Intermediate bosonic metallic state in the superconductor-insulator transition

With the support by the National Natural Science Foundation of China, the research team led by Prof. Li YanRong (李言荣) at the State Key Laboratory of Electronic Thin Films and Integrated Devices, University of Electronic Science and Technology of China and Prof. Wang Jian at the International Center for Quantum Materials, Peking University, uncovered the bosonic metallic state in high temperature superconducting films, which was published in *Science* (DOI: 10.1126/science.aax5798).

Quantum materials and quantum phase transitions have become research highlights in the field of condensed matter physics and materials science of the century. Different from thermal phase transitions, the quantum phase transitions occur at zero temperature adjusted by non-thermal parameters of the system. During the quantum phase transition, besides the superconducting and insulating ground states, whether a quantum metallic state can exist in two-dimensional superconducting systems has been a core issue (*Rev Mod Phys*, 2019, 91: 11002). Although possible signature of quantum metallic state has been observed in various two-dimensional electron systems, the existence of quantum metallic state is still under intensive debate over the past 30 years due to the low critical temperature and the influence of external high frequency noise.

Recently, Li's group and Wang's group demonstrated the existence of quantum metallic state in high temperature superconducting films patterned with an array of holes. The direct evidence of quantum metallic state is that the resistance drops and saturates with decreasing temperature in the low temperature regime. For high temperature superconducting YBCO films, the saturation of resistance occurs at around 5 K, 10 to 100 times higher than that observed in conventional superconducting systems, which makes the quantum metallic state in the YBCO films very stable and convincing. An ultralow temperature control experiment indicates that the resistance saturation behavior remains almost the same with or without the filters, which safely excludes the possible influence of external high frequency noise and provides undoubted experimental evidence of quantum metallic state.

More interesting, the $h/2e$ magneto-conductance quantum oscillations are also observed in nanopatterned YBCO films, indicating that the quantum metallic state is bosonic and the Cooper pairs (bosons) play a crucial role in quantum metallic state (the carriers of a conventional metallic system are electrons, i.e. fermions).

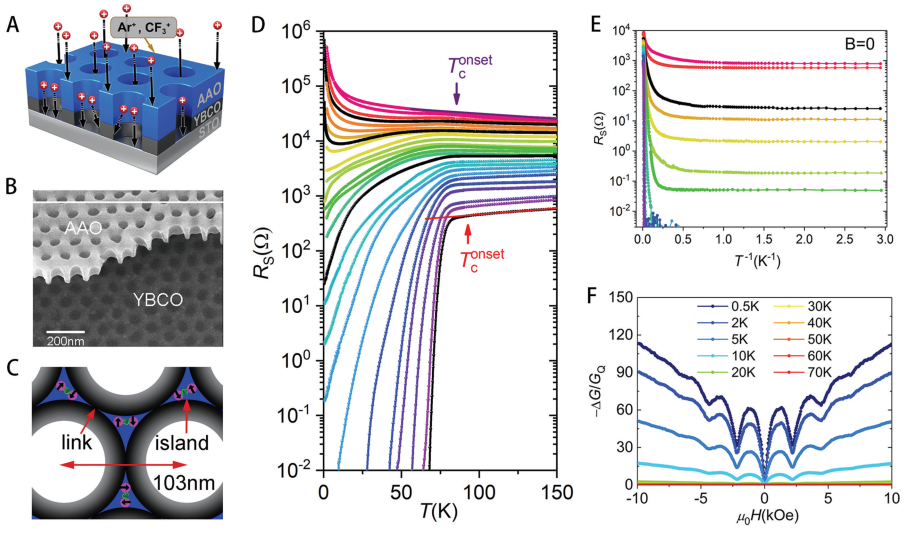

Figure The superconductor-quantum metal-insulator transitions in nanopore modulated YBCO thin films.