Anomalous metallic states and Ising superconductivity in 2D crystalline superconductors

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Abstract: After decades of explorations, suffering from the subtle nature and sample quality, whether a metallic ground state exists in a two-dimensional (2D) system beyond Anderson localization is still a mystery. Our work reveals how quantum phase coherence evolves across bosonic superconductor-metal-insulator transitions via magneto-conductance quantum oscillations in high-Tc superconducting films with patterned nanopores. A robust intervening anomalous metallic state characterized by both resistance and oscillation amplitude saturations in the low temperature regime is detected, which suggests that the saturation of phase coherence plays a prominent role in the formation of the anomalous metallic state. [1] Furthermore, we carried out a systematic transport study on the macro-size ambient-stable ultrathin crystalline PdTe2 films grown by molecular beam epitaxy (MBE). Remarkably, at ultralow temperatures, the film undergoes superconducting state and anomalous metallic state with increasing perpendicular magnetic field. The high quality filters are used to exclude the influence from external high frequency noise. [2] Our findings offer the reliable evidences on the existence of anomalous quantum metallic ground states in 2D systems, which could be of fundamental importance for the understanding of quantum materials.

Ising superconductor is a kind of superconducting system with strong spin-orbit coupling (SOC). It is reported that the broken in-plane inversion symmetry gives rise to Zeeman-type SOC, which polarizes the spins of the electrons to the out-of-plane direction and leads to a huge in-plane critical magnetic field much larger than Pauli limit. The Pauli limit is defined as the magnetic field required to destroy the Cooper pairs via the spin pair breaking effect in conventional superconductors. This special superconductivity with strong Zeeman-type SOC is called Ising superconductivity. Because of Zeeman-type SOC and spin polarizations, Ising superconductors exhibit large in-plane critical field up to several times of the Pauli limit. For the first time, we reported the observation of Ising superconductivity in macro-size monolayer NbSe2 films grown by MBE [3] and the interface induced Ising superconductivity in ultrathin crystalline Pb films [4]. Furthermore, the 6-monolayer (ML) (around 3 nm) PdTe2 film exhibits a large in-plane critical field more than 7 times of the Pauli limit, which is the characteristic of Ising superconductivity. Different from the previously reported Ising superconductors, the PdTe2 film keeps the in-plane inversion symmetry, which indicates that there exists a new mechanism of Ising superconductivity, so-called type-II Ising superconductivity [2].

References: