing carbon-neutral and energy storage. However, the development of high energy-density multi-carbon products has been a substantial challenge, due to the complicate surface structures of heterogeneous catalyst surfaces, slow charge transfer kinetics on gas-liquid-solid interfaces, and competition among multiple reaction pathways. Thus, it requires to rationally design and develop electrocatalysts with high-selectivity, high-activity surface sites. In this talk, I will discuss our recent efforts in developing electrocatalysts for conversion of C1 small molecules toward hydrocarbons, alcohols, acids, and more complex products.[1-7] The interplays between catalytic sites with reaction pathways will be discussed.

Key words CO_2 reduction • electrocatalysis • Cu catalyst • reaction mechanism • C2+ alcohols

Session: Emerging Applications

Presenting Type: Oral-Invited

Optimization of The Microwave Absorptivity of SiCf/Resin Composites in The GHz Range

Siwei Li*、Kaisheng Guo、Qiaoying Shi
Xiamen University

The effects of structural factors on the electromagnetic wave absorption properties of SiC fibre reinforced resin composites (SiCf/Resin) were investigated. Transmission line theory was used to calculate the reflection loss and to tap the potential of SiC fibres as broadband wave absorbents. The structure of the SiCf/Resin composite was optimized based on a double-layered laminate containing high-resistance SiC fibres (H-SiCf) in the upper layer and low-resistance SiC fibres (L-SiCf) in the bottom layer. The calculation suggests that to achieve a high absorptivity better than - 10 dB, the permittivity of the L-SiCf/Resin bottom layer must be enhanced to quite a high value with a specific frequency dispersion degree. The desired permittivity was realized by controllable addition of carbon black into L-SiCf/Resin. Under the optimized thickness combination, the reflection loss of the double-layered composite could be lower than - 13.3 dB in the whole X and Ku bands.

Key words Composites, Dielectric properties, SiC fibre, Functional applications.

Session: Emerging Applications

Presenting Type: Oral-Invited

Assembly of Polymer-tethered Gold Nanoparticles into Superlattices

Shutao Wang*
Technical Institute of Physics and Chemistry, CAS

Bio-interfacial adhesion has become a frontier hot in interfacial chemistry. It is not only helpful for us to understand the mystery of living systems, but also important for the development of new functional interfacial materials and related technologies. Leaning from nature, our group has recently investigated several special adhesion phenomena on biointerfaces and developed a series of bio-inspired adhesive interfacial materials. 1) We discovered the superdurability of bird feathers against tears originated from their cascaded slide-lock system, not from the "hook–groove system" proposed centuries ago; Inspired by the arrester system of dragonfly, we developed a new mechanical interlocker with a nylon pestle instead of the traditional hook, which breaks the limitation of traditional Velcro with undesirable deformation, breaking and noise. 2) Inspired by immune system, we proposed the concept of synergistic effect of biointerface adhesion based on structural matching and molecular recognition for detecting circulating tumor cell (CTC). We have developed a series of CTC detecting biochips by chemical etching, vapor deposition, electrochemical deposition, template replication, electrospinning and others; We also developed an emulsion interfacial polymerization strategy to fabricate bio-inspired immunomagnetic bead (spanning from Janus to porous) with controllable topology and surface chemistry. 3) We disclosed the microstructure of wound blood scab and developed a series of wound dressing, greatly promoting wound healing.

Key words bioinspired, adhesion, interfacial material, multiscale

Session: Emerging Applications

Presenting Type: Oral-Invited

Bioinspired Hybrid Optical Structures

Mingzhu Li*
Institute of Chemistry, CAS, China

Controlling the interaction between light and matter through optical structures has laid the foundations for a broad spectrum of applications, ranging from colors, lasers, and optoelectronics, to quantum information processing. To design and fabricate optimum optical structures towards highly efficient light management has been of growing interest.

Inspired by the natural hierarchical optical structures, we developed a series of composite optical structure materials with a low spatial footprint and enhanced light-matter interaction. [1-5] Deep-strong coupling of different optical structures, such as Fabry-Pérot interferometers, distributed Bragg reflectors, photonic crystals and grating structures, unlocks a large variety of novel phenomena spanning traditionally distant research areas. Moreover, we emerge composite optical structure materials with surface-functionalization, chemical regulation, and optoelectronic device which open prospects for diverse applications, including anti-counterfeiting, encryption, sensing, displays, photovoltaics and imaging.

Key words bioinspired, composite optical structure, light management, information, photovoltaics

Session: Emerging Applications

Presenting Type: Oral-Invited

Parity-Protected Anomalous Diffraction in Optical Phase Gradient Metasurfaces

Yanyan CAO[1]、Yadong Xu*[2]
1. Soochow University
2. Suzhou University

In the past years, phase gradient metasurfaces (PGM) have provided unparalleled possibilities for controlling the propagation of light or electromagnetic wave and revealing new mechanism for the light-materials interactions. The core concept in the PGM is to introduce spatially continuously varying phase at the interface, so that the light reflection and transmission occurring on the interface, is governed by the generalized Snell's law. However, in the actual case, the phase gradient metasurfaces are periodic structures, because of folded phase profile, where each supercell consist of m unit cells, with m being an integer. In some cases, higher order diffraction caused by the periodicity can be observed, while the diffraction mechanism is still not fully understood, especially in more complicated transmission-type phase gradient metasurface, since the transmission and reflection diffraction channels are concurrently included.

We try to address these problems by designing and studying the transmission-type gradient metallic metagratings. We theoretically and experimentally uncover the anomalous diffraction effect and mechanism in phase gradient metagratings. Starting from the effect of multiple reflections, the new diffraction equations is discovered. In addition, the number of unit cells m can be regarded as a new degree of freedom for manipulating the propagation of electromagnetic wave. By the parity of m, the higher order diffraction can be reversed between the anomalous transmission and reflection, and this phenomenon is very robust. Moreover, by studying several optical PGMs with popular designs, we have demonstrated the universality of the parity-dependent diffraction effect. we believe that the parity-dependent effect can provide a new way to manipulate light fields, enabling some new optical phenomena and potential applications.

Key words metasurfaces; phase gradient; parity-protected; anomalous transmission and reflection

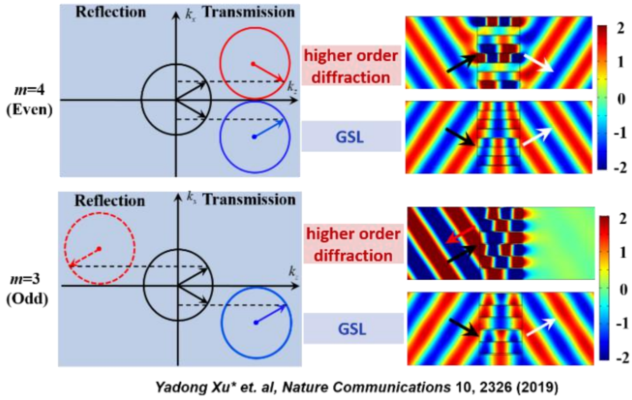


Fig. 1. Parity-protected anomalous diffraction phenomena in Optical Phase Gradient Metasurfaces.

Session: Emerging Applications

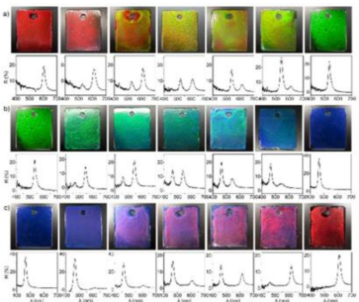
Presenting Type: Oral-Invited

Spray Synthesis of Photonic Crystal Coatings and Fabrics

Chuan Wang[1,2]、Jianping Ge*、Yuying He[1]、Jianping Ge*[1]
1. East China Normal University
2. Shandong University of Technology

Photonic crystal (PC) coatings and fabrics are promising composite materials with durable structural colors under intense illumination and various chemical environment. More importantly, it produces much less water pollution as no chemical dyes are used in the fabrication. Among different methods developed to prepare PC coatings and fabrics, spraying colloidal solutions is believed to be a possible solution with good control and affordable cost in mass production. However, it is a great challenge to prepare highly crystalline PC structures via spray coating because the atomization in spray usually accelerates solvent evaporation and facilitates the formation of amorphous PC structures with less saturated colors. Here, a two-step spraying process followed by thermal curing was developed to prepare PC coatings with bright, uniform, and angular-dependent structural colors. Solvent with "low surface tension" and high boiling point in colloidal solution will favor the spreading of PC layer on the substrate and the crystallization of PC structure. After spraying, the colloidal particles quickly precipitate to form a liquid PC intermediate, which transforms into a highly crystalline PC coating. Thanks to the narrow and intense reflections, the as-made coatings present colors with high saturation, including the RYGB colors achieved by tuning the particle size and many spectral/non-spectral colors via mixing base colors. Furthermore, the spray synthesis can also be extended to the synthesis of PC fabrics with durable colors and a good wearing experience. Here, solvents with "high surface tension" and high boiling point in colloidal solution are favorable for forming high-quality PC fabrics. The spray process helps to precisely assemble the colloidal PC inside every yarn of the polyester fabric, which avoids the blocking of weaving holes and ensures soft and breathable textures.

Key words Spray; Photonic crystal, Coating, Fabric, Structural color



Session: Emerging Applications

Presenting Type: Oral-Invited

DNA Based Bio-functional Polymeric Materials

Dayong Yang*、Dayong Yang
Tianjin University

DNA is the central biomacromolecule in living systems, and also a new material in line with the development concept of "precision chemistry". Our recent research focused on the design and synthesis of DNA-based dynamic materials for the delivery of therapeutic agents and treatment of diseases: 1) developing dynamic DNA assembling strategies in living cells to construct organelle-like architecture and explore the biological intervention effects; 2) developing dynamic DNA functional networks to achieve controllable stem cells capture and non-destructive delivery of cells in confined space; 3) Synthesizing DNA cross-linked polymeric nanoframework to achieve spatiotemporally programmable cascade hybridization of DNA under nanoconfinement for enhancing siRNA precision delivery and tumor gene therapy.

Key words DNA; therapy; biomedical applications

Session: Emerging Applications

Presenting Type: Oral-Invited

Application of Composite Materials in Consumer Electronics Industry

Huina Cui、Yunfeng Jiao、Dujun Luo、Cuiyi Wang、Ting Wang*
Xiaomi

Composite materials are increasingly being adopted for use in structures of almost every industry primarily due to their high stiffness and strength to weight ratios. Correspondingly they become critical and promising structural material candidates with the rising demand for thinner and lighter design in consumer electronics applications. As the vast difference in property requirements between structural parts in consumer electronics and other manufacturing industries, the key challenge for electronic composites in our research is to realize the most reliable user experiences in various application scenarios with extremely thinner-wall design. In this paper, we introduce the composite materials we developed typically for smart phone application including parts consolidation and designing for aesthetics and flame retardancy and their manufacturing methods. Additionally, trends in consumer electronic industry emphasize the necessity of efforts how composite materials can be tailored to provide improved functional properties, such as thermal conductivity, radio transparency and so on, while balancing surface quality and cost considerations.

Key words composite materials, consumer electronics, lightweight, thinner design, reliability, functional composites

Session: Emerging Applications

Presenting Type: Oral-Invited

Miniature Soft Robots with Composite Materials for Biomedical Applications

Li Zhang*
The Chinese University of Hong Kong

Robotics at small scales has attracted considerable research attention both in its fundamental aspects and their potential biomedical applications. As the characteristic dimensions of the robot or machines scaling down to the milli-/microscale or even smaller, they are ideally suited to navigating in tiny and tortuous lumens inside the human body which are inaccessible to regular medical devices. Although the materials, structural design, and functionalization of micro-/nanorobots have been studied extensively, several key challenges have not yet been adequately investigated for in vivo applications, such as controlled locomotion in a dynamic physiological environment, in vivo localization, the efficiency of therapeutic intervention, biosafety of the micro-/nanorobots, and autonomy level of the system.

In this talk, I will first present the recent research progress in development of magnetic soft robots with composite materials, from the remote actuation, motion control, and functionalization to rapid delivery. Then the key challenges and perspective of using magnetic soft robots and clinical applications with a focus on clinically relevant applications will be discussed.

Key words Soft matter, soft robots, composite materials, magnetic actuation

Session: Emerging Applications

Presenting Type: Oral−Invited

Application of Composite Materials in Consumer Electronics Industry

Shiyong Liu*
University of Science and Technology of China

We initially attempted to read sequence-defined self-immolative polymers with discrete molecular weights and predetermined sequences upon triggered degradation. We later unexpectedly found that the sequence could be directly read by MALDI tandem MS (Bruker LIFT module), exhibiting a clean pattern with the interval between neighboring peaks reflecting corresponding monomer sequences. For these amphiphilic mini-block copolymers containing PEG dendron and sequence-encoded self-immolative segment, it was found that self-assembled nanostructures (nanospheres and nanorods of different length) could be finely tuned by sequences and DPs, reminiscent of protein folding/assembly. We further quantified the pharmacokinetics and biodistributions of a mixture of different types of self-assembled nanostructures by MALDI TOF-MS and MALDI Imaging at organ and tissue slice levels. We further utilized the high throughput and label-free MALDI quantification platform to explore the effects of protein coronas on nanocarrier characteristics.

Key words Sequencing, Digital Micelles, Polymeric Amphiphiles, Self-Assembly

Session: Emerging Applications

Presenting Type: Oral-Invited

Electromagnetic Stability of Nanocrystalline Metallic Powders Doped by Metal Hydride for Microwave Absorption at Elevated Temperature

Zhihong Chen*、ziwen Fu、Yanqi Wang、Wei Li、Jianguo Guan
Wuhan University of Technology

Nanocrystalline metallic powders (NMPs) are one of the key components in microwave absorbing coatings. However, when NMPs work at high temperature, their magnetic properties would deteriorate rapidly due to occurrence of oxidation and grain growth. Antioxidation and stabilizing of grain size at high temperature are still challenges for NMPs. In this work, we proposed a new attempt to simultaneously enhance the antioxidation and grain-size stability of NMPs by doping of metal hydrides. Firstly, the effect of heat treatment on electromagnetic properties of NMPs was investigated. The evolution of grain size, permittivity and permeability with temperature, as well as the interplay mechanism among them, was discussed. Secondly, preparation, grain-size stability and antioxidation of metal hydride-doped NMPs were reported. The effect of milling time on distribution and grain size of metal hydride-doped NMPs were investigated. Special focus was placed on the thermal decomposition of metal hydrides into metal and hydrogen atoms. The relationship between the concentration of decomposed metal atom and the pinning effect of grain boundary were discussed in detail. The results indicated that the grain size and electromagnetic properties of metal hydride-doped NMPs were stable even it was heated to a temperature as high as 500 ^{o}C. The enhancement of antioxidation properties with the doping of metal hydrides was also studied. The decomposed hydrogen atoms were found to be able to improve the antioxidation of NMPs. The starting temperature for oxidation of NMPs was delayed more than 50 ^{o}C after doped with metal hydrides. This work exhibits a promising route to tackle the oxidation and grain size growth of NMPs simultaneously.

Key words nanocrystalline, grain stability, anti-oxidation, microwave absorption, high temperature

Session: Emerging Applications

Presenting Type: Oral-Invited

Bio-inspired Multiscale Adhesive Interfacial Materials

Jintao Zhu*
Huazhong University of Science and Technology

Polymer-tethered inorganic nanoparticle (NP), acting as a special building block, could mimic block polymer to self-assemble into various hierarchical structures. Due to their combined unique properties of NPs (e.g., dielectric confinement effect, etc) and excellent mechanical property of polymers, their assemblies have attracted intensive attentions.

We will introduce a series of ordered assemblies with polymer-tethered gold NPs by utilizing confined assembly strategy, which can supply an impervious space and has been applied as a powerful route to manipulate the structure of polymer assemblies. Comb-like supramolecular polymers based on hydrogen bonding interaction was formed, and polystyrene-tethered gold NPs (AuNPs@PS) was mixed with the supramolecules. Lamellar structure from the supramolecules created a soft confined space for assembly of the AuNPs@PS into ordered superlattice during solvent annealing processing. Moreover, when confining the AuNPs@PS with different NP sizes and polymer chain lengths in emulsion droplets, core-shell assemblies with particle size segregation were obtained. The location/arrangement of AuNPs can be effectively tuned by tailoring the PS chain length. This strategy is general and can be applied to NPs with different shapes and sizes, and the formed superlattice is potentially useful for photothermal and optical materials, and memory devices.

Key words Self-assembly; Nanoparticles; Confinement; Superlattices; Polymer-grafting

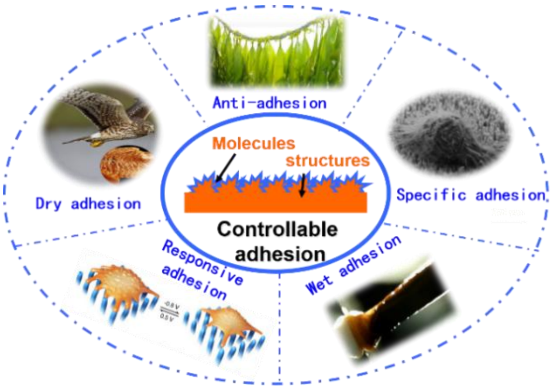


Fig. 1. Bio-inspired multiscale adhesive interfacial materials

Session: Emerging Applications

Presenting Type: Oral-Invited

Functional Nanomaterials with Ordered Structures by Supramolecular Block Copolymer Self-assembly

Renhua Deng*
Huazhong University of Science and Technology

Block copolymer (BCP) self-assembly has been widely used for the preparation of nanomaterials with ordered microstructures. We developed methods by adopting a supramolecular strategy to control the assembled structures and performance of BCP polystyrene-block-poly(vinyl pyridine) (PS-b-PVP), in which PVP can complex with additives.

A facile yet versatile route was developed to prepare anisotropic mesoporous carbon microparticles (MCMPs) by combining neutral interface-guided 3D confined self-assembly (3D-CSA) of PS-b-P4VP with a self-templated direct carbonization strategy. This route enables preengineering BCP into microparticles with oblate shapes and hexagonal packing cylindrical mesostructures, followed by selective crosslinking and decorating of the P4VP continuous phase with functional species (such as platinum nanoparticles and Pt NPs) via in situ growth. To realize uniform in situ growth, a “guest exchange” strategy is proposed to make room for functional species and a pre-crosslinking strategy is developed to preserve the structural stability of preformed BCP microparticles during infiltration. Finally, Pt NP-loaded MCMPs are derived from the continuous phase of BCP microparticles through selective self-templated direct carbonization without using any external carbon source.

Key words block copolymers, self-assembly, polystyrene-block-poly(4-vinylpyridine), mesoporous carbon spheres

Session: Emerging Applications

Presenting Type：Oral-Invited

Achieving Super Broadband Electromagnetic Absorption by Optimizing Impedance Match of rGO Sponge Metamaterials

Yibin Li*、Xianxian Sun 、Ye Yuan
Beihang University

The reduced graphene oxide (rGO) sponges exhibit exciting electromagnetic absorption performance in high frequency range. However, it is still a great challenge to realize desirable electromagnetic absorption property at low frequency (such as 2-4GHz) due to the great difficulty in balancing the good interfacial impedance matching and strong dielectric loss. Herein, we report the electromagnetic absorption metamaterials based on rGO sponge with different unit shapes (sphere, cubic, hexagonal prism and frustum pyramid). The relationship between the unit shape and electromagnetic absorption performance is explored by experiment and simulation. The results show that frustum pyramid metamaterial exhibits ultrabroad band electromagnetic absorption: the qualified absorption (the reflection loss lower than -10 dB) of electromagnetic wave can be achieved at 2.4-40 GHz. The average absorption intensity is -22.9 dB in the band of 2-40 GHz. Moreover, the bandwidth for strong absorption with absorption rate of 99% (-20dB) is up to 32 GHz. It is significant that the reflection loss has ignorant change even though the incident angle is increased from 5° to 40°. These are contributed to the excellent impedance matching confirmed by calculated results and strong dielectric loss. Moreover, it is theoretically proved that impedance matching properties play an important role in the absorption of low-frequency electromagnetic waves. Our lightweight frustum pyramid metamaterials are very promising in the application for broadband electromagnetic protection.

Key words Metamaterials, Microwave absorption, Broadband, Lightweight, rGO sponge

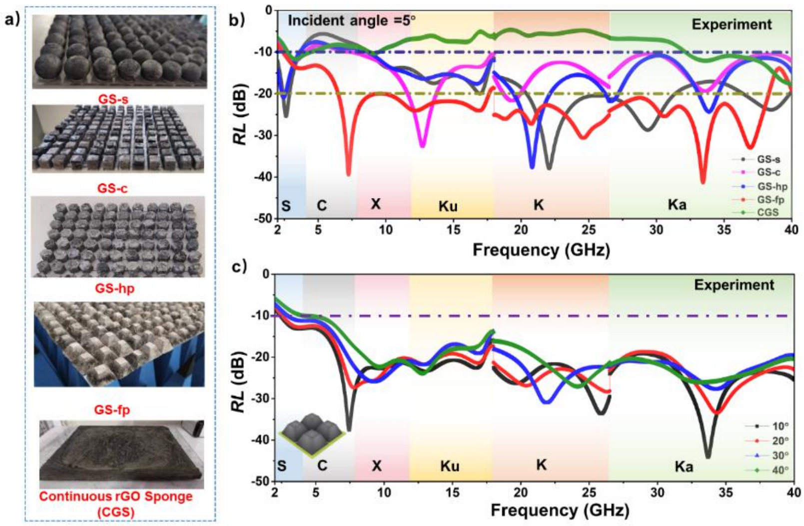


Fig. 1. a) Photographs of GS metamaterials with various shapes. b) The experimental RL of GS metamaterials with various shapes at 2-40 GHz. c) The experimental RL of GS-fp as the incident angle increases from 10 degrees to 40 degrees at 2-40 GHz.

Session: Emerging Applications

Presenting Type: Oral-Invited

Design Strategies for MOF-derived Electromagnetic Wave Absorbing Composites Based on Multi-level Structural Control

Chen Wu、Jiaqi Tu、Panbin Zhu、Mi Yan、Chen Wu*
School of Materials Science and Engineering, State Key Laboratory of Silicon Materials, Zhejiang University

Metal organic frameworks (MOFs) and their derivatives featuring with tunable microstructures serve as ideal models to understand the structure-performance correlations during electromagnetic wave absorption. Here a series of MOF-derived composites have been designed with multi-level structural factors investigated, involving morphology, dimension and pore distribution. For the morphologic factor, parameters including symmetry, aspect ratio and arrangement have been proposed to evaluate the anisotropy of complex 3D MOFs. Also, dimensional factor has been investigated for 2D MOFs with tuned size and thickness. For both 3D and 2D MOF-derived absorbers, strong structural anisotropy is beneficial for enhanced absorption. It has further been found that the dynamic permeability is more sensitive to the anisotropy compared with the permittivity. This opens up the opportunity to tune the magnetic loss to be complementary to the dielectric loss in the pursuit of strong absorption over wide bandwidth. Lastly, core-shell MOF-derived absorbers with gradient pore distribution have been constructed to break the trade-off between absorbing efficiency and impedance matching. Compared with individual MOF derivatives, the core-shell derivative not only inherits strong electromagnetic attenuation capability from the micro-pore core but also exhibits improved impedance matching due to macro-pore shell. As such the work not only provides versatile strategies for structural engineering of MOF-derived electromagnetic wave absorbers, but also insights on impacts of multi-level structural factors on the electromagnetic parameters, which are extendable to various areas including but not limited to magnetics, electrics and optics.

Key words Metal organic frameworks; Morphology; Dimension; Pore distribution, Electromagnetic wave absorption

Session: Emerging Applications

Presenting Type：Oral-Onsite

Topology Isomerization Network

Tao Xie*
Zhejing University

Bond exchange in a typical dynamic covalent polymer network allows access to macroscopic shape reconfigurability, but the network architecture is not altered. An opposite possibility is that the network architecture can be designed to switch to various topological states corresponding to different material properties. We call this latter class of polymer network as Topology Isomerizable Network (TIN). In this talk, I will introduce the basic principle of TIN and show three examples on how TIN can be designed. The concept of TIN paves a way to programmable regulation of network polymers.

Key words Topology Isomerizable Network

Session: Emerging Applications

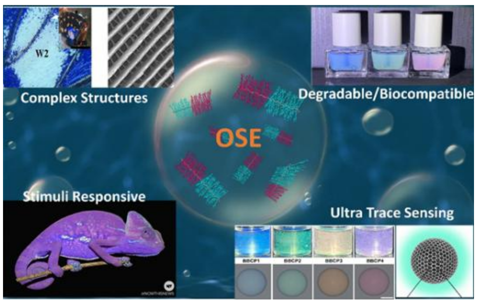
Presenting Type: Oral-Onsite

Eco-friendly Photonic Pigments via Organized Spontaneous Emulsification

Dongpo Song*、Xi Chen、Yulian Li、Qilin Guo、Yuesheng Li
Tianjin University

Photonic microspheres with vivid structural colors typically contain periodically ordered nanostructures with strong Bragg reflections. Such interesting photonic materials have great potential to be widely used as eco-friendly photonic pigments in many important areas such as invisible cloaking, cosmetics products, toys, car coatings, etc. However, the fabrication of polymeric photonic pigments has been evolved in difficult, complicated, time-consuming, and high-cost procedures, which represent a significant barrier for real applications. In this presentation, we demonstrate a new mechanism of organized spontaneous emulsification (OSE) for one-step fabrication of the useful photonic pigments. Thermodynamically stable water-in-oil-in-water (w/o/w) multiple emulsions with uniform internal droplets arranged in ordered arrays were obtained with amphiphilic bottlebrush block copolymers (BBCPs) as the stabilizer. With the ordered w/o/w multiple emulsion droplets as the template, ordered porous structures are facilely created within the microspheres upon complete loss of the organic solvent. Pore diameters are widely tunable from 100 to 400 nanometers, leading to reflected color varied across the whole visible range. This strategy is generally useful for making photonic spheres using different polymer materials as the skeleton such as polystyrene, poly(dimethyl siloxane), polyacrylate, and polyesters. This allows for many applications in different areas. Moreover, bioinspired complex photonic structures, such as bridged lamellae, are demonstrated through precise manipulation of the OSE process. Stimuli-responsive photonic microspheres are also successfully fabricated, showing color changing properties similar to a Chameleon. The obtained photonic pigments possess can be the ideal alternatives to traditional toxic colorants as well as nondegradable plastic microbeads in many cosmetics products.

Key words photonic microspheres, structural color, block copolymer, self-assembly



Session: Emerging Applications

Presenting Type: Oral-Onsite

Novel Broadband Electromagnetic-Wave Absorption Metasurfaces Composed of C-doped FeCoNiSiAl High-Entropy-Alloy Ribbons with Hierarchical Nanostructures

Yuping Duan*、Yuping Duan*
Dalian University of Technology

Although various absorbers have been developed for electromagnetic-wave absorption materials (EAMs), the uniform composition and microstructure limit the design freedom of the soft magnetic properties, thus resulting in a ceiling of the absorption properties. Herein, we propose a revolutionary concept of C-doped FeCoNiSiAl high-entropy-alloy (HEA) ribbons with hierarchical nanostructures composed of ultrafine grains (400 nm), B2 nanoprecipitates (80 nm), and C@FeNi core–shell nanoparticles (15 nm) to induce superior soft magnetization and absorption. The hierarchical nanostructures resulted in a low coercivity (HC, 589.04 A/m) and a low conductivity (294.1 S/cm) to support the loss effect and impedance matching, and 87% of the saturation magnetization (MS, 135.13 emu/g) was maintained, even at the high temperature of 973 K, corresponding to ultra-stable magnetization. Furthermore, the Curie-temperature was greater than 1000 K. The B2 nanoprecipitates and corresponding interfaces created strong stray magnetic flux lines and magnetic domain vortices, and thus, the metasurfaces innovatively fabricated with HEA ribbons induced a strong absorption peak (−50.88 dB) and effective broadband absorption (reflection loss (RL) ≤ −10 dB within 5.86–18 GHz) due to the strong magnetic coupling. The hierarchical nanostructure is a promising strategy to tailor magnetic HEAs with a new degree of freedom for advanced EAMs.

Key words electromagnetic-wave absorption materials, high entropy alloys, hierarchical nanostructures, soft magnetization, metasurface.

Session: Emerging Applications

Presenting Type: Oral-Onsite

Preparation and Enhanced Microwave Absorption Properties of Structural Sericin-derived Carbon Nanocomposites

Xiuyan Deng、Yaqin Fu*
Zhejiang Sci-Tech University

Structural carbon nanocomposites with multiple losses and tunable microwave absorption performance have become a research hotspot to meet the "thin, lightweight, wide and strong" requirements in the field of microwave absorption (MA). The industry wasted-sericin accounted for 25-30 wt% silk protein is a potential candidate for structural carbon source owing to the tunable secondary structures, abundant functional groups, and natural heteroatoms doping. In this paper, the core-shell multi-component alloy@sericin-based carbon (SC) nanocomposites and lightweight cellular-like SC/reduced graphene oxide (rGO) nanohybrids were successively prepared through self-assembly technique and subsequent carbonization process, the microwave absorption properties and mechanism were discussed as well. Notably, the core-shell structure of the synthesized alloy@SC nanocomposite leads to the enhanced interfacial polarization. Meanwhile, the magnetic loss originated from metal, the conductive loss and dielectric loss attributed to SC make the alloy@SC nanocomposite with good microwave absorption properties. Moreover, the incorporated cellular-like SC nanostructures of SC/rGO contribute to hetero-interfaces and continuous conductivity networks, thus promoting the dominant conductive loss and polarization loss mechanism. The optimized microwave absorption of SC-rGO40 reached -53.68 dB with the effective absorption bandwidth of 4.4 GHz at the thickness of 1.51 mm. The experimental characterizations demonstrate that multi-components and suitable structure can endow the microwave absorber with excellent impedance matching performance and a multi-loss mechanism, which provides new inspirations for designing high-efficiency MA materials.

Key words Sericin-based carbon; structural carbon nanocomposites; Multi-loss mechanisms; Microwave absorption

Session: Emerging Applications

Presenting Type：Oral−Onsite

Ultralight Biomass-derived Carbon Fibre Aerogels for Electromagnetic and Acoustic Noise Mitigation

Yi Hou*
Nanjing Tech University

The ever-increasing electromagnetic (EM) and acoustic noise are threatening public health in modern cities. Though materials are being developed, there is a lack of simple solution to address the two types of noise at the same time. Herein, flexible and ultralight (~15 mg/cm3) silk fibre derived carbon fibre aerogels (SA) are developed. The silk fibre mats, carbonized at different temperatures, are stacked together to form a compressible multi-layer structure. With optimized gradient impedance, the SA could achieve low-reflection coefficient ($R < 0.02$) electromagnetic interference (EMI) shielding in X and Ku band (8.2 to 18 GHz). Moreover, the SA demonstrates an outstanding sound absorption performance (average absorption coefficient > 90%) from 1000 to 6000 Hz. Besides, the aerogel also shows a low thermal conductivity of ~0.026 Wm-1K-1, implying a potential thermal insulator. With such excellent performance and facile fabrication, the SA is expected to serve as a promising building material to be applied on the surface of architectures for the demand of both noise mitigation as well as energy conversation. The strategy to achieve the multiple functions by using a multi-layered fibrous aerogel could also apply to other natural fibres.

Key words Carbon fibre aerogels; Low-reflection EMI shielding; Sound absorption; Thermal insulator; Multiple functions

Session: Emerging Applications

Presenting Type：Oral-Onsite

Preparation of Carbon Nanotube/epoxy Resin-based Srain Sensors for Steel Damage Identification

Danfeng Zhang、Jun Wang*
Nanjing Tech University

High-performance strain sensors are urgently required with the development of health monitoring system. Based on the good electrical and mechanical properties of carbon nanotube (CNT), a CNT/epoxy resin-based strain sensor was proposed. The effects of epoxy resin viscosity, and purity, diameter, content and type of CNTs on the electrical conductivity and sensing property of CNT/epoxy resin-based strain sensors were evaluated. The highest electrical conductivity of CNT/epoxy resin-based sensors was 190 S/m in the case of epoxy resin viscosity of 200-300MPa·s, CNT purity of 95%, CNT aspect-ratio of 1333-6250 and CNT array type. The percolation threshold of the CNT/epoxy resin-based strain sensors was determined as 3.5 wt.%. The sensitivity of the CNT/epoxy resin-based sensors was 68.5% higher than metal-foil stain gauge. Moreover, the sensors were used to calibrate the total stress-strain relationship of steel plates and estimate the damage of steel plates with holes. When the damage area of the steel plates increased by 2.56 times, the sensitivity of the CNT/epoxy resin-based sensors increased by 2 times. The decrease of the distance between the damage and the sensor led to increase of the sensors. The damages within 70 mm from the sensor can be identified. The developed sensors offer a high application potential in damage monitoring of steel structures.

Key words Carbon nanotube; Epoxy resin; Strain sensor; Percolation threshold; Steel; Damage identification

Session: Emerging Applications

Presenting Type: Oral-Onsite

Steric Repulsion-stabilized Magnetically Responsive Photonic Crystals and Their Applications

Wei Luo*[1]、Huiru Ma[2]、jianguo Guan[2]
1. Wuhan University of Technology
2. Wuhan University of Technology

Magnetically responsive photonic crystals (MRPCs) exhibit unique advantages of strong diffraction, rapid, reversible and significant colour changes across the entire visible spectrum under external magnetic field. To date, numerous MRPCs have been developed based on various forms of monodisperse magnetic colloidal particles and their composite structures. They are highly desirable for widespread potential applications, such as colour displays, photonic prints, chemical and bio-sensors, coding and anti-fake technology etc. In this presentation, steric repulsion-stabilized MRPCs are demonstrated to have tunable structure colors nearly within the entire visible spectrum and almost independent of the solvent polarity, ionic strength or pH value. Based on this feature, various external magnetic field-assistant hydrolysis–condensation or UV-light fast polymerization methods have been developed to fabricate stimuli-responsive polymer-based one-dimensional magnetic photonic crystals in diverse forms ranging from macroscopic films and photonic crystal spheres to individual photonic nanorod and nanochain. The preparation principles of them are illustrated in detail, followed with the response characteristics of the ordered structures and optical properties to external stimuli. At the end, their potential applications in sensing, anti-counterfeiting as well as camouflage are also demonstrated.

Key words magnetic responsivie; photonic crystals; sensing; anti-counterfeiting

Session: Emerging Applications

Presenting Type: Oral-Onsite

Bioinspired 3D Nanoporous Membrane for Salinity Gradient Energy Harvesting

Yahong Zhou*
Institute of Physics and Chemistry, Chinese Academy of Sciences

The electric-eel is well known for generating up to 600 V and 1 A of current in a shock. The key is the potassium channel embedded in the cell with asymmetric structure leading to an inwardly rectifying K+ current. Compared to the symmetric pore structure, this structure leads to non-linear ionic transport across the membrane. This type of ionic-diode-nanofluidic provides an option for novel RED based energy harvesters. During the energy conversion process for traditional membrane, counterions are enriched on the dilute solution side, resulting in concentration polarization. Energy is lost within the membrane itself, dissipating osmotic energy as Joule heating in the nanopore. With respect to the Janus membrane, an opposite charge of the membrane on the lower concentration side can prevent the accumulation of counterions. Thus, the resistance of the asymmetrically structured membrane works as a Shockley diode and the back current is blocked. Hence, this type of membrane can avoid power dissipation and eliminate the polarization phenomenon. We have developed a series of heterogenous membrane which show great potential in blue energy harvesting. Particularly, scaled-up Janus (two-faced) membranes with 3D pores were obtained via a phase separation process. The nanofluidic behavior of this system membrane is unique in hypersaline solutions. When mixing natural sea water and river water, the power output achieved a high value of ~5.06 W/m^{-2}, reaching the benchmark of 5.0 W/m^2 for industrial requirements.

Key words bioinspired nanochannels, osmotic gradient, electric eel

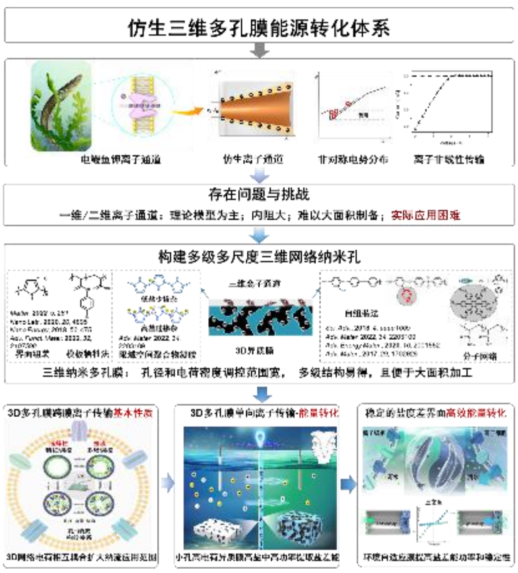


Fig. 1. Bioinspired 3D nanoporous membrane.

Session: Emerging Applications

Presenting Type: Oral−Virtual Platform

Direct Sequencing and Quantification of Digital Polymeric Amphiphiles

Yanlin Song*
Institute of Chemistry Chinese Acadamic of Sciences

Based on the research of droplet drying process on the surfaces with different wettability, controllable nanoparticles assembling and stereo structures patterning were achieved. Through controlling the droplet spinning motion and the movement of the vapor-solid-liquid three phase contact lines, the basic units from 0D to 3D structures (dot, line, plane and stereo structures) via the printing technology can be precisely printed. Significantly, we achieved the functional nanoparticles assembled patterns with single nanoparticle resolution. With the assembly of metal nanomaterials via printing process, patterned various linear or curved 1D/2D structures on diverse substrates are achieved. The desirable patterns contribute remarkable applications in sensitive electronical skin, multi-layer circuits, ultra-integrated complex circuits, solar cells, soft actuators and biological chip. These achievements are benefited from the fundamental researches on interfacial wettability manipulation, morphology control of drying droplets, as well as functional nanomaterial fabrication, which constructs the theoretical and technical system of Green Printing Technology.

Key words Green Printing Technology, Optical Devices, Electrical Devices, Droplet Spinning Motion, Pattern

Session: Emerging Applications

Presenting Type: Oral-Virtual Platform

Ultralight Biomass-derived Carbon Fibre Aerogels for Electromagnetic and Acoustic Noise Mitigation

Lihong Li*
Institute of Chemistry, Chinese Academy of Sciences

Anisotropic materials have attracted much attention due to their various physical and chemical properties and wide application prospects in devices, sensing, catalysis, medicine, energy and other fields. Perovskite materials, due to their applications in piezoelectric, ferroelectric, solar cells and other fields, once again set off a research boom. The structure of perovskite is mainly cubic or octahedral ABO3. Generally, the shape of crystal particles depends on their intrinsic structure, which means that cubic materials usually form isotropic particles. Therefore, the preparation of anisotropic perovskite materials is challenging. We report a high-yield synthesis strategy of perovskite niobate based on multi-element topological chemical molten salt method. The perovskite-type niobate materials obtained by this synthesis strategy are used to print and fabricate flexible piezoelectric devices. In addition to the above topological synthesis strategy, we also propose an environmentally friendly two-step method for the preparation of vacancy transition metal sulfides at room temperature. Typically, the MoS2 crystal was intercalated by electrochemical intercalation, and then the desulfurization reaction was carried out on it. A large number of sulfur vacancies were created on the base of MoS2 nanosheets (P-MoS2), so as to obtain two-dimensional desulfurization MoS2 nanosheets (D-MoS2) with enhanced electrocatalytic hydrogen production performance Rice chips. By applying different desulfurization voltage, different degrees of desulfurization effects were achieved, and the desulfurization efficiency could reach up to 30%. The current density of D-MoSx increases to 230% as much as that of P-MoS2 (at -0.3 V VS RHE) and the Tafel slope of the D-MoSx was reduced. This strategy of large-scale preparation of D-MoS2 nanosheets can be extended to other two-dimensional materials. This work provides a new idea for the synthesis of non-noble metal catalysts and provides a new material basis for the preparation of two-dimensional material devices.

Key words Sensing; Piezoelectrice; Anisotropic functional materials; Pattern; 2D materials

Session: Emerging Applications

Presenting Type: Oral−Virtual Platform

Sustainable Biochar-based Strain Sensor

Justin George*、Debes Bhattacharyya
University of Auckland

Stretchable and flexible strain sensors, based on renewable and sustainable eco-friendly materials, are in great demand for health monitoring applications. However, challenges still exist in the synthesis of conductive renewable material for the manufacturing of strain sensors. Here, we synthesized conductive biochar with high carbon content through pyrolysis of pinewood in an inert atmosphere (nitrogen) at 1200 °C with a heating rate of 10 °C/min to manufacture a flexible and stretchable strain sensor. The electrical conductivity of the biochar is due to the presence of sp2 hybridized graphitic carbon produced during the pyrolysis process. The produced biochar was powdered and sieved to less than 100 particle size. We employed the solution casting method for manufacturing strain sensors where the conductive silicone rubber (SR) biochar composite acted as a conductive layer, sandwiched between the two insulating layers of SR. The insulating layers act as support, and the conductive SR biochar composite layer helps biochar particles be embedded in SR and create a highly conductive channel. The dispersion of biochar in the SR (conductive layer) is ensured by using toluene as a dispersing agent. The biochar powder with sharp edges shows excellent interfacial interaction with SR, making it a potential material for strain sensing applications. The developed strain sensor shows excellent stability up to 55 % of strain with a maximum gauge factor of 2.45, caused by the separation of biochar particles during stretching. In this work, we demonstrated the facile synthesis and applicability of this cheap renewable pinewood biochar for stretchable strain sensor fabrication as a human health monitoring device.

Key words Biochar, pyrolysis, interfacial interaction

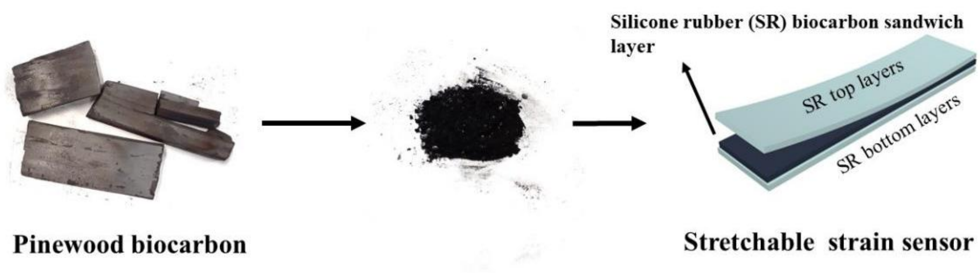


Fig. 1. Schematic illustration of strain sensor manufacturing process

Session: Emerging Applications

Presenting Type：Oral−Virtual Platform

Bioinspired Stimuli Responsive Multilayered Composites

Luyi Sun*、Songshan Zeng、Andrew Smith、Kuangyu Shen
University of Connecticut

After millions of years, living organisms have evolved to develop well-adapted structures and compositions. Nature has been able to solve numerous biological problems such as self-healing, self-assembly, and solar energy harnessing. Humans have looked to nature for solutions to our problems throughout our existence. In this talk, several bioinspired stimuli-responsive multilayered composites will be presented. The macro/nano-scale designs for these materials were all inspired by the diverse biological solutions found in nature, with the goal to potentially surpass their natural counterparts and bring new functionalities to these brilliant structures. Their broad applications will also be discussed.

Key words Bioinspired, Stimuli Responsive Composites, Multilayered Structure

Session: Emerging Applications

Presenting Type: Oral-Virtual Platform

Intelligent Broadband Electromagnetic Wave Absorption Materials

Ke Chen*、Ke Chen、Yijun Feng
Nanjing University

Recently, metasurfaces composed of patterned structures have shown unprecedented potentials in manipulating and tailoring wavefronts with subwavelength resolution. Due to their exotic advantages of compact configuration, flat profile, and easy fabrication, metasurfaces have been utilized to facilitate numerous applications, including holographic imagers, invisibility cloaks, beam shapers, and highly-directive antennas. To surmount the obstacles of fixed electromagnetic responses and static wavefront manipulations of conventional passive metasurfaces, reconfigurable metasurfaces have been proposed by integrating tunable components or materials such as diodes, liquid crystals, and graphene into the architectures. Despite the rapid development of this community, most of the existing designs can only function under a single linearly or circularly polarized incidence. Although there are a few attempts in anisotropic polarization-sensitive bifunctional metasurfaces which are capable of enacting distinct wave functions for orthogonal incident polarizations, most of them are limited to phase modulation for both polarization channels, leaving other intrinsic properties of electromagnetic waves unexploited.

Here, we will present our recent progress of anisotropic metasurfaces that can enable independent control of phases and amplitudes for a pair of orthogonal linear polarization channels. For horizontally polarized incidence, the anisotropic metasurface is designed to exhibit phase modulation with a near-unity reflection by modulating the diodes loaded on the metasurface, which is promising for wavefront manipulation, for example, dynamic beam scanning. Meanwhile, for vertically polarized incidence, the anisotropic metasurface manifests near-zero reflections, which not only provides amplitude modulation as another degree of freedom in manipulation, but also exhibits great potentials in energy absorption that may be used for stealth technique. Our approach provides a new platform for multifunctional devices by increasing the polarization channels and integration level, which may have further potentials in antenna systems, intelligent communication systems, and holographic imaging.

Key words metasruface, absorption, microwave, wavefront

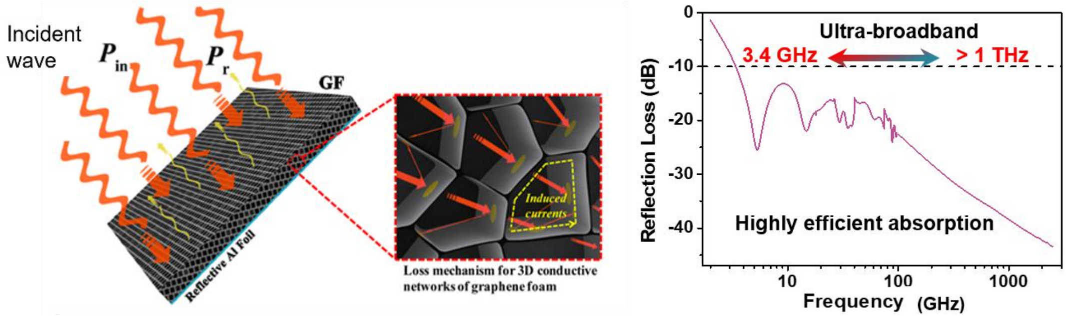


Fig. 1. microwave and terahertz absorption properties of graphene based materials

Session: Emerging Applications

Presenting Type: Poster

Nitrogen and oxygen co-doped porous carbon materials prepared from polyacrylonitrile/polimide films for supercapacitors

Ruijie Li[1,2]、Chenyang Cai[1]、Yonggang Zhang[1]、Xuefei Wang*[1]
1. Ningbo Institute of Industrial Technology, Chinese Academy of Sciences
2. University of Chinese Academy of Sciences, Beijing, 101400, China

Porous carbon materials are widely used in energy storage, adsorption, catalysis, and wastewater treatment. Polymer composite films of polyacrylonitrile and polyimide were firstly prepared by modulating the composition of coagulation bath (ratio of DMSO to H_2O in weight). Using these composite films as the precursors, nitrogen and oxygen co-doped porous carbon materials were successfully fabricated by NaOH activation. The porous carbon had a three-dimensional network structure with a specific surface area of 450-737 m^2 g^{-1}. The pore volume was 0.245-0.508 m^3 g^{-1} and the pore size mainly located between 1-5 nm. The porous carbon obtained at DMSO/H2O=3/7 showed a high oxygen content of 27.98 wt% and nitrogen content of 3.30 wt%. The resultant carbon material exhibited a good mass-specific capacitance of 407.7 F g^{-1} at a current density of 0.5 A g^{-1}, an excellent rate capability (237.69 F g^{-1} at 20 A g^{-1}) and cyclic stability. High N and O content is advantageous for the redox process, which improves the wettability of the material and then its pseudocapacitance. The porous structure promotes the adsorption and desorption of electrolyte ions and enhances the electric double-layer capacitance. The high amount of heteroatoms as well as the texture properties could be beneficial for the improvement of electrochemical performance of the porous carbon based supercapacitors.

Key words Supercapacitor, porous carbon, nitrogen/oxygen co-doping, coagulation bath

Session: Emerging Applications

Presenting Type: Poster

Novel conductive fibrous materials with high electromagnetic transmittance and low reflectivity

H ZHANG*、Z YU、X GUO、H SU、Y XU、X GAO、L XU
Beijing Graphene Institute Co., Ltd.

Conventional conductive/electrothermal materials have strong electromagnetic wave reflectivity, which is difficult to meet the electromagnetic stealthy requirements of current combat aircrafts. Graphene fibre glass fabric (GFGF) is based on quartz fibre, with a certain thickness of graphene layer deposited on its surface by CVD process, which endows the originally insulating quartz fibre with electrical and thermal conductivity. The coating coverage of graphene on the surface of quartz fibre is more than 99%, and the surface resistance of the whole fabric can be adjusted within the range of 50-5000Ω/□, and the electromagnetic wave transmittance in the 1-40GHz frequency band can reach more than 80%. In addition, graphene fibreglass fabric has the characteristics of light weight and flexibility, with an area density as low as 110g/m2; it has strong compatibility with the molding process of resin-based composite materials, and is suitable for vacuum bagging, resin transfer moulding and vacuum tank processes.

GFGF not only satisfies the high transmittance of electromagnetic waves, but also has the functions of electric heating and electric transmission. It is suitable as an electric heating module for aircraft or other vehicles that are prone to icing. It has broad application prospects in the fields of national defense and military affairs, information communication, and integrated circuits.

Key words graphene, glass fibrefabrics, composites, high electromagnetic transmittance, conductive fabrics

Session: Emerging Applications

Presenting Type: Poster

A light-weight broadband all-dielectric metamaterial absorber based on carbon black composite

Mengchao Guo、Yi Yang*

School of Electronic Science and Engineering, Nanjing University

Here, a light-weight broadband all-dielectric metamaterial absorber (ADMMA) is proposed. It consists of a cylinder array and a FR4 substrate. The cylinder is made of carbon black composite, which is obtained by mixing carbon black powder with paraffin wax uniformly. The simulation result shows that broadband absorption can be achieved from 7 GHz to 19.3 GHz with two absorption peaks under a total thickness of 3.7 mm. The first peak is attributed to high-contrast gratings based spoof surface plasmon polaritons (HCG-based SSPPs), while the other is attributed to diffraction effect. The excellent electric loss ability of the carbon black composite also plays an important role over whole frequency range. In addition, the estimated surface density of this ADMMA is only 2.08 kg/m2. It is believed that this work will push forward the applications of carbon series composite in light-weight broadband ADMMAs.

Key words carbon black composite, broadband absorption, all-dielectric metamaterial

Session: Emerging Applications

Presenting Type: Poster

Highly sensitive detection of thiram residues on fruit peel surfaces using a filter paper-based SERS sensor with AgNWs@ZIF-8

Nuan Xu、Zhenhua Tang*、Yanping Jiang、Junling Fang、Li Zhang
Guangdong University of Technology

Thiram is an organic compound widely applied as a fungicide to control crop diseases. Excessive or illegal use of thiram can cause harm to various animals and human health, as well as serious pollution of the environment. The widely used pesticide thiram is found in various environments and foodstuffs, posing a risk to human health and contaminating the environment. In this work, the novel SERS flexible sensor (FP/AgNWs@ZIF-8) consisting of silver nanowires and zeolite imidazole frameworks combined with filter paper was prepared for the sensitive and rapid detection of thiram on fruit peel surfaces. The effect that different coating cycles of ZIF-8 films exert on the Raman signal enhancement of the sensor was investigated. The results show that the FP/AgNWs@ZIF-8 sensor has an optimal Raman response to 4-Aminothiophenol (4-ATP) when the coating period is 5. Furthermore, a novel SERS FP/AgNWs@ZIF-8 sensor with a porous and flexible structure on low-cost and eco-friendly paper was obtained, as to be immersed in a solution of thiram or wiped on a nectarine skin surface. Therefore, this facile, rapid, and sensitive flexible sensor at low-cost has excellent potential for pesticide residue detection and environmental toxicity analysis.

Key words AgNWs@ZIF-8; SERS flexible sensor; Synergistic enhancement; Pesticide residue detection; Thiram

Session: Emerging Applications

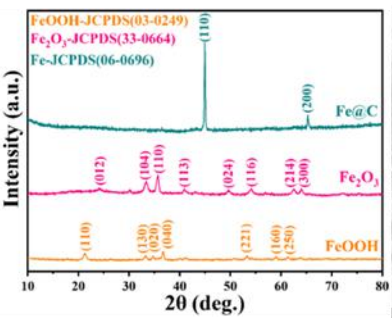
Presenting Type: Poster

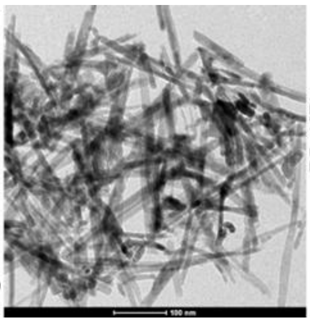
Synthesis and electromagnetic wave absorbing properties of Fe@C composite Fiber

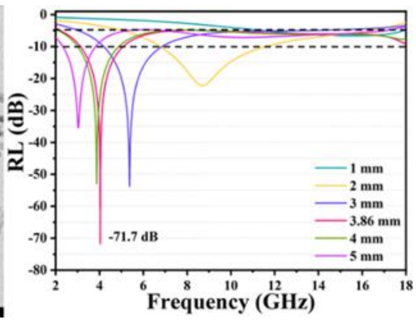
Yuanyuan Zhang、Jiantang Jiang*
Harbin Institute of Technology

Fe based fibers are potential candidates for electromagnetic wave absorbing (EAM) fillers for the large aspect ratio, high axial permeability and high saturation magnetization. The introduction of carbon can bring about excellent dielectric loss and block the agglomeration of Fe fiber simultaneously, which thus inspired the current study. Fe@C composite fibers were successfully prepared by introducing C on the Fe_2O_3 fibers' surface and the subsequent hydrogen-thermal process, the microstructure was characterized and the electromagnetic properties was tested. It was found that, Fe@C composite fiber retains the fibrous shape of the precursor very well throughout the hydrogen-thermal process. The Fe@C fiber exhibit a three-dimensional network in which fine fiber interwoven with each other and contributed to enhance conductivity loss. The saturation magnetization was significantly enhanced as the Fe_2O_3 was converted to Fe, which then lead to enhanced ferromagnetic loss. The multiple interfacial polarization and the improved impedance matching, originated from the core-shell structure of Fe@C, can be contributive. Coating using Fe@C fiber as fillers was expected to present reflection loss (*RL*) up to -71.7 dB at 4.03 GHz at the thickness of 3.86 mm. The Fe@C fiber can be promising candidates as high performance EMA fillers.

Key words Electromagnetic absorption; Fiber; Ferrites metal; Carbon







Session: Emerging Applications

Presenting Type: Poster

Outstanding Electromagnetic Absorption Carbon-materials: High Modulus Polyacrylonitrile-based Carbon Fiber Coated with Composite Structures Derived from CoZn-bimetallic ZIFs

chunjie li、xin qian、mengyuan hao、yonggang zhang*
Ningbo Institute of Materials Technology&Engineering,Chinese Academy of Sciences

Apart from being widely used in aerospace, military, civil and other fields as the common structural composite reinforcement, carbon fiber is proved to be a functional material in electromagnetic wave absorption areas such as radar positioning and electromagnetic protection. In this study, three-dimensional (3D) bimetallic nanoparticles were constructed on the surface of high modulus carbon fibers to endow them with appropriate impedance matching and excellent electromagnetic wave absorption performances. In details, bimetallic ZIFs were grafted onto the surfaces of oxidized high modulus carbon fibers by in situ hydrothermal synthesis, and the composite carbon fibers with three special morphologies were prepared after annealing at high temperatures. To achieve better electromagnetic wave absorption performance, the obtained CFs (named HMCFs@BMZs-C700) with modifiable microstructure in addition to the dielectric and magnetic properties could be rationally adjusted by changing the ratio of two metal salts and ligand. Remarkably, the rodlike carbon fiber absorption material named HMCFs@BMZ-R-C700 showed optimal microwave absorption performance. With 25% HMCFs@BMZ-R-C700 loadings, the minimum reflection loss (RLmin) reached -67.67 dB (electromagnetic wave loss above 99.9%) at the 2.2 mm thickness with an effective absorption bandwidth (EAB) of 3.8 GHz. Furthermore, with the thinnest thickness of 2.0 mm, HMCFs@BMZ-F-C700 acquired the maximum effective absorption bandwidth of 4.28 GHz among the three investigated samples. In summary, the mechanism of the enhanced electromagnetic wave absorption included interfacial loss, conductive loss, polarization loss, multiple scattering and excellent impedance matching. More impressively, the composite structures of HMCFs@BMZ-R-C700 were demonstrated with the favorable electromagnetic loss property and high performance, which could provide a referable route toward efficient, lightweight carbon fiber microwave absorbers.

Key words Microwave absorption, High modulus carbon fiber, Bimetallic ZIFs, Impedance matching

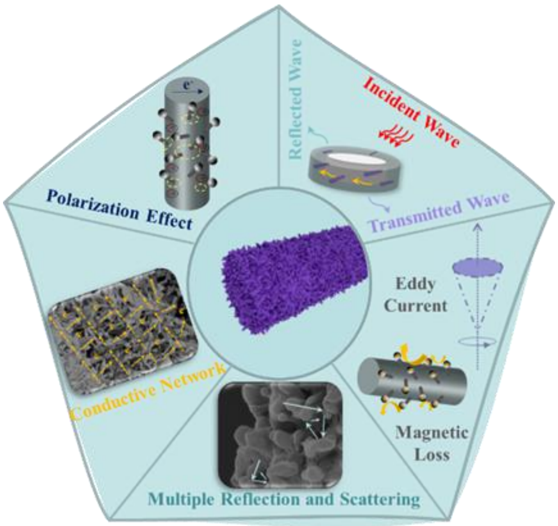


Fig.1. Schematic illustration of the microwave absorption mechanisms of HMCFs@BMZ-R-C700

Session: Emerging Applications

Presenting Type: Poster

Electromagnetic wave absorption properties of flaky FeSiAl particles by annealing in Ar atmosphere

Yining Li、Jiantang Jiang*
Harbin institute of technology

FeSiAl alloy with a specific composition of Fe-9.6Si-5.4Al, well known as Sendust alloy, presents the unique potential of efficient EMA in P-band for the high resistivity, low magnetocrystalline anisotropy and low magnetostrictive coefficient. The electromagnetic properties of this kind of alloy are highly sensitive to the shape and the microstructure despite the unique potential. To tailor the microstructure properly in flattened particles is crucial for excavating the potential. Flaky FeSiAl particles prepared via ball milling were put into annealing for microstructure tailoring. The microstructure evolution and the influence on the properties was investigated. The $D0_3$ phase shape up when the FSA particles were annealed at 600 ^{o}C and that the distribution of Al and Si in the Fe matrix varied apparently. FeSiAl particles annealed at temperature of 400~700 ^{o}C presented high ε'' and thus exhibit efficient dielectric loss. Permeability was found the μ' and μ'' of the annealed FeSiAl particles are greatly improved, indicating that proper annealing can contribute to ferromagnetic loss efficiency. An RL_{max} of -22.76 dB together with an effective absorbing bandwidth (RL less than -5 dB, EAB5) of 1.51 GHz (0.49-2.00 GHz) was expected when FeSiAl particles annealed at 800 ^{o}C was used as fillers, when the thickness was set at 4.0 mm. This work indicated the feasibility for achieving high EMA efficiency in P-L band via the microstructure tailoring.

Key words flaky FeSiAl, Sendust alloy, P-band, electromagnetic property, EMA property

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Presenting Type: Published only

Multi-objective optimization of multifunctional composite laminate considering load-bearing capacity and EMW absorbing performance

Bowen Li、Feng Zhang、Peng Jin*、Qihao Zheng、Tianyi Huang
Huazhong University of Science and Technology

This article introduces a multifunctional composite laminated structure based on continuous fiber 3D printing technology, as well as its optimization design method. The structure consists of 19 layers of Glass Fiber Reinforced Plastics (GFRP) and 1 layer of Carbon Fiber Reinforced Plastics (CFRP), the thickness of each layer is fixed at 0.2mm, wherein, the matrix of each layer of GFRP is polylactic acid (PLA) dispersed with graphene oxide (GO) of different volume fractions, which has the function of transmitting and absorbing electromagnetic waves (EMW). Meanwhile, CFRP has the function of reflecting EMW. Under the premise of the constant total thickness, the multi-objective optimization design of composite laminates is carried out with the ply orientation and volume fraction of GO as design variables, the bending stiffness and EMW absorbing bandwidth of the overall structure as design objectives, and the JAYA algorithm as the optimizer. Results show that the optimization algorithm can automatically adjust the structure to a proper state and compared with composite laminate designed by traditional design methods, the structure has stronger load-bearing capacity and EMW absorbing performance.

Key words Multifunctional Composite Laminate, Load-bearing Capacity, Electromagnetic Wave Absorbing Performance, Multi-objective Optimization

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Invited

Selective Laser Sintering of Self-Healing Polymer Composites

Hesheng Xia*
Sichuan University

Selective laser sintering (SLS) three-dimensional (3D) printing of polymer composite materials remains a big challenge and largely unexplored due to the lack of suitable materials. Here, we developed several different kinds of polymer composites containing covalent adaptable networks (CANs) with self-healing functions for SLS 3D printing. The dynamic mechanism of the reversible covalent bonds was confirmed by 1H NMR and in situ FTIR. Furthermore, the kg-scale self-healing polymer materials as well as their carbon nanotube (CNT) composite powders were prepared by the freeze-grinding method. The SLS printed self-healing polymer materials show nearly isotropic mechanical properties due to the improved interlayer interaction by dynamic cross-linking. The SLS printed polymer/CNT composites possess stimuli-triggered self-healing functions. This study provides a paradigm for designing dynamic self-healing polymers/composites for SLS 3D printing.

Key words self-healing polymer composites, 3D printing

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Invited

Green Manufacturing Technologies of Thermoplastic-Based FRP Composites: Current Situation and Future Development

Jinglei YANG*、Yan SHEN、Sepideh Sadat HOSSEINI NOORABADI
The Hong Kong University of Science and Technology

This paper presents a review of the current situation of green manufacturing technologies of thermoplastic-based fiber reinforced polymer (FRP) composites. Developing thermoplastic FRP composites and its green manufacturing technology is of long-term significance on the sustainable aerospace, automotive, construction and other industrial field. Different types of technical solutions for green manufacturing of thermoplastic FRP composites are outlined. First, the existing thermoplastic resin systems that can be polymerized at room or low temperature compared with the traditional curing approaches are summarized. Compared with common commercial FRP composites, the overall mechanical performance and energy consumption of these novel thermoplastic-based FRP composites is analyzed and their research challenges and application status are discussed. On the other hand, latest non-traditional rapid energy-efficient manufacturing technologies are introduced, with a particular focus on frontal polymerization, which is considered as the most promising alternative to the traditional curing technologies for high-performance FRP composites. This review also provides a detailed introduction on the research progress in thermoplastic FRP composites frontal polymerization and analyzes its challenges in the further development. Finally, current research progress and challenges related to green manufacturing technologies of thermoplastic-based FRP composites is summarized and an outlook of the further research trends is discussed.

Key words Thermoplastic-based FRP composites, green manufacturing, energy-efficient process, mechanical properties

Session: Composites Repair, Self-healing, Recycling and Machining

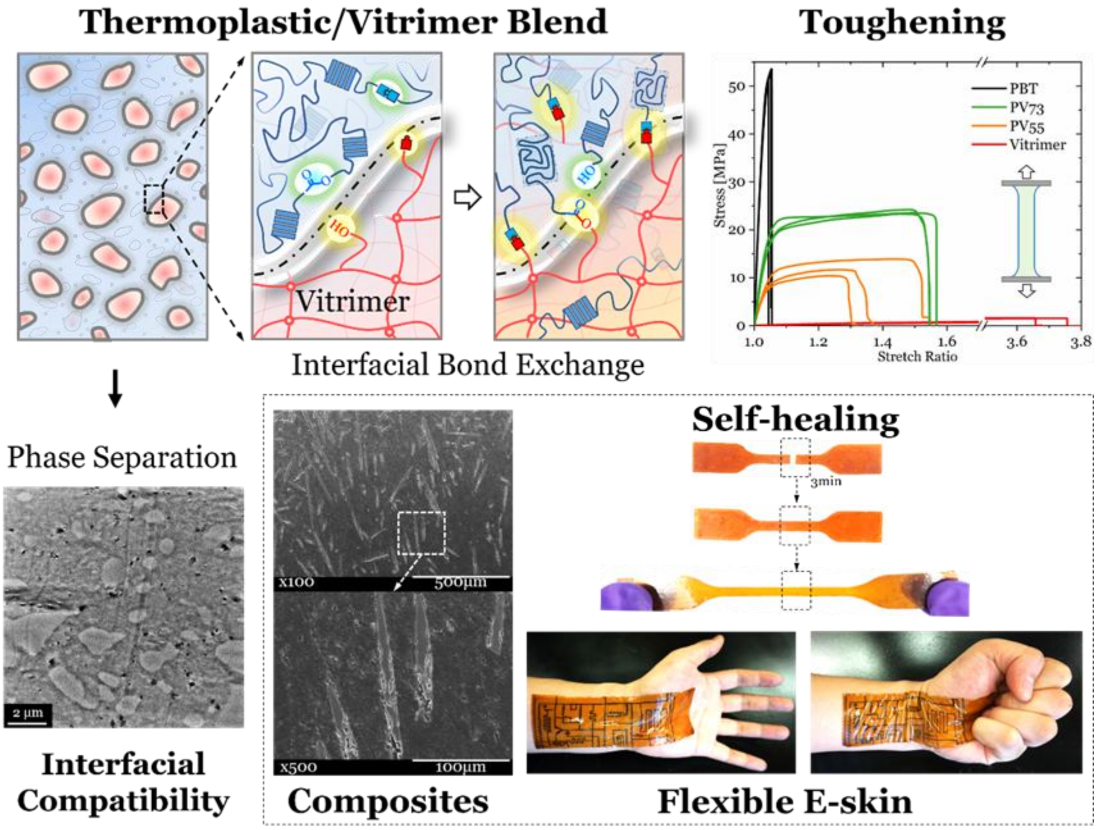
Presenting Type：Oral–Invited

Thermoplastic/vitrimer blend with interfacial design: mechanical properties and potential applications

Zhiqiang Chen*、Tiejun Wang
Xi'an Jiaotong University

Polymer blending is an efficient way to obtain extraordinary polymeric materials, which can combine several distinctive advantages from different component materials. However, once permanently cross-linked thermosets are involved in blending, there are challenges in designing and optimizing the structures and interfacial compatibility of blends. Vitrimer with dynamic covalent polymer networks provides an innovative opportunity for blending thermoplastics and thermosets. Dynamic bond exchange reactions lead to rapid stress relaxation and low viscosity at elevated temperatures, thus endowing vitrimers with excellent malleability. Interestingly, vitrimer can melt blend with thermoplastics to produce new polymeric materials with tailor-made mechanical properties, which points out a very promising direction for designing new polymers by simply blending thermoplastics and thermosets. More importantly, interfacial bond exchange between two components can rearrange the structure of the polymer network and enhance the interfacial compatibility of blends. The obtained blends can combine the mechanical merits of vitrimer and thermoplastics. The polyurethane (TPU) /vitrimer blend is highly flexible, recyclable, reprocessable and possesses self-healing behavior at the same time, showing potential applications in adhesive film and wearable electronics. On the other hand, the polybutylene terephthalate (PBT)/vitrimer blend is very tough and thermostable due to desirable microstructures and interfacial interaction. In addition, the rapid covalent adaptable fluid topology of vitrimers can promote uniform dispersion of component materials, which allows vitrimers to compound with nanofillers to produce homogeneous composites. In summary, we proposed a reactive blending strategy to develop novel thermoplastic-thermoset blend with enhanced compatibility on the basis of dynamic covalent chemistry. It not only provides an opportunity to design and fabricate new polymeric materials with superior mechanical properties, but also paves the way for recycling and reprocessing different types of thermoplastic or thermosets just relying on the widely used blending technologies in the polymer industry. The new polymeric materials also have great application prospects in composite production, functional devices and other fields.

Key words Polymer blend; Thermoplastic; Vitrimer; Mechanical properties.


Thermoplastic/Vitrimer Blend
Toughening
Vitrimer
HO
Interfacial Bond Exchange
PBT
PV73
PV55
Vitrimer
Stress [MPa]
Stretch Ratio
Phase Separation
2 μm
Interfacial Compatibility
x100
500μm
x500
100μm
Composites
Self-healing
3min
Flexible E-skin

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Invited

High Performance Dynamic Covalent Crosslinked Polyacylsemicarbazide Composites with Self-healing and Recycling Capabilities

Zhanhua WANG*、Hesheng Xia
Sichuan University

Self-healing and recycling of fiber reinforced polymer (FRP) composites are of great significance towards pursuing a sustainable and circular economy, but remain a huge challenge due to the infusible and insoluble properties of thermoset polymers. The newly developed dynamic covalent polymers provide a great opportunity to resolve this issue for FRPs. Here we developed a novel type of dynamic covalently cross-linked polyacylsemicarbazide exhibiting a high modulus and self-healing/recycling capability due to the reversible properties of the dynamic acylsemicarbazide (ASC) moieties. Introducing different ASC moieties composed of different dihydrazides into the polymer can dramatically tune the mechanical, self-healing and reprocessing properties. An optimized polyacylsemicarbazide with a Young's modulus of 2.84 GPa, a stress at break of 100 MPa and a glass transition temperature of 123 oC exhibits a self-healing efficiency of 94.4% and great reprocessing properties. Furthermore, using this newly developed PASC material as the matrix resin, the carbon fiber reinforced polymer composite was successfully prepared through solution impregnation and thermal pressing. The composite exhibits an interlaminar shear strength of 40 MPa and a healing efficiency of 76.2%. The great dynamic reversible properties of ASC moieties enables the recycling of the carbon fiber and matrix resin, respectively, from the composites by a solvolysis method.

Key words Dynamic Covalent Polymer, Reprocessing, Self-Healing, Carbon Fiber Reinforced Polymer Composite, Recycle

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Invited

Self-healing of Jute Fiber Composite with Epoxy Loaded Core-Shell PLA Nanofibers

Mohamad Tarmizie BIN HASSIM、Maksym Li、M. N. Prabhakar、Jung-il Song*
Changwon National University

Electrospun core-shell nanofibers are deemed to have precedence over other self-healing carriers due to its simplicity during fabrication, relatively low manufacturing costs, high aspect ratio resulting in an improved dispersion in the composite and its favorable effect on the mechanical properties of the composites. Nanofibers as self-healing agent carriers does not only serve as a healing agent carrier, but it also acts as an interfacial toughening agent between the fiber laminates. This study utilizes a two-part core-shell PLA nanofibers carrying epoxy resin and amine-based curing agent separately. 12wt% PLA solution was prepared as the shell solution whereby the epoxy resin and amine curing agent were used as procured for the core solutions. The viability of these two-part healing carriers, core-shell nanofibers with each constituent were layered and subjected to a scratch test with a sharp razor blade. SEM images showed that scratching the mat induces the release of the healing agents which solidifies at room temperature after 48hours. Jute FRP was fabricated with self-healing nanofiber mats interleaved between each jute laminates to assess the self-healing capabilities. The addition of core-shell PLA nanofiber mats increased the tensile strength and modulus by 12% and 14% respectively. To assess the self-healing traits of these composites, the composites were subjected to tensile test until failure 48 hours after being pre-damaged. The control composite and the self-healing composites had a reduction of 12 and 2% respectively in their tensile modulus after its first healing cycle indicating that the presence of healing agents minimized the modulus loss.

Key words self-healing, core-shell nanofibers, PLA nanofibers

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type：Oral-Invited

High-performance Self-healing Epoxy Based on Microencapsulated Epoxy-Amine Chemistry

He ZHANG*、XIAO Kaibin、PENG Junjie、FANG Xinglei
South China University of Technology

Attributed to the advantages of low toxicity and low cost, high self-healing performance, good material compatibility, high thermal stability and long-term stability, the self-healing epoxy based on microencapsulated epoxy-amine chemistry is a potentially practical self-healing system with great prospective. My research team has been making great efforts in microencapsulation techniques to microencapsulate the dual healants and developing this self-healing system, and accumulate considerable achievements during the last 3-5 years. This report shares the knowledges and the progresses including the novel microencapsulation techniques to fabricate high-quality microcapsules respectively containing polyamine hardeners and epoxy monomers, self-healing structural epoxy composites and functional anticorrosion epoxy coatings, fast self-healing epoxy, self-healing high-temperature-cured epoxy, and multifunctional self-healing epoxy. Besides, based on the current developments and bottlenecks of this self-healing system, this report also looks forward to the work to be done in the future, with the purpose to lay a solid theoretical and technical foundation for the practical development of this self-healing system.

Key words self-healing, epoxy, amine, microcapsule

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Invited

Malleable and Recyclable Crosslinking Thermoset Based on Dynamic Covalent Bonds

Yanfeng ZHANG*
Xi'an Jiaotong University

Thermosets have excellent mechanical properties, solvent resistance, abrasion resistance, and load bearing capacity compared with thermoplastics due to their covalently cross-linked structure. However, unlike thermoplastics that can be molded through injection or extrusion with the application of heat or solvent, most thermoset must be polymerized in the mold to set the desired shape since they generally lack the ability to be reprocessed or recycled after curing. Recently, researchers have been trying to solve this problem by incorporating dynamic covalent bonds, which facilitate stress relaxation and reversible depolymerization through bond exchange.1 However, most of them are limited by the availability of commodity raw materials.
Recently, we reported that by introducing bulky substituents on one of the nitrogen atoms of a urea bond, the resulting hindered urea bonds (HUB) show dynamic nature under ambient/catalyst-free condition for soft organogels and malleable thermoset.2-3
Other kinds of malleable thermosetting soft materials were developed also by using novel dynamic covalent bonds, such as imine, urethane.4-6 Those thermosets have comparable mechanical properties and solvent resistance with conventional thermosets, but showed malleability under mild heating without the need of catalyst. Furthermore, Those thermosets could be efficiently recycled, which avoids the use of energy intensive degradation condition and tedious monomer purification.

Key words Dynamic Covalent Bond; Thermosetting Resin; Self-healing; Recyclable

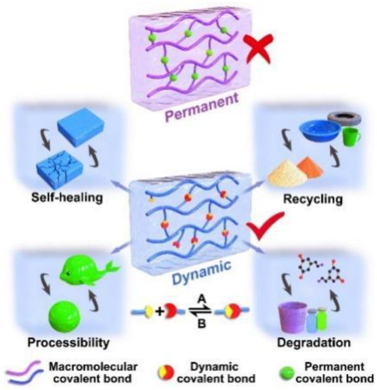


Fig. 1. Comparison between dymamic covalent polymer and permanent covalent polymer.

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Invited

Covalent Adaptable Networks Enable Smart Processing of Highly Filled Polymer Composites

Mingqiu ZHANG*、Yuan Cao、Min Zhi Rong
Sun Yat-sen University

To tackle the challenge of manufacturing highly filled composite materials via melt compounding and injection molding, the authors proposed a novel approach based on Diels-Alder (DA) chemistry. Polycaprolactone oligomers (PCLolig, Mw = 2000 g/mol) were firstly crosslinked by DA bonds, and then the resultant network PCLolig-DA was also connected to maleimide functionalized Al2O3 particles (Al2O3-M) via DA bonds. Upon being heated to the retro-DA reaction temperature, the covalent adaptable composite network exhibited low viscosity due to decrosslinking, enabling melt processing and well dispersion of high-concentration fillers. During the subsequent cooling, the composite network was regained because of DA reaction, benefiting increase of the composite's strength. Consequently, the contradictory requirements for molecular weight of matrix polymer under the circumstances, which had better to be as low as possible during the manufacturing but as high as possible in the ultimate composites, were skillfully satisfied.

Key words Polymer matrix composites, Injection molding, Self-healing, Recycling

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type： Oral–Invited

Self-growing Polymer Materials

Jiaxi CUI*
University of Electronic Science and Technology of China

Living organisms, systems that are open and non-equilibrium, can vary their size, mass, inherent properties, and/or shapes by growth. In contrast, synthetic crosslinked soft materials typically possess fixed structure and specific properties, and usually do not allow for post-variation once fabricated. Recently, the growing concept of living organisms has been applied to design intelligent polymer materials with post-tailorable sizes. In this contribution, I will present our photo-assisted growing strategy to post-update various structural parameters and properties of crosslinked polymers. This strategy involves three steps, i.e., the swelling and the in-situ polymerization of polymerizable compounds, followed by polymer chain exchange. This method allows for exquisite control over crosslinked polymer materials' sizes, shape, composition, and properties. I will demonstrate how to use this method to create structural surfaces, fabricate conductive hydrogel circurts, induce rigid polymers (Modulus: 1 GPa) self-heal, and fabricate chromatic structural color patterns.

Key words polymer networks, growth, chain exchange, self-healing, structural color

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Invited

Synthesis and Properties of High-performance Readily Recyclable Thermosets and Their Application in Composites

Songqi MA[1,2]、Pengyun Li[2]、Xiwei Xu[2]、Sheng Wang[2]、Wangchao Yuan[2]、Jin Zhu[2]、Songqi Ma*[1,2]

1. Jiangnan University

2. Ningbo Institute of Materials Technology and Engineering, Chinese Academy of Sciences

Thermosets have been widely used in plenty of applications such as coatings, adhesives, composites, etc. due to their excellent chemical resistance, dimensional stability, thermal and mechanical properties which are much higher than thermoplastics, and are irreplaceable. Nevertheless, the arduous recycle of thermosets not only cripples the introduction and development of thermosetting polymers, but also severely impacts the recovery of downstream products such as carbon-fiber (CF) reinforced composites (CFRC), electronic packaging materials, coatings, etc. Recently, our group focused on developing degradable or recyclable thermosets. A series of thermosets with high performance and excellent degradability were developed based on phenyl cyclic acetal structure and phenyl-conjugated Schiff base structure. The degradability, degradation mechanism, and the thermal and mechanical properties of the thermosets were systematically investigated. The thermosets could be readily degraded in mild acidic conditions while kept stable in neutral and basic conditions. The glass transition temperature, tensile strength and modulus of the acetal epoxy resin were comparable to or even higher than bisphenol A epoxy resin, and the performance could be easily modulated via adjusting the chemical structure of raw materials. Some thermosets were utilized to produce carbon fiber reinforced composites. Due to the readily degradability of the thermosetting matrices, the carbon fiber could be reclaimed from the composites, and the morphology, chemical structure, and mechanical properties were well maintained compared to the virgin carbon fiber.

Key words thermosets, acetal, epoxy resins, recycle, carbon fiber reinforced composites

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Invited

Joining of Room Temperature Curable Thermoplastic Composites: Current Trends and Future Perspectives

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School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50, Nanyang Avenue, 639798, Singapore

Composite structures are increasingly used in diverse applications such as aerospace, sports, automotive, and many more. Fusion bonding methodologies can produce high weld strength and it can be performed in an extremely short time as compared to other conventional joining methods especially the adhesive based solutions. Elium is a novel acrylic thermoplastic resin as it can be cured at room temperature and can potentially be used in many industrial applications which requires joining of two structural parts. Current state of art of joining these composites is using control adhesives and there is a growing need to explore alternative solutions. Ultrasonic welding and resistance welding of Elium based composites with similar and dissimilar material has been investigated by many researchers and has shown promising results. Current presentation will focus on explaining the state of art of joining these novel Elium based composites using ultrasonic welding with different kind of reinforcements. Their performance comparison in static and dynamic lap shear tests are investigated and the complex failure mechanisms are understood using the detailed scanning microscopic analysis. Features such as shear cusps, plastic deformation, fiber pullout, and fiber imprints were observed from the in-depth SEM investigation for maximum lap shear strength and were indicative of the strong bonds between adherend. The lap shear strength (LSS) performance dependency on the weld parameters, the type of coupling layer and the type of energy director will also be explained. A novel manufacturing strategy which is conceptualized to create a thermoplastic coupling layer on top of the epoxy composite to create the desired interphase to improve the welding strength of the dissimilar will also be presented. Furthermore, the future perspectives of using the fusion joining methodologies for room temperature cured Elium based composites will also be deliberated.

Key words thermoplastics; acrylic; joining; ultasonic welding; Failure mechanisms

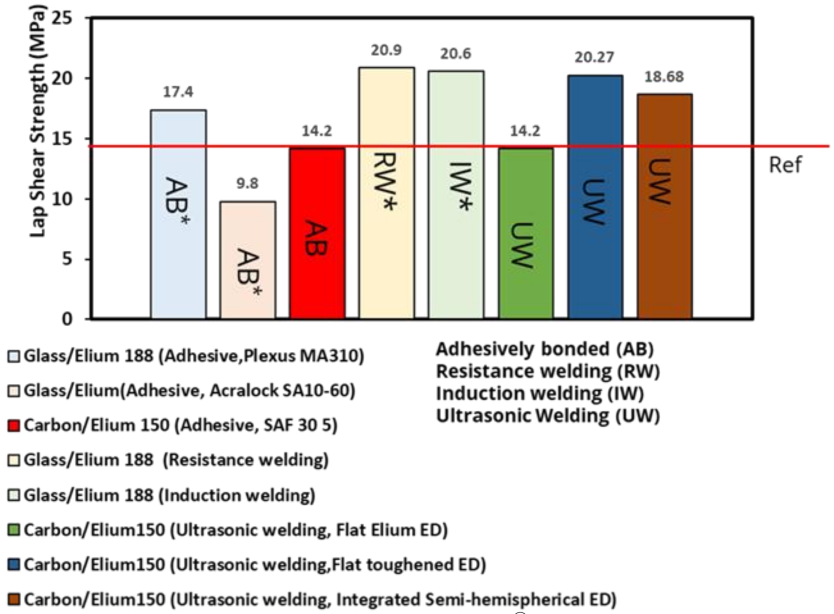

Fig. 1. Comparison of average LSS of acrylic Elium® based composites using welding and controlled adhesive approach

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Onsite

Tribological behaviors of tungsten carbide against Ti and CFRP under the condition of supercritical carbon dioxide cryogenic minimum lubrication

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Drilling titanium alloy (Ti) and carbon fiber reinforced polymer (CFRP) stacks is a necessary step for aircraft assembly and this process is preferably completed in one shot to ensure for production and precision purpose. However, Ti and CFRP are both hard-to-cut materials with extremely different material properties, and during drilling, the cutting tools are susceptible to rapid and severe wear; therefore, a proper cooling process is needed. Supercritical carbon dioxide (scCO2) cryogenic minimum lubrication (CMQL) is an emerging cooling method for the cutting process, which is supposed to lower the temperature as well as friction. This paper has conducted an experimental study on the tribological behaviors of tungsten carbide against Ti and CFRP under CMQL condition to further understand its advantages in the application of Ti and CFRP stack. The results show that CMQL can effectively improve the severe friction between tungsten carbide and Ti and reduce the average friction coefficient by nearly 0.05. It was found that the wear mechanism in both dry and CMQL is titanium adhesive wear, but CMQL can significantly suppress the adhesive wear under Ti case. Comparatively, the friction between tungsten carbide and CFRP is relatively steady under both dry and CMQL conditions. CMQL reduces the average friction coefficient by nearly 0.1 and improves the degree of abrasive wear under CFRP case. This paper can provide a basis for revealing the tribological behaviors under CMQL condition.

Key words Ti; CFRP; Supercritical carbon dioxide; Cryogenic minimum quantity lubrication; Tribological behavior

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Onsite

Key Technologies and Equipment for High-value Recycling and Utilizing Waste Fiber-reinforced Composites

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Shanghai Zhishi Alloy Technology Co., Ltd

Fiber-reinforced resin-based composites have been widely used in many important fields because of their excellent properties, such as high specific strength, high specific stiffness, corrosion resistance, and temperature resistance. However, since the resin matrix is not soluble or even non-molten, while the interface between the fiber and the resin is strongly bonded, it is very difficult to decompose the matrix and extract the fibers. Therefore, the environmental pollution and waste of fiber resources, caused by the waste of composites, have become serious environmental, social, and economic problem in our country. In this report, in view of the serious shortage of lacking key technologies for industrial recycling fiber-reinforced composites and extracting recycled fiber with high performance, we analyzed the key scientific and technical issues of composite matrix decomposition, fiber regeneration, and recycled-fiber-based composites reconstruction with the pyrolysis recovery treatment of fiber reinforced composites. In addition, this research has been carried out on the design, manufacturing, and application of the key technologies of efficient and environmental-friendly pyrolysis recycling equipment, along with the recycled-fiber resin-matrix composites, promoting the innovative development of composite recycling and reuse industry.

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Onsite

Research on Influencing Law of Cutting Parameters and Chip Formation in Orthogonal Cutting of Composite Material

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This paper investigated the effects of the fiber cutting angle, cutting speed and cutting depth on the cutting force and thrust force in orthogonal cutting of CFRP. The cutting mechanism and chip formation were analyzed. The machined quality was described by the machined surface roughness, three dimensions morphology and subsurface damage depth. The results showed that the fiber cutting angle was the main factor affecting the machinability of composite materials. The cutting forces at $\theta>90°$ were 8 times higher than those of $\theta<90°$ on average. At $\theta=90°$, the influence of cutting speed and cutting depth on cutting force and thrust force was significant due to fiber bending deformation and fiber kinking. At $\theta=0°$, the cutting mechanism was interface debonding and fiber buckling, forming discontinuous and slightly curly chips. For $0°<\theta<90°$, the fibers were cut off by the cutting edge and then slipped along the rake face of the tool, resulting in a continuous and curly chips. At $\theta=90°$, the fiber debonding occurred firstly under the extrusion of the rake face, and then broke under the shear action of the cutting edge, producing a discontinuous and flaky chip. In the cases of $90°<\theta<180°$, the fibers underwent large bending deformation, leading to flaky or long strips of chips. Besides, the coupling effect of small cutting depth (h=0.02 mm) and medium cutting speed (v=7 mm/s) made the cutting process unstable extremely. The high cutting speed and medium cutting depth were recommended to reduce cutting force and improve machined surface quality.

Key words CFRP, Orthogonal cutting, Chip formation, Machined surface quality, Subsurface damage

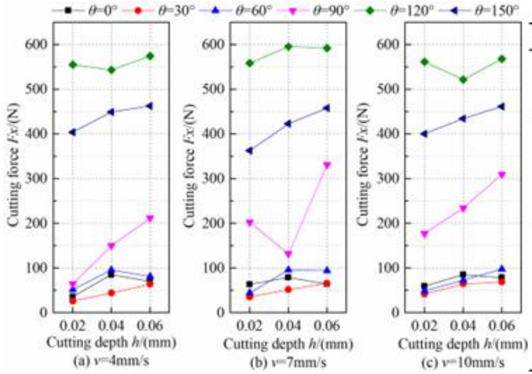

Fig. 1. The curves of cutting force varying with the cutting depth at three cutting depths.

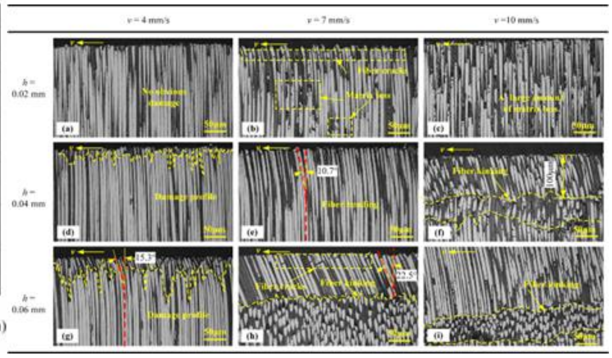

Fig. 2. The subsurface damages of microstructure in orthogonal cutting of UD-CFRP with θ=90°.

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Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Onsite

Repeatable Autonomic Healing of Low-velocity Impact Damage in CFRP Composites

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The fiber-reinforced polymer composites (FRPs) could offer excellent specific strength and stiffness. However, the reinforcing fibers are mostly in the two-dimension distribution in FRPs, resulting in relatively poor performance under dynamic impact loading. In this study, repeatable self-healing carbon fiber/epoxy composites (RSH-CFRPs) have been prepared. Low-velocity impact (LVI) tests and compressive tests were conducted to study the self-healing performance of undetectable delamination inside these RSH-CFRPs.

Design and fabrication of RSH-CFRPs

Hollow glass fibers containing microcapsules (HGFs-Ms) were prepared (Fig. 1). Then the epoxy resin, microcapsules containing hardener and HGFs-Ms, were mixed and brushed onto the carbon fiber fabrics to fabricate the RSH-CFRPs.

Key words Repeatable self-healing carbon fiber/epoxy composites (RSH-CFRPs); Hollow glass fibers; Mircrocapsules; Low-velocity impact

Fig. 1. Preparation of HGFs-Ms.

The compression strength of RSH-CFRPs

Tab. 1. Results of compression tests of Base and RSH-CFRP laminates.

Specimen type			Base		RSH-CFRP		
			Strength (MPa)	% of undamaged Base	Strength (MPa)	% of undamaged Base	% of undamaged RSH-CFRP
	Undamaged		223.75 (3.32)	100%	157.33 (8.58)	70%	100%
1st	Damaged	4 J	222.46 (4.17)	99%	152.26 (5.02)	68%	97%
		12 J	180.87 (8.09)	81%	137.47 (3.54)	61%	87%
		20 J	167.44 (6.47)	75%	122.65 (3.75)	55%	78%
	Self-healed	4 J			160.7 (6.68)	72%	102%
		12 J			160.06 (4.74)	72%	102%
		20 J			137.42 (4.35)	61%	87%
2nd	Damaged	4 J	219.83 (5.10)	98%	158.68 (2.79)	71%	101%
		12 J	170.69 (0.80)	76%	131.36 (5.03)	59%	83%
		20 J	104.74 (3.76)	47%	96.69 (4.34)	43%	61%
	Self-healed	4 J			160.06 (2.26)	72%	102%
		12 J			143.88 (3.81)	64%	91%
		20 J			107.02 (4.74)	48%	68%

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type：Oral-Onsite

Preparation of SiC aerogel with continuous skeletons for microwave absorption and thermal insulation

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Central South University

With the increase of flight speed and flight time of aircraft, the development of high temperature resistant and thermal insulation aerogel becomes the key to ensure the normal operation of aircraft thermal protection system. Aiming at the defects that the traditional silica-based aerogel is not resistant to high temperature, has weak protection against high-temperature thermal radiation and needs the auxiliary molding of a second component, In this study, a template conversion method was used to prepare rigid framework silicon carbide foam by reacting carbon foam with gaseous silicon monoxide at 1400 °C. The reaction mechanism was described in detail. The method has the advantages of simple steps, easy control of conditions and suitability for large-scale production. The prepared silicon carbide aerogels have ultra-low density (8 mg/cm−3), superior high temperature resistance (up to 1500 °C), high compressive strength (up to 0.35 MPa) and ultra-low thermal conductivity (minimum 0.024 W/m·K).This research work provides technical support and theoretical reference for the development of the next generation of high temperature insulation materials.

Key words thermal insulation, thermal resistance, continuous skeletons, microwave absorption

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type：Oral-Onsite

Performance Assessment of GFRP Waste Powder/FA Based Geopolymer Pastes at Ambient and Elevated Temperatures

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Nanjing Tech University

Environmental issues caused by glass fiber reinforced polymer (GFRP) waste have attracted widespread attention. The geopolymer has the advantage of using by-product waste containing aluminosilicate phases to reduce carbon footprint. In this study, glass fiber-reinforced polymer (GFRP) waste powder was blended with fly ash (FA) as precursors of geopolymer pastes to partial replace cement production in construction. The effects of GFRP powder content, activator concentration, liquid-to-solid ratio (L/S), activator solution modulus and synthetic temperature on the physico-mechanical properties of geopolymer pastes were discussed. Based on 7-day compressive strength, the optimal combination of the geopolymer mixture was determined to be 30 wt.% GFRP powder content, an activator concentration of 85%, L/S of 0.5, an activator solution modulus of 1.2 and curing temperature of 60 °C. The incorporation of 30% GFRP powder in geopolymer pastes to replace FA could enhance the compressive strength to flexural strength of geopolymer pastes by 3 times, which indicated that the incorporation of GFRP powder improved the geopolymer brittleness. The 7-day compressive strength of the GFRP waste powder/FA-based geopolymer pastes curing at 60 °C was 5 times higher than that of geopolymer pastes curing at 25 °C. The activator solution modulus had an insignificant effect on the compressive strength when in the range of 1.2–1.4. Microstructure analysis showed that a large amount of cluster gels was found in the matrix at 60 °C, and many micro cracks was detected at 80 °C in the GFRP waste powder/fly ash geopolymer, leading to poor mechanical strength. The developed GFRP powder/FA-based geopolymer pastes exhibited comparable compressive strength and superior flexural strength to those of the FA-based geopolymers, which could be applied as a high application potential in building construction material.

Key words Glass fiber reinforced polymer powder; Fly ash; Geopolymer; Physico-mechanical properties; Synthetic temperature

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Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Onsite

Structural Hardening and Enhanced Energy Absorption of ILSTF Microcapsule Under Dynamic Load for Potential Impact-Resistant Composite Application

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2. Southern University of Science and Technology

Shear thickening fluid (STF) is featured as one of the promising energy-dissipative materials for its shear rate sensitive nature. Thus, it has been adopted as impact-resistant material for emerging flexible liquid body armor and other protective applications. However, leakage and hard to directly incorporated into matrices restrict its application in fabrics and laminates till now. Microencapsulation of STF is a promising solution to broaden its applicable composite forms. Also, the actual mechanical response of this core-shell structure in various loading rates shall be fully understood before its incorporation into protective structures. Therefore, a new type of shear thickening fluid microcapsule is fabricated with STF core made of fumed silica dispersed in the ionic fluid BmimBF4 herein (ILSTF MC). Based on that, the mechanical response of the single ILSTF MC under increasing strain rate has been evaluated via nanoindentation of displacement control mode. By analyzing the compressive response of a single microcapsule under various loading rates, dynamic structural hardening and improved energy absorption under compressive loads of higher nominal strain rates are verified. More evident in microcapsules with a diameter of around 100μm, the structural stiffness of a single ILSTF MC evaluated by the loading process has been enhanced by over 700%, and the energy absorption enhancement is correspondingly significant. For comparison, the microcapsules containing pure ionic liquid BmimBF4 (IL MC) are compressed under the same loading condition, but the corresponding improvement is only marginal. Those structural responses are compared to prove further the enhancement of ILSTF MC is mainly caused by the shear thickening effect of its core. The results uncover a potential impact-resistant composite system based on ILSTF MC, which serves as easy-to-disperse/process defensive units.

Key words Shear-thickening fluid, Impact-resistant, ILSTF Microcapsule, Structural hardening, Energy absorption

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Onsite

Quality Assessment and Integrity of Circular Drilled-Holes: Influence of Surface Roughness on CFRP Laminates

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Introducing circular holes in carbon-fibre-reinforced polymer (CFRP) laminates by drilling is a typical process involved in the assembly of composite aircraft parts. It is a complex process, owing to the heterogeneity of materials and the processing configuration, and to the fact that reinforcements and debris are very abrasive. As CFRP laminates are prone to drilling-induced damage in the form of delamination and edge chipping, a conventional twist drill is no longer conclusive as different configurations of drill bits have been developed for practical use. In this study, the drilling performance and integrity of circular holes in CFRP laminates to assemble a flat panel of a commercial aircraft were investigated. The analyses were focused on three different bit configurations of dagger drill, drill reamer, and twist carbide drill, employing drilling speeds at 500, 1000, and 2000 rpm with different backing supports. Quantification of output responses, including thrust force and torque were measured. Assessment of the quality and integrity of holes was accomplished by evaluating surface roughness, heat distribution, roundness, chip size, and damage factor defining delamination at the hole edge, providing guidelines for optimization of machining parameters for introducing circular holes in practical operation.

Key words Composite Machining, Drilling, CFRP, Surface Roughness

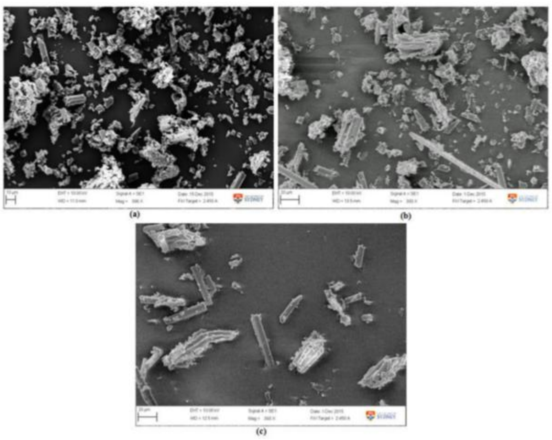

Fig.1. Morphology of chip shapes produced at a spindle speed of 500 rpm:(a) GT50 dagger drill, (b) GT15 drill reamer, and (c) twist drill.

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Onsite

A process parameter optimization method in peripheral milling of CF/PEEK: Reasonable control of cutting force and cutting temperature

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Carbon fiber reinforced PEEK matrix composite (CFRTP) is an emerging material for aerospace industrial due to its superior properties. Milling CFRTP would be an important step during its application to achieve accurate shape for assembly. However, due to its high sensitivity on temperature, the machining surface quality is strongly affected by cutting force as well as cutting temperature. This paper conducted the studies about the effects of cutting force and cutting temperature on the quality of machined surface respectively and optimized machining parameters to improve the roughness of the machined surface. First, the suitable ranges of the cutting force and the cutting temperature are figured out, based on the specific analysis on the effects of the cutting force and cutting temperature on machined surface quality. It was found that the cutting force has a linear relationship with the feed rate. Then the relationship between cutting temperature and cutting speed under different feed rates is studied through neural network. Further, with this method, the temperature can be predicted according to cutting speed within an error of 6%. With that, the machining parameters optimization is conducted. The surface roughness is signally improved by using the optimized parameters. The research results are hope to provide guidance for high quality milling of CFRTP.

Key words CFRTP; Milling; Cutting force; Cutting temperature; Surface quality

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Virtual Platform

Improved Adhesive Bonding Strength of Bonded Repair of Thermoplastic Composites Using Laser Surface Patterning

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Hong Kong University of Science and Technology

Composite structures are gaining more and more importance in a variety of industrial applications, thereby novel maintenance and repair techniques are required to ensure their proper operation. Surface pre-treatment is one of the key processes in the bonded repair of fiber-reinforced polymer composites. Laser surface treatment can be easily monitored and adjusted for fast, precise, scalable, and reproducible surface patterning of composites that is capable of automation. This paper, for the first time, investigates the feasibility of laser surface patterning as a surface activation method for the repair of Thermoplastic Glass Fibre/Elium® Composites. The composite adherents are structured in parallel lined-like textures using a 1064 nm pulsed nanosecond laser. The influence of laser parameters such as fluence and hatch space on the produced surface microstructures and resulting bonding performance are discussed. The surface morphology and microstructure were characterized by scanning electron microscopy (SEM) and optical profilometry, surface wettability determined by water contact angle measurement, and fourier transform infrared spectroscopy (FTIR) analyses were carried out to study the effect of laser texturing on the functional groups of composites' surfaces. Bonded specimens were mechanically tested using a single lap shear test. It was found that the optimum laser fluence and hatch spaces are 12.8 J/cm2 and 125 μm respectively, leading to the bonding improvement of up to 50% compared to the untreated specimens and the highest shear strength of 17.6 MPa thus reducing repair area and costs significantly. Furthermore, it is demonstrated that this substantial improvement in adhesive strength is achieved only by selective removal of resin at controlled laser parameters without exposing or damaging fibers on the composite surface resolving the main concern about damaging the underlying plies.

Key words Laser Surface Treatment, Interface, Bonded Repair, Thermoplastic Composite

ACCM 12
Hangzhou, PR China 25-28 April, 2023

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Virtual Platform

Fibre structure preservation for retaining mechanical properties of remanufactured composites using thermally recovered carbon fibres

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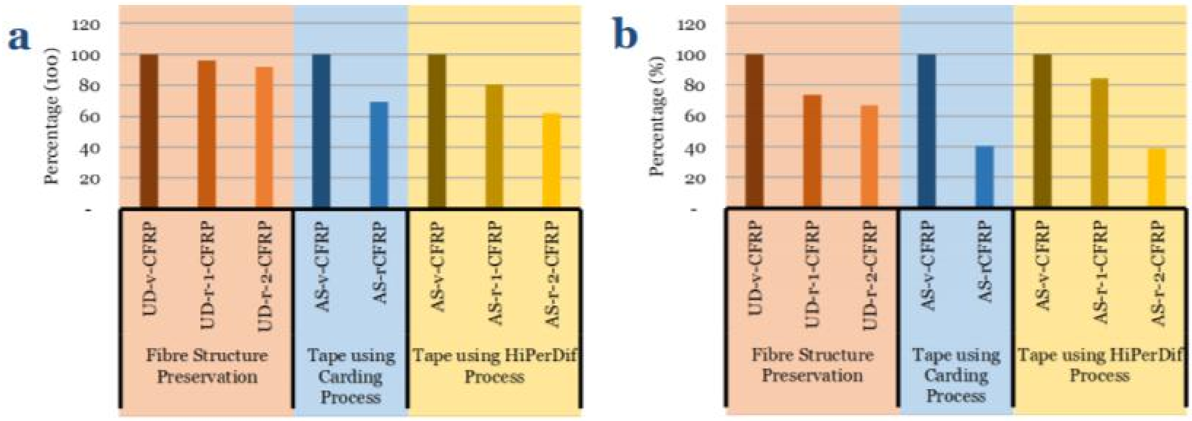
The University of Auckland

Carbon fibre reinforced polymer (CFRP) is an expensive material primarily due to the energy-intensive production process, making it a high-value material. Yet, at any time during the material's life cycle, the CFRP becomes a waste; it is destined for landfill or incineration, instantaneously diminishing its value. The amount of CFRP waste is increasing due to the ever-rising CFRP market demand. Thus, it makes sense to recycle the valuable material, except that carbon fibre recovery is a sophisticated process, especially for the thermoset CFRP composites, due to the irreversible cure reactions of thermoset polymers. Thermal recycling of CFRP waste has emerged as a technologically mature process to recirculate carbon fibre into the supply chain. However, the thermally recovered carbon fibres lose their material value due to their short, discontinuous, and fluffy form. The recovered fibres from thermal recycling are usually post-processed to form a semi-finished product suitable for remanufacturing. These post-processing steps increase the primary energy demand by 11.4% compared to a 26.3% reduction if the fibre architecture is retained during the recycling stage. The current study demonstrates the effectiveness of fibre structure preservation during thermal recycling, resulting in the recovered fibre structure with fibre orientation, alignment, and length, well preserved and intact, ready for remanufacturing without any need for a post-posing step. The multiloop recycling and remanufacturing with fibre structure preservation was performed to analyse the retention of mechanical properties of the remanufactured parts. The results suggest that even after 2nd recycling, the strength and stiffness of the remanufactured composite parts with preserved fibre structure were up to 50% better than the properties reported in the literature for composites manufactured from post-processed semi-finished products with aligned recovered fibres.

Key words Carbon fibre reinforced polymers, Composites, Thermal recycling, Recovery, Mechanical properties



UD: unidirectional (for continuous fibers); v: virgin; r: recycled; 1, 2: recovery cycle; AS:aligned short fibres (less than 12mm);

Fig. 1. Percentage of (a) specific modulus ratio and (b) specific strength ratio between recovered and virgin CFRP samples.

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Oral-Virtual Platform

Develop High Wear Resistant Fibre Reinforced Polymer Composites using the Additive Manufacturing Technology

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Over the past few decades, with continuing development and adoption of additive manufacturing (AM), the fabrication of polymer composites has drawn increasing attention from both industrial and academic communities. Nevertheless, AM also has drawbacks such as poor surface finishing and voids formation. This has raised concerns about the mechanical properties of the printed materials, especially the time-dependent properties such as friction and wear properties, which, however, has not been well understood. To enable AM technology for a wider mechanical applications, it is important to study and understand the basic process-structure-property relationship of the printed materials.

This study systematically investigated the tribological performance of polymers that were fabricated by additive manufacturing, and emphasis was placed on the anisotropic properties of fibre reinforced polymer (FRP) composites, as well as their dependence on the printing parameters. Further, the convex squared texture was designed and created in printing process to improve materials' tribological performance. It was found that with the textured surface, the wear resistance of the printed FRP was enhanced under dry sliding conditions, which could be explained by the debris collection or cleaning effect of surface texture. However, such a cleaning effect was less noticeable under lubricated conditions, as the liquid could effectively clean the surface. On the other hand, the induced surface texture would increase the surface area exposed to water, causing surface softening due to the higher water absorption rate. As a result, the samples having surface textures showed the higher wear rates under lubricated conditions. The work has provided new insights into how to design wear resistant polymer materials using 3D printing technologies, subjected to different sliding conditions.

Key words 3D printing; fibre reinforced polymer composites, friction and wear, surface texture

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Poster

Thermally induced self-healing behavior of carbon nanotube composite fibers

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As an assembly of carbon nanotubes, carbon nanotube fibers (CNT fibers) inherit the excellent properties of carbon nanotubes, thus owning superior mechanical properties such as ultra-high strength and modulus. Therefore, carbon nanotube fiber and its composite fiber is a potential engineering nanomaterial and an excellent advanced lightweight fiber. When CNT fiber and its composites were applied in aeronautics, astronautics, industry, or other fields, the structure may inevitably encounter long-term load, high temperature, and other complex working conditions commonly. Any micro-crack may lead to catastrophic damage and failure. However, the structure can not be repaired in time generally in practical application. Therefore, it is of crucial importance to investigate and design the self-healing structure. When micro cracks or damage are formed inside a structure, self-healing will greatly improve the durability and reliability of CNT fibers and their composite components while applied in aerospace. The thermoplastic resin carbon nanotube fibers have the characteristics of thermal self-healing. When the PE-CNT fiber enters into plastic yield, some internal micro-damages were repaired after heat treatment. However, the melting temperature of thermoplastic resin PP/PE/PLA is generally between 200-300 °C, while the initial oxidation temperature of carbon nanotube fibers is 134 °C. Therefore, to improve its heat resistance and thermal stability, a simple and low-cost method is proposed. Coating a layer of silane on the surface of CNT fiber can effectively improve the thermodynamic properties of the fiber. The treated carbon nanotube composite fibers have good mechanical properties and excellent self-healing properties under heat exposure. At the same time, the fracture mechanics and thermodynamic properties of carbon nanotube composite fibers were characterized by an in-situ scanning electron microscope and improved micro Hopkinson rod.

Key words Thermal-induced, carbon nanotube fiber, self-healing

Hangzhou, PR China 25-28 April, 2023

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Poster

Experimental Investigation of Impact Resistance and Compression Behavior of CF/PEEK Laminates after Melt Method Damage Repair with Different Stacking Sequences

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Unidirectional fiber-reinforced composite laminates have a weak out-of-plane impact resistance and will inevitably suffer structural integrity damage in service due to low-velocity impact (LVI). In this paper, the hot-press fusion method is used to repair the impact damaged unidirectional carbon fiber reinforced poly-ether-ether-ketone (CF/PEEK) thermoplastic composites. No impact-induced delamination or matrix cracking was observed in the repaired specimens by ultrasonic scanning and digital microscope, and the broken fiber was re-covered by the resin matrix, which demonstrating the feasibility of the solution. Afterwards, typical responses of CF/PEEK composite laminates to re-impact and post-repair compression are presented in a comprehensive and detailed manner, and compared with initial impact response and compression after impact (CAI) behavior. The effects of two stacking sequences and three impact energies are considered. The results show that due to the presence of initial fiber breakage, quasi-isotropic laminates are more susceptible to localized fracture damage on re-impact than orthotropic laminates as the impact energy increases. The hot-press treatment increases the compression residual strength of the laminate by 20-30% compared with the specimen before repair. These studies provide technical ideas for exploring the use of hot-press fusion method to improve the mechanical properties of composite laminates after suffering impact damage.

Key words CF/PEEK composites, Low-velocity impact, Hot-press fusion repair, Compression residual strength

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Published only

Self-healing Polysiloxanes and Its Applications in Soft Electronics

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Harbin Institute of Technology

Longevity, reliability, particularly healability, are increasingly attractive for the next-generation materials. Self-healing polysiloxanes possess excellent biocompatibility, heat resistance and chemical inertness, hydrophobicity, making them used as substrate materials in the fields of soft electronics. In this report, rapidly self-healing polysiloxane systems were constructed, and their self-healing properties and functional properties were explored and developed to enrich the self-healing theories. By integrated with active components, self-healing sensors and energy harvesting devices were fabricated with excellent sensitivity or energy output performances.
Firstly, the self-healing strategy is deeply explored and developed. Inspired by the microstructure of spider silk, a slippery thiourea-hydrogen bond arrays (SHAs) strategy combining slidable thiourea hydrogen-bond arrays and β-nano-crystalline domains is proposed to impart toughness, ultrastretchability and rapid self-healability to siloxane-based polymers. Secondly, the interfacial properties between self-healing polysiloxane and active components were researched and adjusted to achieve self-healable conductive networks. Thirdly, self-healing polysiloxane-based stretchable perovskite solar cells (S-PSCs) were constructed. Based on the chelation and hydrogen bonds, S-PSCs exhibited a self-healing efficiency of 81% after 800 cycles under 20% tensile strain. This work provides a new strategy for developing self-healing polysiloxanes, and a brand-new solution for constructing self-healing polymer-doped PSCs.
In summary, the “structure-performance-application” relationship of polysiloxane-based electronics was explored and established to meet the urgent demand for multifunctional self-healing substrate materials in smart soft electronics.

Key words Self-healing; Polysiloxane; Soft electronics;

Session: Composites Repair, Self-healing, Recycling and Machining

Presenting Type: Published only

healable proton exchange membrane

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The lifetime of the proton exchange membrane (PEM) fuel cell is the main issue restricting its commercialization. In the process of fuel cell operation, under alternating wet and dry conditions, the periodic expansion and contraction of PEM will lead to mechanical degradation. The degradation of fuel cell components, PEM, is the primary cause of the short service time. PEMs that can heal mechanical damage to restore original functions are important for the fabrication of durable and reliable PEM fuel cells. The fabrication of healable PEMs that exhibit mechanical stability, enhanced proton conductivity, and suppressed hydrogen permeability via hydrogen-bonding complexation between Nafion and poly(vinyl alcohol) (PVA). By preparing PEM withPVA, the proton exchange membrane has excellent self-healing ability. The healing property originates from the reversibility of hydrogen-bonding interactions between Nafion with PVA and PVA with PVA.

Key words proton exchange membrane; self-healing;