EXPERIMENTAL EVIDENCE FOR UNIVERSAL FIELD-INDUCED QUANTUM FLUCTUATIONS (QF) IN CUPRATE SUPERCONDUCTORS

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Introduction

Cuprate superconductivity (SC) differs fundamentally from conventional SC because strong electronic correlation in cuprates can give rise to competing orders (CO) besides SC in the ground state. These CO are known to exist from experimental and theoretical investigations [1], but the role of CO in cuprate SC remains a subject of intense research. In this work, we find experimental evidence for universal field-induced QF in cuprates arising from their proximity to a quantum critical point (QCP) separating a pure SC state from a SC/CO coexistence state. Further, we observe varying degrees of proximity to the QCP among different cuprates. Finally, we find that when a magnetic field, H, greater than a field, H*, is applied to cuprate samples, they are in the pure SC state below H* and the SC/CO state above H*. In the SC/CO state, the samples show enhanced QF relative to the pure SC state, leading to magnetic reversibility. Hence, H* is the irreversible field (IF) as $T\rightarrow 0$.

Experimental

To study QF, we carried out pulsed field (up to 65T) and DC magnetization measurements (using the 14T PPMS) to determine the irreversibility line (IL), $H_{irr.}(T)$, at LANL at low temperatures and to reduce thermal fluctuations, and we examined properties of H||ab (CuO_2 plane), where intrinsic pinning between CuO_2 layers overwhelms disorder fluctuations from random point disorder. We found H* by extrapolating the value of the IL as $T\rightarrow 0$. Experiments were conducted on polycrystal (PX) and grain-aligned (GA) $HgBa_2Ca_2Cu_3O_x$ (Hg-1223), PX $HgBa_2Ca_3Cu_4O_x$ (Hg-1234), and GA $HgBa_2Ca_4Cu_5Ox$ (Hg-1245) [DC-field: PX Hg-1223. Pulsed field: PX Hg-1223 and Hg-1234. Low field SQUID [1]: GA Hg-1223 and GA Hg-1245]. These samples are members of the Hg-based cuprate family, having 3, 4, and 5 CuO_2 layers per unit cell, respectively. In Fig. 1a, for example, the IF was identified by identifying reversibility in M vs. H hysteresis loops.

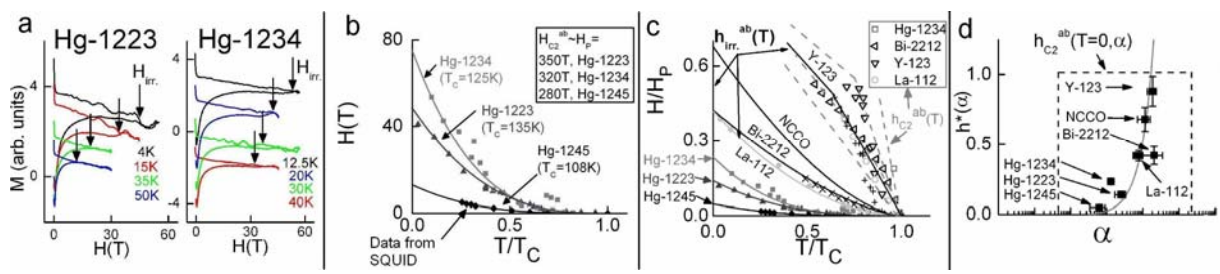

Figure 1: $La_{0.9}Sr_{0.1}CuO_2$ (La-112), $Nd_{1.85}Ce_{0.15}CuO_x$ (NCCO), $YBa_2Cu_3O_x$ (Y-123), and $Bi_2Sr_2CaCu_2O_x$ (Bi-2212).

Results and Discussion

Despite large values of T_c and upper critical field, H_{c2}^{ab}, Fig. 1b shows that $H^* << H_{c2}^{ab}$ in the Hg-samples, where we estimate H_{c2}^{ab} by $H_P=\Delta/\sqrt{2}\mu_B$ (Δ: SC gap), the paramagnetic field. In Fig. 1c, we compare these samples to other samples we previously measured, La-112 and NCCO, and from other groups, Y-123 and Bi-2212, normalizing H to H_P and T to T_c [1]. We find substantial reduction of H* from H_P in the Hg-based cuprates due to strong QF and evidence for QF in all cuprates studied. We map the proximity of each sample to the QCP using $h^*=H^*/H_P$ and a material parameter α in Fig. 1d at T=0 [1].

Acknowledgements

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References

[1] Beyer, A.D., *et al*., cond-mat[0612380] and references therein. The material parameter α is discussed in more detail.