中国材料大会 2025
暨新材料科研仪器与设备展

7 月 5-8 日, 2025

福建 厦门

D50-纳机电系统
D50-Nanoelectromechanical Systems

主办单位

中国材料研究学会

会议网址: https://cmc2025.scimeeting.cn

D50. 纳机电系统

分会主席：陈延峰、刘开辉、沈国震、郭传飞、谢梦莹、王曾晖、杨睿

D50-01

声表面波声子晶体的原理、制备与应用

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摘要内容：

声表面波声子晶体作为一类具有人工微结构的新型固体声学材料，在调控表面弹性波方面展现出独特优势，拓展了传统固体声学材料的功能边界。通过声表面波能带及拓扑能带结构，能够对 Rayleigh 波、Love 波、Lamb 波等多种表面波进行精确控制。本文报告我们的系列研究工作：1、建立了多种表面波模式的声子能带论和声拓扑能带理论，揭示了微结构调控声子色散和传播的规律；2、发展了声表面波声子晶体的制备工艺，构建出纳米结构的薄膜 $LiNbO_3$ 声子晶体材料体系；3、在此基础上，制备出多种表面波拓扑声子晶体，包括拓扑半金属与拓扑绝缘体等，验证了非对称传播、缺陷免疫等新物理效应及功能；4、发展出基于拓扑新原理的 GHz 片上声表面波激发、滤波、谐振、传感等功能集成的声学原型器件。

二维材料声学器件

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摘要内容：

声音是人类交流和环境感知的重要媒介，面向高灵敏度次声波军事活动探测、高音质声学产业、高传输带宽智能互联超声通讯系统的需求，亟待发展新一代先进声学材料：大尺寸超薄悬空材料。理论表明，悬空薄膜厚度越小、直径-厚度比越高，器件的发射频率越宽、声压传感灵敏度越高、电-声转化失真越小。目前，悬空薄膜主要由硅、金属、高分子等材料构成，厚度为微米量级、直径-厚度比约为 104。二维材料是迄今已知厚度最薄（小至 0.3 纳米）、机械性能最强（比钢高 200 倍）的材料，是下一代悬空薄膜的理想材料体系。然而，目前二维材料晶体质量不高、转移易破损，大尺寸悬空二维材料的制备及应用仍需基础研究的突破。本报告将介绍我们在超大径厚比自支撑薄膜的制备，以及超高灵敏度声学传感器件方面的研究进展。发展基于自支撑二维材料的新一代声学器件，有望为国防建设、声学产业、智能生活提供关键材料和技术支撑。

碳纳米管-石墨烯片上扭秤

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摘要内容：

扭秤是一种古老的科学测量仪器，至今仍然作为精密传感器在众多研究领域里发挥重要作用。它的灵敏度正比于平衡臂和悬丝的长度，而反比于悬丝直径的四次方，因此减小悬丝直径是实现高灵敏度扭秤的最高效的方法。

本次报告将介绍利用微纳加工工艺制备的片上扭秤阵列。该扭秤由单根超长碳纳米管为悬丝，以双面镀铝的石墨烯-交叉超顺排碳纳米管复合薄膜为平衡臂和超薄镜子。在气压为 10^-6Pa 的真空腔内和室温条件下使用该扭秤对功率为几微瓦的激光的光压进行了测量，实验结果表明碳纳米管-石墨烯扭秤具有飞牛级力分辨率。不同气压下测量的扭转角-时间序列遵循简谐势场的一维布朗运动，随机扭转的动能与热运动能量接近。

与传统材料制作的扭秤相比，碳纳米管-石墨烯扭秤在测量速度、悬丝扭转刚度以及灵敏度等方面都取得了数量级的进步。该扭秤的片上制备方式和百微米级尺寸使它很容易整合到芯片中，作为室温下飞牛级力分辨率的传感器，为探测微弱效应和发现新的物理规律等基础研究提供研究平台。

柔性智能隐形眼镜的研究

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摘要内容：

眼睛是人体内最复杂的器官之一，包含丰富的生理信息，例如眼压，角膜温度，pH 值和一些代谢物标志物等等。智能隐形眼镜，是实现非植入式传感的重要一环。它可以通过监测一些物理信号实现诊疗，这是一种无创的方式，并且涵盖的范围很广，比如说通过电化学信号检测葡萄糖，通过光学谐振检测眼压变化等等。在获得实时的生理信号后，经过信号处理，角膜接触镜还可以作为治疗平台，提供药物释放、热疗、电刺激等。

在此次报告中，将简要汇报我们团队在柔性智能隐形眼镜式传感器方面的最新进展，即在新材料设计，传感器性能提升，信号传输和供能等方面的探索。

D50-03

离电型柔性压力传感器：材料、结构、器件与应用

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摘要内容：

柔性压力传感技术在机器人触觉和健康医疗领域有重要的应用价值。近年来，离电型柔性压力传感技术因其优异的传感性能而获得广泛关注——这类器件基于双电层电容，可获得比常规电容型器件有更高的灵敏度和量程。本工作围绕离电型柔性压力传感技术，探讨其材料开发、界面结构、器件性能，以及其在机器人和健康医疗方面的应用，研究材料-结构-性能构效关系。特别是针对器件中软材料和敏感界面带来的信号漂移和迟滞，进行了材料在分子层面以及在微结构界面上的设计，有效抑制了传感过程中材料和界面的能量耗散，实现了对静压和振动信号的精准计量。

触觉传感与机器人应用

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摘要内容：

随着机器人日益深入医疗卫生、教育服务、智能制造以及家庭服务等对操作精细度和环境适应性要求极高的领域，其亟需超越传统视觉的、更为安全、灵敏且类人化的环境交互能力。传统方法在动态、多物理量交互环境（尤其是抓取过程中的力、纹理、形状识别）中面临显著瓶颈。因此，嵌入式智能感知技术成为实现机器人安全与智能化控制的关键。高性能触觉传感器的设计、制造与性能优化是提升机器人智能化水平，特别是在复杂抓取操作中实现精准通过创新的材料选择、结构设计、信号处理优化及多模态集成，提升传感器的灵敏度、动态范围、鲁棒性等性能，是获取高质量触觉信息的基础。这些性能优化使机器人能够实时、精确感知抓取过程中的接触力分布、物体纹理、形状轮廓及刚度等关键物理特性，为实现安全、稳定且自适应的抓取提供基石。结合人工智能，触觉感知能使机器人得以精准控制抓取力度、识别物体属性与状态、适应不确定环境，并显著增强人机协作安全性。随着传感技术与人工智能技术的不断发展，未来触觉感知技术将在机器人领域发挥更加重要的作用，推动机器人技术向更高层次发展。

超宽禁带材料微纳机电谐振器的性能与传感应用研究

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摘要内容：

微纳机电系统（M/NEMS）谐振器以其极低的质量和极高的面积-厚度比，展现出对外界物理刺激的高度敏感性，这使其成为高精度物理信号传感的理想选择，比如温度、质量及辐射强度检测等。因为一系列超宽禁带材料出色的机械和机电转导特性（如铁电性和压电性），基于这类材料的微纳谐振器成为 M/NEMS 领域的一个重要发展方向。此外，这些材料对可见光不敏感，但可以通过构建异质结构来定制对特定波长（例如红外线、毫米波等）敏感的传感元件。

报告聚焦于六方氮化硼（h-BN）、氧化镓（Ga_2O_3）、氧化锆铪（$Hf_xZr_{1-x}O_2$）等超宽禁带材料的 M/NEMS 谐振器的设计、制备与测试。研究内容涵盖了这些材料的低维微纳结构构建、机械性能评估、谐振器的物理传感性能以及信号转导机制分析，在高频（HF）频段内实现了 170,000 以上的品质因数（Q 值），完成了谐振器对温度、气压、日盲紫外线等的传感应用研究。这些成果不仅为超宽禁带材料在 M/NEMS 领域的应用提供了理论与实验依据，未来还可通过集成其他材料（如石墨烯、超材料等）的方式拓展超宽禁带材料 M/NEMS 谐振器的传感能力。

面向纳米材料热分析的 MEMS 传感器

贾浩*
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摘要内容：

纳米材料在石化、新能源、半导体领域应用广泛，其材料热稳定性、物理相变、化学反应等过程需要热分析表征。然而，传统热分析技术灵敏度低、需要毫克量级粉末块体，无法对痕量材料进行表征和同步分析。课题组基于 MEMS 技术开发出热分析传感器，实现痕量材料的超灵敏热分析，推动新一代热分析技术的发展。

二维纳机电谐振器的耗散调控

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摘要内容：

物联网和人工智能等应用产生大量数据，需要低功耗传感、计算、数据存储和传输的纳米级智能系统。本报告介绍了我们利用二维半导体谐振式纳机电系统（NEMS），特别是其品质因数和动态范围调控进行低功耗传感和信息处理的研究成果。二维纳机电谐振器具备非常小的质量，使其维持强而稳定的谐振只需皮瓦级功耗。我们进行了多物理耦合的建模，加工制备了大规模的悬空二维二硫化钼纳机电器件，并测量了其谐振特性。基于此，我们建立了应变调控的耗散模型，并对品质因数进行了大于 400%的调控。进一步研究了非线性耗散的调控机理和调控方法，并实现了利用栅极电压对线性动态范围进行大幅调控，调控范围达到 32.8dB，质量分辨率达到一个氧原子的质量。进一步开发了基于纳机电谐振器的新型存储和计算器件，其在高能效传感、信息处理、存储和计算等方面具有非常好的潜力。

D50-04

柔性增敏结构设计与应用研究

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摘要内容：

随着人机交互、智能医疗等新兴领域的发展，机器人从基本的搬运，简单的协作，逐渐发展到需要与机器、人和环境交互的精细、复杂任务。机器触觉能够提供重要的触摸信息，比如在预接触/抓取下感知物体粗糙度/纹理/位移等微小压力变化。这在机器人顺应性操作中至关重要，但同时对柔性压力传感器的灵敏度/量程等性能也提出了高要求。当前，三维微结构已经在生物医疗监测、人机交互接口、机器人触觉和微飞行器等方面引起了研究者的广泛兴趣。而柔性压力传感器中间结构层的三维力学设计与其性能息息相关。提出了一种基于马拉高尼流驱动的成形方法，实现了具有空心微结构阵列的柔性薄膜制备。相比于实心微金字塔结构，基于空心微金字塔结构的压力传感器将灵敏度提升了 10 倍并具有更高的量程。此外，该方法通用性强，可实现空心微金字塔、空心微球、空心微柱等各种不同形状的阵列化制备。

Three-Axis Mechanical Characterization of Suspended Double-layer Graphene with an Attached Proof Mass

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摘要内容：

Graphene-based nanoelectromechanical accelerometers have the potential to be utilized in consumer electronics, wearable devices, biomedical implantable systems and Internet of Things due to their ultra-small size and high sensitivity. Here, an acceleration transducer has been modelled and simulated in three-axis directions, which consists of suspended double-layer graphene and an attached SiO2/Si proof mass. Using finite element analysis method, the impacts of geometrical sizes and built-in stresses of suspended graphene as well as applied forces on the deflections, strains and first- to sixth-order resonance frequencies of acceleration transducers were studied. The simulation results indicate distinct variations in deflections, strains and resonance frequencies under forces applied along each axis. Notably, out-of-plane forces induce the most pronounced changes. These findings reveal that suspended graphene-based acceleration transducers exhibit directionally dependent responses to three-axis acceleration. This work suggests that graphene could be a promising material to develop next generation three-axis nanoelectromechanical accelerometer.

基于二维纳米机电系统的材料表征与调控

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摘要内容：

得益于二维材料的维度优势和丰富的物性，二维纳机电系统通常具有高灵敏度、宽频率调谐范围、超低功耗等显著优势，在微纳器件与系统领域展现了巨大发展潜力。作为器件功能设计与性能优化的基础，二维材料力学特性研究及其参数表征至关重要。针对传统表征方法难以准确识别二维材料力学各向异性的挑战，本研究创新性地基于器件的多模态谐振响应特性，利用二维材料力学各向异性对各阶模态谐振频率与振动形貌的调控效应，通过对器件机械谐振性能的精密表征，首次实验测定了二维 ReS2 纳米晶体机械各向异性参数，解决了关于其力学特性的争议。进一步整合原位拉曼光谱测量手段，本研究实现二维材料机械振动信号和晶格振动信息的同步测量和提取，解决了动态激励条件下材料微观晶格振动信息表征的难题，有效地揭示了 MHz 纳米机械谐振模式与 THz 晶格振动模式之间的耦合效应，为 THz 信号的调制和处理，以及在原子尺度上动态操纵二维材料提供了新的实验手段。

Tunable Stochastic State Switching in 2D MoS_2 Nanomechanical Resonators with Nonlinear Mode Coupling and Internal Resonance

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摘要内容：

We report the observation of stochastic switching between two resonance states in two-dimensional (2D) molybdenum disulfide (MoS_2) nanoelectromechanical systems (NEMS) exhibiting 1:1 internal resonance (IR) induced by nonlinear mode coupling. These resonators are directly driven into the critical coupling regime without the need for parametric pumping. The probability of switching between the low- and high-energy IR states can be continuously tuned from nearly 0% to 100% by adjusting the radio-frequency (RF) driving voltage. Moreover, we investigate the effect of external white noise, showing that increasing noise amplitude leads to a reduced probability of occupying the high-energy state, eventually suppressing the switching behavior altogether. These findings are consistently observed across multiple devices with varying MoS_2 thicknesses, demonstrating the repeatability of the phenomenon. Our results highlight a robust and tunable mechanism for state switching in coupled NEMS resonators and offer promising avenues for applications in sensing, memory, and stochastic computing.

Polymethyl Methacrylate (PMMA) Pyrolysis Assisted Transfer of 2D Materials for Large-Scale NEMS Resonator Arrays

Zuheng Liu, Jianyong Wei, Pengcheng Zhang, Yueyang Jia, Rui Yang*
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摘要内容：

We develop a novel transfer technique based on polymethyl methacrylate (PMMA) pyrolysis process for the fabrication of large-scale two-dimensional (2D) molybdenum disulfide (MoS_2) nanoelectromechanical resonator arrays. We experimentally demonstrate a consistent upward frequency tuning up to 160% and downward quality (Q) factor shift as DC gate voltage (V_{GS}) increases, and the measured resonance frequencies and Q among different devices show smaller variation compared with previous reports. The innovative transfer technique enables consistent and high-quality 2D resonator arrays, and paves the way towards scalable production of 2D NEMS resonators.

D50-06

基于 NEMS 双自由度方法的二维非层状材料热性能研究

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摘要内容：

原子尺度的纳米机电系统（NEMS）有望为低维材料的物性研究研究带来了全新机遇。通过将材料特性与机械自由度耦合，有机会建立基于 NEMS 平台频率响应的材料性能研究新范式，并借助新型二维材料，推动实现具有全新架构和更优性能的纳米传感器。随着器件迈入纳米尺度，声子的平均自由程超越器件厚度，热传导受到边界散射和晶体结构对称性等因素的影响，展现出与体材料不同的热输运特性，这带来了新的机遇也引入了诸多不确定性。然而，由于现有的光谱法等热学测量技术通常基于预设的理论模型来测定某一热参数，难以对热传导的不同过程进行实验解耦，从而阻碍了二维非层状材料等新兴材料体系热输运性质的可靠实验测定。

针对这一挑战，本报告巧妙利用谐振式纳米机电系统（NEMS）作为测热“探针”，有效地提取了二维 β-In_2S_3 的面内热导率及其与 SiO_2 间的界面热导系数，揭示了此类材料显著低于石墨烯、MoS_2 等层状二维材料的面内热导率特征。进一步地，借助于该特性，构建了“功率-频率”响应率高达-447 ppm/μW 的热辐射传感器，达到了同类型器件的领先水平。

Suspended trilayer graphene-based pressure sensors

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摘要内容：

Pressure sensors are widely used in consumer electronics, aerospace, medical and health monitoring, and other fields. In recent years, graphene has become one of the promising materials in the field of nanoelectromechanical pressure sensors due to its atomically thin thickness, excellent electrical and mechanical properties. However, previous studies on suspended graphene-based pressure sensors are commonly limited to monolayer and bilayer graphene. Suspended multilayer graphene such as trilayer graphene membranes have the great potential to improve the fabrication yields, stability and durability of graphene-based pressure sensors. Here, a piezoresistive self-suspended trilayer graphene membranes based NEMS pressure sensor is proposed and fabricated. The experimental results show trilayer graphene-based pressure sensors had a sensitivity of 1.98×10^{-5} kPa^{-1} in the pressure range of 20 kPa ~ 100 kPa. In addition, the trilayer graphene-based pressure sensor showed good stability (resistance drift of 0.02%) in long-term pressure maintenance measurements. These experimental results will provide the guidance for the comparative study of graphene-based NEMS pressure sensors with different number of atomic layers and contribute to the practical application of graphene-based sensors.

氧化镓纳米机电谐振器中机械能量耗散途径的研究

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摘要内容：

β 相氧化镓（β-Ga_2O_3）因其超宽禁带特性、卓越的机械性能和潜在的成本优势，在高功率、高频率及光电微纳机电器件领域展现出极佳的应用前景。为充分发挥其性能优势，深入理解并有效抑制器件中的机械能量耗散机制至关重要。本研究详细探讨了双端固支结构与圆形鼓面结构的 β-Ga_2O_3纳米机电谐振器的能量耗散机制及如何通过设计优化提高其品质因数（Q 值）。本研究首先通过理论分析和 COMSOL 软件仿真，深入探讨了 Akhiezer 效应、热弹性阻尼、支撑阻尼和表面阻尼等能量耗散过程，并制备了器件，采用激光干涉法对 β-Ga_2O_3纳米机电谐振器的振动特性进行了实验表征与验证。结果表明，表面阻尼与支撑阻尼是当前限制 β-Ga_2O_3纳米机电谐振器 Q 值的主要因素，而 Akhiezer 效应和热弹性阻尼则决定了 Q 值的上限。本研究不仅阐明了氧化镓微纳机电谐振器能量耗散的复杂机制，更为后续通过优化器件几何设计以及改进表面处理工艺等手段有效调控器件带宽和 Q 值提供了重要的理论依据与实践指导。

基于二维 WSe_2 纳机电系统的动态应变工程与晶格调控

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摘要内容：

二维纳机电系统（NEMS）由于其原子厚度的振动结构，在纳米尺度上能产生显著的拉伸应力和垂直位移，为探索二维材料中动态应变工程和跨尺度振动耦合提供了理想平台。本文利用 WSe_2 NEMS 这一具有机械自由度的器件结构来探索二维 WSe_2 的物理特性并实现其动态调控，通过 MHz 电激励有效地调控了 THz 原子晶格振动，并且在二维 WSe_2 材料中探索到了 THz 的原子晶格振动以及 MHz 的纳米机械振动，通过机械振动实现准粒子（激子或声子）的动态调控。着重研究了薄层 WSe_2 NEMS 中原子晶格振动和纳米机械共振之间的跨尺度动态耦合。

Hole Doping Mechanisms of O_2 and Water Molecules in Different Graphene Substrates and Thicknesses

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摘要内容：

Graphene's high mechanical strength and excellent electrochemical properties prove its great potential for sensor applications. However, the selection and layout of electrode materials, as well as the presence of O2 and moisture in the environment significantly influence the electrical properties of graphene. In this work, monolayer graphene (MLG), bilayer graphene (BLG), and few-layer graphene (FLG) were prepared using wet transfer and mechanical exfoliation techniques, respectively. By discussing the binding mechanisms of O2, water molecules and inert gases (N2, Ar) on graphene, we elucidated the reversible hole doping rules and thickness-dependent doping behaviors of graphene with different number of layers and preparation methods on SiO2/Si substrate, hBN/SiO2/Si substrate, and suspended structure. The results indicate that O2 and water molecules can penetrate

the SiO2 interface through graphene defects or gaps (edge doping), forming high density charge fluctuation region in graphene/SiO2. Moreover, transfer characteristic curves and DFT simulations demonstrate that water molecules can significantly promote the hole doping induced by O2; In graphene/hBN/SiO2/Si substrate, hBN works as a wide bandgap (~6 eV) insulator, blocking the direct charge transfer between the SiO2 substrate and graphene, weakening the effect of substrate doping on the electrical properties of graphene (4-fold decrease in the responsivity); Whereas, in suspended graphene substrate, the suspended structure isolated the substrate doping by O2 and water molecules, which enhanced the graphene carrier mobility but weakened the responsivity. Furthermore, we also proved O2 and water molecule doping was enhanced by grain boundaries and defects in CVD graphene, further indicating that the moisture-sensitive properties of graphene depend on the doping of O2 and water molecules in the environment.

焦耳热效应对二维二硫化钼纳机电谐振器品质因数及频率调谐的影响

袁帅、张鹏程、杨睿*
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摘要内容：

本研究主要探究二维二硫化钼（MoS_2）纳机电（NEMS）谐振器中焦耳热效应对谐振频率与品质因数（Q 值）的调控作用及其物理机制。实验表明，随着漏极电压增大，焦耳热效应增强，导致谐振频率与品质因数下降。焦耳热效应对品质因数的调控能力（约四倍）显著强于栅极电压引起的热弹性耗散效应。该结果为二维 NEMS 谐振器的能量耗散机制提供了新见解。

墙报

D50-02 和 D50-05

单层 2H-$MoTe_2$ 等轴应变的振动响应

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摘要内容：

基于密度泛函理论（DFT）和密度泛函扰动理论（DFPT）计算，我们系统研究了单层 2H-$MoTe_2$在等轴应变下的振动响应。研究表明，在 Γ 点上，拉曼活性模（E′，A_1′和 E″）与红外活性模（A_2″和 E′）的频率偏移呈现相似趋势：拉伸应变下频率单调下降，而压缩应变下频率先升高后迅速下降。在 K 点处，一个特定的声学模式在压缩应变为-11.27%时发生软化并且频率降至零。分析发现，Mo 的 dz2 轨道以及 Te 的 p_x、p_y 轨道中的电子占据削弱了 K 点表现为 Mo 原子的面内振动与 Te 原子的面外振动的振动模。此外，压缩应变增强了费米能级附近的电子态嵌套，导致该声学模式的振动频率急剧降低。这些结果为通过振动频率测量探测单层 2H-$MoTe_2$的应变状态提供了一条有效途径。本研究中，该材料独特的应变敏感振动特性，使其有潜力开发为高灵敏度的应变传感器元件，或用于构建基于应变调控谐振频率的可调谐纳机电系统谐振器。

Nonlinear Dynamic Characterizations of Few-Layer $MoSe_2$

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University of Electronic Science and Technology of China

摘要内容：

Nanoelectromechanical systems (NEMS) devices, owing to their linear and nonlinear dynamical behaviors, serve as an excellent platform for fundamental research and applications, such as dynamical phonon softening mode coupling, and exciton-optomechanical coupling tuning. Notably, the nonlinear response is closely related to the physical properties of materials, especially their mechanical propertiesation of ultrathin materials. We fabricate resonators using a novel transition metal dichalcogenides, MoSe2, and further characterize their linear and nonlinear behaviors in the frequency domain. We extract the Young’s modulus of a 7-layer MoSe2 device (E = 200 GPa) and its pretension (n0= 48.44 mN/m). These findings provide critical insights into the mechanical behaviors of few-layer MoSe2, enabling its further fundamental study and applications.

Laser-Tunable Gold Nanomechanical Resonators

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University of Electronic Science and Technology of China

摘要内容：

Ultrathin gold materials exhibit unique optical, thermal, and electrical properties, making them well-suited for biological imaging, hydrogen sensing, and photovoltaic applications. However, their mechanical properties

and potential in NEMS-based sensing remain underexplored.

In this study, we synthesize single-crystal gold nanoflakes and further demonstrate that gold nanomechanical resonators can function effectively as laser sensors. Specifically, we employ a custom-built interferometry system to detect ultrathin gold circular drumhead resonators at room temperature and vacuum conditions. By varying the laser power from 2.31 μW to 478 μW over 18 cycles, we observe a periodic frequency shift (Δf = 55.4 kHz), corresponding to a relative responsivity of 11.9 ppm/μW. Furthermore, our analysis reveals an excellent linear correlation between the resonance frequency and the laser power, with R^2 values exceeding 0.98. To broaden the operational frequency range of the gold resonators, we fabricate 35 gold nanomechanical resonators of varying sizes and derive the frequency scaling law for such devices. Through this analysis, we successfully extract the Young's modulus of gold E_Y= 60 - 80 GPa with the surface tension γ = 0.05 - 0.5 N/m. These findings highlight the unique advantages of 2D gold resonators and their exceptional potential for high-performance integrated sensing applications.

High-Precision Determination of Complex Refractive Indices in Ultrathin $ReSe_2$ Towards Enhanced Optomechanical Transduction Efficiency

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University of Electronic Science and Technology of China

摘要内容：

Rhenium diselenide ($ReSe_2$) stands out due to its distorted 1T′ phase, which leads to anisotropic optical and electrical properties. Studying its light-matter interaction is essential for advancing nanoelectromechanical systems (NEMS) by optimizing light absorption or transmission efficiencies. However, due to the miniscule sample size, accurately determining the complex refractive index ($n - j\kappa$) of ultrathin $ReSe_2$ remains challenging.

In this work, we propose a spectroscopic approach for quantitatively determining the complex refractive indices of two-dimensional (2D) materials using a three-interface interferometric model. Specifically, we build a fine-engineered spectroscopy setup to measure spatially-resolved reflectance spectra of nanoflakes under white-light illumination. A total of 17 $ReSe_2$ nanostructure samples with varying thicknesses are prepared, introducing thickness as an essential variable for analysis. By fitting the measured data, we extract the complex refractive indices spectra of $ReSe_2$ over the 450 – 750 nm wavelength range. Furthermore, leveraging these experimentally determined optical constants, we establish effective guidelines for optimizing efficiency of light-induced operations in nanodevices, not only enhancing the performance of optomechanical systems for device design but also facilitating nanoflake identification for sample preparation. Our approach provides solid insights for advancing the development of ultrathin-material-based NEMS devices, and details will be presented at the conference.

Few-layer $MoSe_2$ nanomechanical resonator with a high laser power-to-frequency responsivity at room temperature

Yalan Wang, Shuang Cai, Bo Xu, Jiankai Zhu, Juan Xia, Zenghui Wang*
University of Electronic Science and Technology of China

摘要内容：

We experimentally study a tunable tri-layer (3L) MoSe2 drumhead nanomechanical system (NEMS) resonator and its laser power-dependent resonance behavior. Using the mechanical exfoliation and dry transfer techniques, we fabricate a 3L MoSe2 NEMS device that exhibit robust vibrations in the very high frequency (VHF) range, with up to 191% frequency tunability. By varying the detection laser power, we further tune the device's resonance frequency and quality factor, achieving a high power-to-frequency responsivity of –284 ppm/μW. Our work demonstrates the great potential of MoSe2 resonators in laser power sensing, and lays the groundwork for device design, thermal stability, and novel applications in nanoelectronics, optical sensing, and optomechanical systems.

Modulating Resonance Mode Sequencing in Nanomechanical Resonators

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University of Electronic Science and Technology of China

摘要内容：

Nanomechanical resonators that utilize suspended two-dimensional (2D) materials as moving components offer remarkable advantages for advanced sensing, actuation and signal processing applications. These delicate devices also exhibit exceptional performance at the device-level, including ultra-high sensitivity and broad tunability. Even more intriguing is that resonators based on mechanically anisotropic 2D materials exhibit enhanced multimodal behaviors with more distinct resonance modes, thus providing extra degrees of freedom for advanced nanoelectromechanical systems (NEMS). However, the controllable modulation of higher-order resonance modes remains largely underexplored, hindering the full exploitation of the extensive multimodal capabilities of NEMS resonators.

In this work, we present the first demonstration of on-site modulation of resonance mode sequencing, in NEMS resonators based on calcium niobate ($CaNb_2O_6$). By leveraging the material's intrinsic anisotropic mechanical and thermal elastic properties, we employ anisotropic strain engineering to achieve a swapping among higher-order resonance modes. This swapping is further experimentally validated by directly visualizing the corresponding resonance mode shapes. We also explore the role of thermal elastic anisotropy and propose a potential mechanism for frequency-based data encoding.

An Ultra-High Sensitivity Magnetic Sensing Mechanism with A Sliding Nanoelectromechanical Resonator

Cao Xia*, Zhujie Zhao, Lijia Zhang, Yuanlin Xia, Zhuqing Wang
Sichuan University

摘要内容：

Magnetometers play an important role in many fields, such as navigation, geographical exploration, and aerospace. To break the sensitivity limit, this work proposed an ultra-high-sensitivity sensing mechanism with an innovative sliding nanoelectromechanical resonator for the first time. A Hard magnetic block is employed to replace soft magnetic film for sensing magnetic fields more sensitively, while a coupled resonant nanodrum is adapted for converting magnetic field into resonant frequency shifts for measurement. Through sliding coupling principle, "separation of magnetic sensing and resonant detection" can be accomplished to overcome the significant negative effect of the magnetic block on the nanodrum's resonant frequency. Theoretical and finite

element simulation results indicate that the sensitivity of our proposed mechanism is up to 3310.384MHz/T in the magnetic field intensity range of 0~1.1T, which is three orders of magnitude enhancement compared with presently the highest sensitivity(1.91MHz/T). A macro prototype was further developed to verify the feasibility of our proposed mechanism, as well as the impact of key structural parameters on the sensitivity were studied, such as geometric dimensions, built-in tensions and two-dimensional membrane atomic layers. This work opens a new avenue for the development of ultra-high sensitivity nanoelectromechanical magnetometers.

In this work, we present the first demonstration of on-site modulation of resonance mode sequencing, in NEMS resonators based on calcium niobate ($CaNb_2O_6$). By leveraging the material's intrinsic anisotropic mechanical and thermal elastic properties, we employ anisotropic strain engineering to achieve a swapping among higher-order resonance modes. This swapping is further experimentally validated by directly visualizing the corresponding resonance mode shapes. We also explore the role of thermal elastic anisotropy and propose a potential mechanism for frequency-based data encoding.

氧化镓微纳机电谐振器的日盲紫外传感性能研究

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摘要内容：

日盲紫外线（SBUV）探测在工业、民用和环境检测等领域有着广泛的应用。因为 β 相氧化镓（β-Ga_2O_3）的超宽禁带（4.5-4.9 eV）特性，其吸收截止波长完美匹配 SBUV 波段（<280 nm），且具有高击穿场强、良好热稳定性等优势，是作为 SBUV 传感器的绝佳材料。本研究基于 β-Ga_2O_3纳米机电系统（NEMS）谐振器，开发了一种高性能 SBUV 传感器。通过双端固支梁谐振结构设计，结合理论分析和 COMSOL 多物理场仿真，揭示了 SBUV 光辐照通过光热效应引发谐振器热膨胀与内部应力变化，进而改变谐振频率的传感机制。仿真结果表明，谐振频率偏移量与入射光功率呈线性响应，平均响应率达-175.5 Hz/nW；进一步优化谐振器厚度（≈100nm）及降低接触电阻可显著提升响应率。本研究为 β-Ga_2O_3微纳机电谐振器的 SBUV 传感研究提供了理论和模型参考，推动其在光通信和环境监测等领域的实际应用。

An Ultra-high-Sensitivity Acceleration Sensing Mechanism with A Sliding Nanomechanical Resonator

Lijia Zhang, Zhujie Zhao, Cao Xia*, Yuanlin Xia, Zhuqing Wang
Sichuan University

摘要内容：

This study proposes an ultra-high-sensitivity sensing mechanism with an innovative sliding nanoelectromechanical resonator for the first time. The accelerator integrates a suspended graphene ribbon with an attached proof mass for acceleration sensing and another graphene ribbon for resonant frequency based readout, interconnected through a van der Waals-mediated sliding interface that enables mechanical decoupling. The applied acceleration will cause a vertical displacement of the proof mass accompanied by the deformation of the graphene ribbon. It can be further transformed into an in-plane tensile strain of the another graphene ribbon via the sliding boundary's strain transfer mechanism. The acceleration can thus be converted into quantifiable modal frequency shifts via stress-dependent resonance modulation. Through sliding coupling principle, "separation of acceleration sensing and resonant detection" can be accomplished to overcome the

significant negative effect of the proof mass on the graphene ribbon's resonant frequency, both theoretical and FEM results indicate that the a 1-2 order sensitivity enhancement can be realized, addressing critical barriers in high-precision navigation for aerospace and defense applications.