Determination of the Upper Critical Field of Cuprates by Electrical Transport Under High Magnetic Field

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Introduction

The upper critical magnetic field (H_{c2}), defined as the strength of the magnetic field that breaks the Cooper pairs, is one of the most characteristic parameters of a high temperature superconductors (HTS). Intense efforts have been devoted to determine H_{c2} for different materials and different dopings. The reported results in the literature, however, are still highly controversial. We propose to perform the magneto-transport measurement on the best $La_xSr_{2-x}CuO_4$ samples and retrieve the doping-dependent, temperature-dependent and magnetic-field-dependent longitudinal resistivity and Hall resistivity. Our goal is to identify H_{c2} for different doping levels and further the nature of superconducting fluctuations of HTS.

Experimental

The high quality single crystalline $La_xSr_{2-x}CuO_4$ thin films were synthesized by the Atomic-Layer-by-Layer Molecular Beam Epitaxy (ALL-MBE) technique located at Brookhaven National Laboratory. Then we brought our samples together with home-built electronics to NHMFL to perform magneto-transport measurements. We used both the 31 T DC electromagnet and the 60 T long pulse magnet to suppress the superconductivity. With our unique combinatorial sample synthesis technique [1], we performed 30-channel resistance/Hall effect measurement simultaneously to retrieve resistance/Hall resistance signal on 30 different dopings at the same time, greatly enhancing the output of the limited magnet time.

Results and Discussion

We have obtained a huge amount of magneto-transport data at the dopings covering the superconductor-to-metal transition. Here is one representative set of magneto-resistance measurements performed at systematically-varying temperatures for one particular doping.

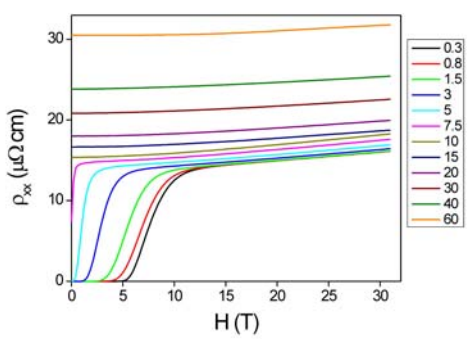

Fig. 1: The magneto-resistance of overdoped $La_xSr_{2-x}CuO_4$ film at systematically-varying temperatures.

The magneto-resistance of a normal metal is expected to show B^2 dependence. Thus this dependence could be used as an indicator of the recovery of Fermi-liquid like behavior of cuprate. The critical field H_{c2} suppresses the superconducting fluctuations and restores the metallic behavior.

Conclusions

By studying the temperature and doping dependence of H_{c2}, we may find clues about the mechanism of the superconducting fluctuations and further the nature of the superconducting state.

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References

[1] Wu, J., *et al.*, Nature Materials, **12**, 877 (2013).