Basic Research

Crossover from Two- to Three-dimensional Superconducting States in Bismuth-based Cuprate Superconductor

To decipher the mechanism of high temperature superconductivity (SC), it is important to know how the superconducting pairing emerges from the unusual normal states of cuprate superconductors, including pseudogap, anomalous Fermi liquid and strange metal (SM). A long-standing issue under debate is how the superconducting pairing is formed and condensed in the SM phase because the superconducting transition temperature is the highest in this phase. Although a lot of theoretical progress on the superconducting mechanism of these high-T_C superconductors has been made, a unified understanding on how the SC state connects with these unusual normal states is still lacking. Because the SM state of the optimally-doped superconductor not only can

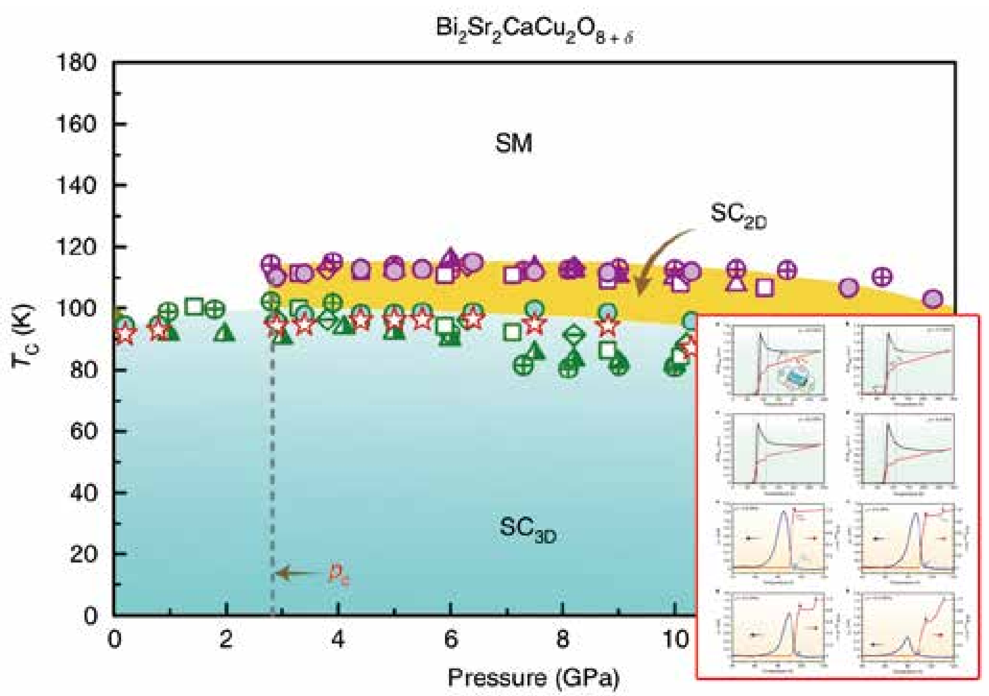

Figure 1: Pressure-T_C phase diagram of optimally-doped $Bi_2Sr_2CaCu_2O_{8+\delta}$. The acronyms of SC_{2D} and SC_{3D} stand for 2D (BKT-like) and 3D superconducting states, respectively. SM represents strange metal state. PC represents the critical pressure above which the 2D superconductivity emerges from the SM state. The lower right panel of the figure (a)-(d) show *Rab*(*T*) and *Rc*(*T*) measured at different pressures, while the figure (e)-(h) display $\Delta\chi'(T)$ and R/R_{120K} at different pressures. The purple and green arrows indicate T_C^{3D} and T_C', the cyan arrow indicates the T_C^{3D} probed by the *a.c.* susceptibility measurements.

develop the SC state with the highest TC but also links the PG and the anomalous FL states, it is of great interest to take the SM state as a breakthrough point to further reveal the underlying physics of cuprate superconductors. Recently, a team led by Prof. SUN Liling from the Institute of Physics (IOP), Chinese Academy of Sciences (CAS) chose to investigate this issue in the optimally-doped $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi-2212) single crystal, a typical nearly-two-dimensional high-T_C superconductor with the SM normal state and widely studied in recent years. They performed high pressure studies on these samples through state-of-the-art *in situ* high-pressure measurements of resistance, magnetoresistance and magnetic susceptibility and discovered a pressure-induced crossover from two- to three-dimensional superconducting states at a pressure above 2.8 GPa. They found that the two-dimensional (2D) superconductivity bridges the SM state and 3D superconducting state and that the two-dimensional (2D) superconducting transition exhibits a Berezinski-Kosterlitz-Thouless-like behavior. These results provide direct and strong evidence that the SM state is predominantly 2D-like. These results have been published in *Nature Physics* (https://www.nature.com/articles/s41567-019-0740-0.pdf).

This study represents the first effort so far to perform the combined *in situ* high-pressure measurements of *ac* susceptibility and resistance for the same sample in the same diamond anvil cell. This kind of measurements is technically challenging, because it is greatly difficult to integrate the standard four-probes for the resistance measurement and the coils for the *ac* susceptibility measurements into the same pressure cell – it requires top-notch high pressure techniques in the experiment.

The high-quality single crystals investigated in this study were provide by GU Genda from the Brookhaven National Laboratory, USA. High pressure X-ray diffraction measurements were performed at 15U beamline at the Shanghai Synchrotron Facilities.

The study was supported by the National Natural Science Foundation of China, the Ministry of Science and Technology of China, CAS, and grants from US.

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