\(^{17}\)O NMR Study of Single Crystal and Aligned Powders of Bi\(_2\)Sr\(_2\)CaCu\(_2\)O\(_{8+\delta}\) (Bi-2212)

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Introduction

Vortices in some high temperature superconductors, such as Bi-2212, have unusual properties including a complex phase diagram that results from their highly two dimensional character [1], weak interplanar Josephson coupling, and very small vortex cores. Understanding these aspects are essential to applications that require stable vortex structures in high magnetic fields. We use \(^{17}\)O NMR methods to study the frozen vortex states, including both the inhomogeneous magnetic field distributions and the electronic excitations that reside in the cores.

Experimental

Our \(^{17}\)O NMR measurements were performed on Bi-2212 single crystals and aligned powder samples obtained by grinding several crystals to 10-20 micron. The crystals, \(T_C = 77 \text{ K}\), and the powder, \(T_C = 73.5 \text{ K}\) (broader), were studied in cell 7 at 30 T and in a superconducting magnet at 13.4 T. We have measured the spectrum and spin-lattice relaxation time (\(T_1\)) by the progressive saturation method, Fig.1, [2]

Results and Discussion

The temperature variation of the Knight shift and the line width for the single crystal, obtained by frequency sweep is qualitatively similar to that obtained by Chen et al. [1]. A sharp upturn of the line width at around 20 K indicates freezing of the vortex lattice. The spectrum obtained by the field sweep method for the single crystal yields a very broad spectrum with the satellite transitions washed out in contrast to a frequency sweep, indicative of strong pinning centers. This is not the case for our earlier work with Bi-2212 crystals [1] or for YBCO powders [2]. In contrast the powder spectrum, Fig. 1, was the same for the field sweep and frequency sweep methods indicating that pinning is much less effective in small grains. This may have significant ramifications for applications of Bi-2212. The powder spectrum was nonetheless rather broad and we associate this with quadrupolar broadening from defects introduced from grinding. There appear to be efficient relaxation centers in the aligned powder sample, which mask the intrinsic magnetic relaxation at the O(1) site from electronic excitations [2]. The processing of the powder sample, in particular the grinding, likely introduces magnetic defects (rather than impurities). The spin lattice relaxation time given by data points in Fig. 1, for the O(1) (broader central peak) in the CuO\(_2\)-plane, and O(2) (narrow peak) in the SrO-plane, are roughly 10 times faster than that for the single crystal. Similar measurements at 8 K and 10 K have shown the same behavior for \(T_1\) across the spectrum.

Conclusions

We conclude that grinding Bi-2212, in stark contrast to YBCO, to make a powder introduces substantial concentrations of magnetic defects providing efficient relaxation pathway’s in both the strontium and copper-oxygen planes.

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References