Torque Magnetometry of High Temperature Superconductors in Pulsed Magnetic Fields

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Introduction

High temperature superconductivity discovered in Fe-based [1, 2] and Cu-based materials [3] has been a treasure trove for condensed matter physicists. Many key issues are under debate: for cuprates, whether they are a normal Fermi liquid with a hidden order state or an exotic phase coming out of a doped Mott Insulator; for Fe-based materials, what catches the essential physics in the parent compound - the "bad metal" seen in early discovered materials or "Mott Insulator"? Direct answers to these questions will essentially determine the right approach to understanding the superconducting mechanism, i.e. whether it is a weak-coupling phenomenon or a strongly correlated effect. Precise measurement of the magnetization *M* in ultrahigh magnetic fields will shed light on the magnetic ground state and the superconducting property.

Experiments

We fabricated insulating cantilevers and metalized their bottom planes. The cantilever deflection was then measured by tracking the capacitance between this conductive plane and a gold film underneath [4]. We first measured the magnetic torque of a current-generated magnetic moment. As shown in the insert of the left panel of Fig. 1, a current loop is patterned on top of the insulating cantilever. A small DC current is passed through the loop to generate a magnetic moment. This method provides an in-situ measurement of the spring constant of the cantilever. The second test was on high T_c superconductor underdoped $YBa_2Cu_3O_{6+\delta}$.

Results and Discussion

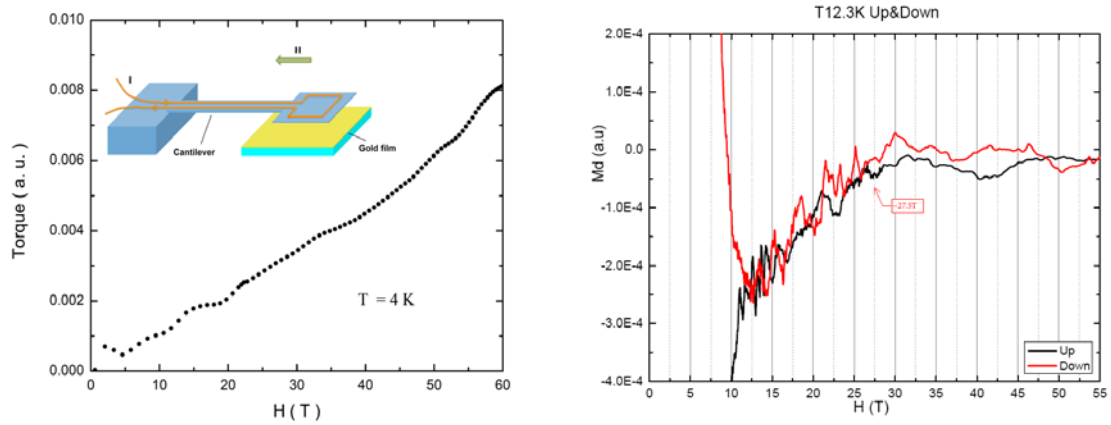

Fig. 1. (Left) Magnetic torque of a current-generated magnetic moment measured in short-pulse field up to 60 T. The magnetic moment is about 2 X 10^{-8} Am^2. (Right) Magnetic torque of the underdoped $YBa_2Cu_3O_{6+\delta}$. The superconducting transition temperature is 61 K.

We passed a small DC current through the wire loop to generate a constant magnetic moment. An example of the magnetic torque is shown in the left panel of Fig. 1, in which the magnetic moment is around 2 X 10^{-8} Am^2. The torque is linear with field H, within noise. We also varied the magnitude and the sign of the DC current to verify the magnetic torque scales with the current. We used the setup to measure the magnetic torque of superconducting underdoped ortho-II phase $YBa_2Cu_3O_{6+\delta}$ (YBCO) with T_c around 61 K. An example of the magnetization curve is shown in the right panel of Fig. 1, taken at T ~ 12 K. At low field, we observed hysteresis due to flux pinning. Well above the melting field 10 T, a kink is observed at ~ 26 T. Further measurements show the kink field value is almost independent with the sample temperature, consistent with the recent observed field-driven charge density wave transition in YBCO of the same phase [5,6].

Conclusions

We set up and tested cantilever torque magnetometry based on capacitance measurements. The magnetic torque measurements on the ortho-II phase YBCO revealed signatures of magnetic field driven CDW transition.

Acknowledgements

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