Spatial Distribution of Internal Magnetic Field in High T_C Superconductors with Pancake Vortices

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Introduction

The electronic structure in the vortex core is closely related to the underlying mechanism of superconductivity in high-T_c cuprate superconductors. Nuclear magnetic resonance (NMR) plays an important role in understanding the nature of the vortex state, particularly at high magnetic fields. In the vortex solid state, the NMR line shape is determined by the local field distribution [1]. The spin-lattice relaxation rate is dependent on the local density of states (LDOS), and is a measure of the supercurrent distribution through the Doppler effect [2]. For a highly anisotropic superconductor, like Bi2212, at low temperature and high magnetic field, the vortices are 2 dimensional pancakes [3]. We report here ^{17}O relaxation rate measurements in single crystals of slightly overdoped (T_c = 82 K) Bi2212 at 5 K, in magnetic fields from 20 - 30 T. Our measurements indicate that the spatial variation of magnetic field and LDOS in the case of a pancake vortices is different from those in a London vortex state. Three crystals were cleaved after ^{17}O exchange (~ 67%) into 12 pieces, each having a thickness of 50-70 microns and were stacked tightly on a flat surface, with an aligned *c*-axis. The relaxation rates of O(1) (the oxygen in the CuO_2 plane) were measured using the progressive saturation recovery method performed in the 29 T medium homogeneity resistive magnet at NHMFL.

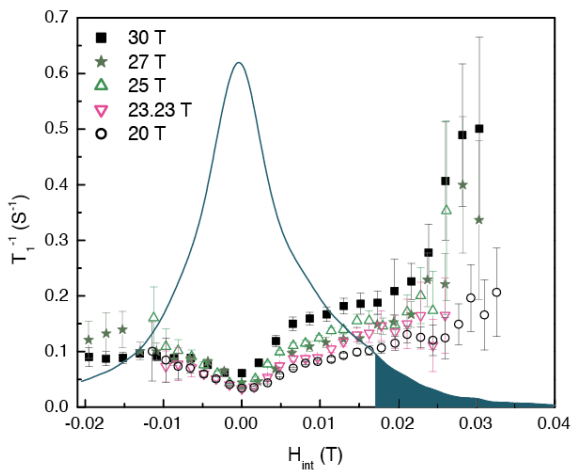

Fig. 1: Relaxation rate at 5 K from 20 - 30 T. The spectrum is for the central transition at 30 T. The shaded region shows the vortex core region.

Results and Discussion

Figure 1 shows the variation of the relaxation rate (T_1^{-1}) in the conduction plane as a function of local field, H_{int}. The peak of the spectrum represents the saddle point of the magnetic field distribution in the conduction plane, and the positive H_{int} side is closer to the vortex core. The relaxation rate, $\propto$ square of the supercurrent density (Doppler effect), is expected to increase monotonically from the minimum field position (the negative H_{int} side of the spectrum) to the maximum field position (near the vortex core) through the saddle point [4]. We observe an anomalously large increase at the smallest local fields in the NMR spectrum, clearly revealing non-monotonic behavior. We attribute this to a non-London type of field distribution for pancake vortices [5-7].

Conclusions and Acknowledgements

The large increase in the spin lattice relaxation rate near the minimum field position in the vortex state shows that the spatial distribution of fields in Bi2212 deviates substantially from the London model. We gratefully acknowledge support from the DOE Basic Energy Sciences grant DE-FG02-05ER46248, the NHMFL from the NSF, and the State of Florida.

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