Effects of spin-orbit coupling and charge-carrier doping on piezomagnetism in altermagnets

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We study effects of uniaxial strain on the electronic and magnetic properties of altermagets using the density functional theory plus U method. For metallic altermagnets, such as RuO_2, we analyze that uniaxial strain generates a piezomagnetic response even without including spin-orbit coupling (SOC). In contrast, insulating altermagnets such as MnF_2 and MnTe show no piezomagnetic response if SOC is not considered. In insulating altermagnets, piezomagnetism requires spin-orbit coupling or charge-carrier doping to enable the spin imbalance. These findings highlight the potential of strain engineering in modifying the magnetic and transport properties of metallic and insulating altermagnets which may be useful for future spintronic applications.

Study on the Cooper Pairing and Phase Coherence Mechanisms in the Cuprate Superconductor Bi2201

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We investigated underdoped $Bi_2Sr_{2-x}La_xCuO_6$ samples by using scanning tunneling microscopy. The first real-space observation of antiferromagnetic order in cuprates was accomplished in insulating samples ($p = 0.08$) by combining spin-resolved technique. The Mott gap was filled by the density of states when the antiferromagnetic order was suppressed, and a high energy pseudogap (200 mV) also emerged consistently with the real-space $4a_0 \times 4a_0$ charge modulation. With further doping ($p = 0.10$), a stripy structure along the Cu-O bond direction was observed within $4a_0 \times 4a_0$ plaquettes, and peaks related to superconducting pairing appeared near 25 mV in the spectra. For superconducting samples ($p = 0.114$), some spectra exhibited half-side peaks at positive energy (11 mV) or negative energy (-11 mV). These distinct half-side peaks could be combined to form a superconducting spectrum with particle-hole symmetric coherence peaks. We propose that the half-side peaks may represent the intermediate states of phase coherence, and correspond to the positive or negative energy branches of the Bogoliubov dispersion. Combining the "two-hole paired ground state" theory, we attribute that the positive and negative energy half-side peaks may correspond to the three-hole and one-hole excited states of the "two-hole ground state". The quantum entanglement of the positive and negative energy half-side peaks arises from the dynamic hopping of charge freedom between the paired ground states, which induces the phase coherence of local pairing.

Superconductivity up to 14.2 K in MnB_4 Under Pressure

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The discovery of superconductivity in 3d transition-metal compounds with strong magnetism is interesting but rare. Especially for Mn-based compounds, there exist only very limited materials that show superconductivity. Here, the discovery of superconductivity is reported with an onset transition temperature up to 14.2 K in a Mn-based material MnB_4, which is the highest value among the stoichiometric Mn-based superconductors. By applying high pressure, the continuous suppression of a weak semiconducting behavior and the occurrence of superconductivity after ≈30 GPa are found. With further increasing pressure, the superconducting transition temperature (T_c) is gradually enhanced and reaches the maximum onset transition value of ≈14.2 K at 150 GPa. The synchrotron X-ray diffraction data reveal the unchanged monoclinic (S.G:$P2_1/c$) symmetry but an unusual crossover of the lattice parameters b and c in a certain pressure region as confirmed by the theoretical calculation. The findings show a promising way to explore high T_c superconductivity by combining the 3d-transition metal magnetic elements and light elements.

Superconducting coherence-peak energy modulation induced by pair-breaking scattering in an iron-based superconductor

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Using high-resolution scanning tunneling microscopy, we reveal the coexistence of both in-phase and anti-phase coherence peak energy modulations at the atomic scale in the iron-based superconductor $FeTe_{0.55}Se_{0.45}$, which hosts $s\pm$ pairing on the hole and electron Fermi pockets. In certain regions, defect-induced quasiparticle interference produces strong spatial modulations of the local density of states (LDOS) with a periodicity matching the Se-Se lattice constant (a_0), corresponding to scattering between electron pockets with the same superconducting gap sign. Meanwhile, we observe anti-phase spatial oscillations of coherence-peak energies at positive and negative sides, demonstrating particle-hole symmetric behavior and a clear oscillation in the peak energy difference. In contrast, other regions exhibit LDOS modulations with a $\sqrt{2}\ a_0$ periodicity, reflecting scattering between hole and electron pockets with opposite gap signs. In these areas, in-phase spatial oscillations of coherence-peak energies emerge at both positive and negative sides, revealing particle-hole asymmetry. These findings align with a recent theoretical work, suggesting that the observed modulations arise from pair-breaking inter-pocket scattering rather than atomic lattice effects. This provides new insights into the origin of superconducting gap modulations.

The regulation of oxygen content and superconductivity in the coexisting Ruddlesden–Popper phase of $La_{n+1}Ni_nO_{3n+1}$

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The discovery of 80 K superconductivity in bilayer $La_3Ni_2O_7$ under pressure has sparked intensive research interest in exploring superconductivity in Ruddlesden–Popper (R–P) nickel oxide. Superconductivity depends critically on Ni 3d and O 2p orbital hybridization, especially interlayer coupling via apical oxygen atoms. Material synthesis and achieving phase purity are challenging due to oxygen content variations, which can cause R–P intergrowths. Synthesizing high-quality samples and determining how oxygen content affects superconductivity in $La_3Ni_2O_7$ is vital for understanding its mechanism. Therefore, in this work, we synthesized samples with varying oxygen contents. Synchrotron radiation XRD, neutron diffraction, and scanning transmission electron microscopy were used to characterize the structure, while oxygen content was analyzed via X-ray absorption spectroscopy combined with thermogravimetric analysis. The effect of oxygen content on superconductivity was then investigated using high-pressure transport measurements. By controlling oxygen content, the microstructures of R–P phases can be tuned. This enables the growth of pure bilayer phases, mixtures of bilayer and hybrid 1212 phases, and bilayer phases coexisting with separated trilayer phases—where the proportion of separated trilayer phase can be precisely controlled. Under pressure, superconducting intergrowth phases originating from these structures were observed. Furthermore, tuning the oxygen content directly affects the bilayer superconducting upper critical field. Our work is significant for the exploration of $La_3Ni_2O_7$ synthesis and the understanding of its superconducting mechanism.

Identification of Superconductivity in Bilayer Nickelate La3Ni2O7 under High Pressure up to 100 GPa

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The ground breaking finding of 80 K superconductivity in $La_3Ni_2O_7$ has aroused enthusiasm in the Ruddlesden-Popper phases of nickelates [1-3]. The discovery of pressure-induced superconductivity of nickelates sheds light on resolving the puzzle of high-temperature superconductivity. Yet, the evolution of superconductivity in $La_3Ni_2O_7$ under high pressure and the controversy of filamentary or bulk superconductivity remains unclear. The crystal structure under pressure is still under debate. In this work, we addressed these issues of bilayer nickelate $La_3Ni_2O_7$ under hydrostatic pressures up to 104.0 GPa [4]. High-pressure transport measurement shows the superconductivity emerges around 10.0 GPa. A maximum onset transition temperature T_c^{onset} of 83 K at 18.0 GPa is achieved and accompanied by zero resistance. The superconducting phase is gradually suppressed and vanishes above 80.0 GPa. A right-triangle-like superconducting phase diagram was obtained. Using high-pressure synchrotron X-ray diffraction, we observe a structural transition from an orthorhombic to a tetragonal phase above 40.0 GPa, indicating the crystal structure where the superconductivity emerges is still in the orthorhombic phase. By adopting high-pressure direct-current magnetic susceptibility measurement, we observed the Meissner effect and derived a superconducting volume fraction of ~41% at 20 K under 22.0 GPa. The bulk nature of superconductivity in $La_3Ni_2O_7$ was for the first time confirmed. Our results highlight the intricate relationship between superconductivity and structural transitions in bilayer nickelate $La_3Ni_2O_7$, and provides solid experimental foundation of further understanding of the underlying pairing mechanism.

References

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A 2D-CFT Factory: Critical Lattice Models from Competing Anyon Condensation in SymTO

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We introduce a "CFT factory" --- a novel algorithm of methodically generating 2D lattice models that would flow to 2D conformal fixed points in the infrared. These 2D models are realised by giving critical boundary conditions to 3D topological orders (SymTOs/SymTFTs) described by string-net models, often called the strange correlators. We engineer these critical boundary conditions by introducing a commensurate amount of non-commuting anyon condensates. The non-invertible symmetries preserved at the critical point can be controlled by studying a novel "refined condensation tree''. Our structured method generates an infinite family of critical lattice models. Notably, we find at least three novel critical points ($c \approx 1.3$, 1.8, and 2.5 respectively) preserving the Haagerup symmetries, in addition to recovering previously reported ones. We show that critical couplings can be precisely encoded in the categorical data (Frobenius algebras and quantum dimensions in unitary fusion categories), thus establishing a powerful, systematic route to discovering and potentially classifying new conformal field theories.

Intrinsic and Extrinsic Josephson Diode Effects in Hybrid Superconducting Devices

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Josephson diode effect (JDE) has garnered growing interests due to its potential applications in superconducting electronics and its connection to novel quantum phases of matter. In general, the occurrence of JDE requires the simultaneous breaking of time-reversal and inversion symmetries. This can arise from intrinsic mechanisms, such as finite-momentum pairing, or extrinsic factors like device geometry or magnetic flux tuning in superconducting quantum interference devices (SQUIDs), each offering distinct advantages. Understanding these realizations is essential for advancing superconducting electronics and exploring novel quantum functionalities. The two types of JDEs—intrinsic and extrinsic—are demonstrated in this presentation as realized in different systems.

The intrinsic JDE is studied in detail in InAs nanosheet-based Josephson junctions. The dependence of the diode strength on magnetic field orientation, field magnitude, and gate voltage indicates that the underlying mechanism is finite-momentum pairing. Such a mechanism involving SOI, Zeeman effect and induced superconductivity, provides an essential basis for investigating novel superconducting states. Additionally, a brief account is also given of an extrinsic JDE in bilayer-graphene SQUID devices, where a diode efficiency of up to 20% is observed. This JDE can be tuned by magnetic flux, gate voltage and microwave radiation power, highlighting the potential of graphene as a material platform for applications in superconducting circuits.

Thermal transport of antiferromagnetic semiconductor BaMn2Bi2

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BaMn2Bi2 (BMB) is a colinear antiferromagnetic semiconductor. While BMB blongs to I4/mmm space group that has inversion symmetry, it is broken due to the antiferromagnetic order because space inversion exchange Mn atoms at opposite sublattices. Interestingly, such materials are symmetric against combination of space inversion and time reversal operation, so-called PT symmetry. Although the relation to PT symmetry is not clear, BMB shows large magnetoresistance (MR) at low temperature. Furthermore, the MR enhances when the magnetic field is applied perpendicular to the antiferromagnetic ordering moment at Mn site in spite of no observation of magnetic phase transition. It is interepted that different orbitals of electron contribute to each, electronic transport and magnetic, properties.

However, the effect of other quasiparticles such as phonon, and magnon has not been discussed.

Remarking expected small contribution of electron in thermal transport and specific heat, we measured these properties and compared with calculation. They shows phonon and magnon contribution reproduces the data. More details will be discussed at the venue.

Disorder operator and surface quantum criticality

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The disorder operator is often designed to reveal the conformal field theory (CFT) information in quantum many-body systems. By using large-scale quantum Monte Carlo simulation, we study the scaling behavior of disorder operators on the surface in the two-dimensional Heisenberg model on the square-octagon lattice with gapless topological edge state. In the Affleck-Kennedy-Lieb-Tasaki phase, the disorder operator is shown to hold the perimeter scaling with a logarithmic term associated with the Luttinger liquid parameter K. This effective Luttinger liquid parameter K reflects the low-energy physics and CFT for (1+1)D surface. At bulk critical point, the effective K is suppressed but it keeps finite value, indicating the coupling between the gapless edge state and bulk fluctuation. The logarithmic term numerically captures this coupling picture, which reveals the (1+1)D SU(2)1 CFT and (2+1)D O(3) CFT at surface criticality. Our work paves a new way to study the exotic surface state and surface criticality.