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Anomalous metallic states and Ising superconductivity in 2D crystalline superconductors

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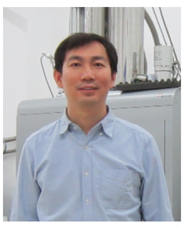
Abstract: After decades of explorations, suffering from the subtle nature and sample quality, whether a metallic ground state exists in a two-dimensional (2D) system beyond Anderson localization is still a mystery. Our work reveals how quantum phase coherence evolves across bosonic superconductor-metal-insulator 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].



王健，北京大学教授，2001年本科毕业于山东大学物理学系，2006年博士毕业于中国科学院物理研究所。2006年到2011年，在美国宾夕法尼亚州立大学做博士后和助理研究员。2010成为北京大学副教授，并于2017年晋升为教授。2015年获得马丁·伍德爵士中国物理科学奖，2019年获得高等学校科学研究成果奖。他目前的研究兴趣是低维超导体和拓扑材料的量子输运性质。近年来，王健课题组与合作者在二维晶体超导中发现了量子格里菲斯七点，并在二维高温超导中发现了反常金属态，通过输运和Meissner测量发现了单晶格厚的FeSe薄膜中高超导转变温度的直接证据，发现了固态系统中对数周期的量子振荡，开发了一种检测拓扑超导的新方法（拓扑材料中尖端诱导的非常规超导电性），首先在超导转变温度大于60K的高温超导中无外磁场下探测到了原子线缺陷两端的Majorana束缚态，发现了无朗道能级的高陈数和高温量子霍尔效应等。他已经撰写了100多篇论文，包括Science, Science Advances, Nature Physics, Nature Materials, Nature Nanotechnology, Nature Physics, Nature Materials, Nature Nanotechnology, Nature Communications, PNAS, Physical Review X, Physical Review Letters, Nano Letters, JACS, Advanced Materials, ACS nano等杂志。北京大学王健实验室拥有超低温-高磁场测量系统和低温扫描隧道显微镜/光谱-分子束外延组合式超高真空系统。

References:

[1] Science 366, 1505 (2019) Accompanied with a perspective paper: Science 366, 1450 (2019)
[2] Nano Letters 20, 5728 (2020) Highlighted by Editors' Choice in Science: Science 369, 388 (2020)
[3] Nano Letters 17, 6802 (2017)
[4] Physical Review X 8, 021002 (2018)