EXPERIMENTAL STUDY OF THE EFFECT OF COMPETING ORDERS ON CUPRATE VORTEX DYNAMICS VIA DC CANTILEVER MAGNETOMETRY

A.D. Beyer, C.R. Hughes, N.-C. Yeh (Caltech, Condensed Matter Physics); M.-S. Kim, K.-H. Kim, S.-I. Lee (Pohang Univ.)

Introduction

The high-temperature superconducting cuprates exhibit various non-universal phenomena (e.g. existence of the pseudogap, the pairing symmetry, quasiparticle spectra, etc.) [1,2] that may be attributed to the presence of competing orders (CO) with energies close to that of the superconducting (SC) order in the ground state. Specifically, non-universality could arise from different cuprates having different degrees of proximity to a quantum critical point (QCP) at T = 0 that separates a pure SC phase from coexisting SC and CO. Furthermore, the application of a magnetic field, H, can transition cuprates initially in the pure SC phase to the coexisting SC/CO phase. One feasible scenario for the field-induced transition is if the CO is a spin density wave (SDW), as illustrated in Fig. 1, where different cuprates are labeled with different material dependent parameters denoted by α. For a given α > α_c, the coexistence region is above some magnetic field H* (α) at T = 0. Above H* (α) where CO and SC coexist, the cuprates exhibit excess low energy excitations as compared to the pure SC state due to strong phase fluctuations between CO and SC, rendering reduced stiffness of the SC order parameter and reversible vortex dynamics above H* (α). If H is applied along the ab-plane of the cuprates at low temperatures, disorder fluctuations and thermal fluctuations are much suppressed, and the resulting vortex dynamics can therefore be attributed primarily to quantum fluctuations. Different cuprates can be compared by evaluating the values of h* (α) = H* (α)/H_{C2,ab} (H_{C2,ab}: upper critical field).

Experimental

To investigate this scenario, we studied different cuprates, including three members of the well-known mercury cuprate family: HgBa_2Ca_2Cu_3O_x (Hg-1223), HgBa_2Ca_2Cu_4O_x (Hg-1234), and HgBa_2Ca_3Cu_4O_x (Hg-1245), using the DC cantilever magnetometry up to 33T at the DC field facility. The three Hg-based samples have 3, 4, and 5 CuO_2 layers per unit cell, respectively. The 4 and 5 layer samples only have 2 outer layers at optimal doping whereas the inner layers are generally underdoped and are found to exhibit dynamic SDW ordering from muon spin resonance studies. If the CO is related to the proximity to the SDW state, the 4 and 5 layer samples will be closer to the QCP than the 3-layer sample.

Results and Discussion

Preliminary results of magnetization, M, versus H for the 4-layer sample are shown in Fig.2, with the resulting phase diagram in Fig.3 (with data from Caltech via DC SQUID and AC susceptibility techniques). Measurements were also performed on the 3 and 5 layer samples, but temperature sensor issues and uncertainty in data analysis, due to low sensitivity, lead us to believe that measurements on all 3 samples need verification via other experimental techniques at low T and high H.

References