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Bulk pinning by planar defects in Ti-doped Bi–2212 single crystals

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Abstract: We demonstrate that Ti-doping in $Bi_2Sr_2CaCu_2O_{8+x}$ (Bi-2212) single crystals results in significantly enhanced pinning properties due to the formation of a peculiar planar defect strucure induced by the dopant.

1. Introduction

The Bi-cuprate superconductors have raised a lot of attention both from technoligical and from fundamental point of view. With a possible feasible application in mind, we are studying the possiblity of enhancing the pinning properties of this compound by a chemical substitution. Previous investigations[1,2] have shown that Ti can be incorporated in the Bi-2212 lattice in concentrations of about 1at.% and 2at.% (with respect to Cu) which leads to lowering of T_c tc about 73K from 85K. High resolution microscopy revealed the presence of a peculiar new defect structure which consists of a high density of planar defects (pairs of antiphase boundaries) parallel to the a,c-plane. In this paper we present magnetic measurements (by means of a Hall probe array and magneto-optics) revealing the enhanced bulk pinning properties.

2. Experimental

1at.% Ti-doped single crystals were grown by means of the travelling solvent floating zone method. ZFC magnetization curves were taken using a sensitive array of Hall-sensors, thus revealing the induction distribution across the rectangular shaped single crystal. Images of the remanent magnetization were made using the magneto-optical technique by means of a Bi-doped garnet indicator, positioned on top of the specimen. The initial noise in the raw data was removed in the Fourier transfomed image.

3. Results and discussion

Figure 1 depicts a set of magnetization curves taken with one of the probes (near the edge of the sample), at various temperatures.

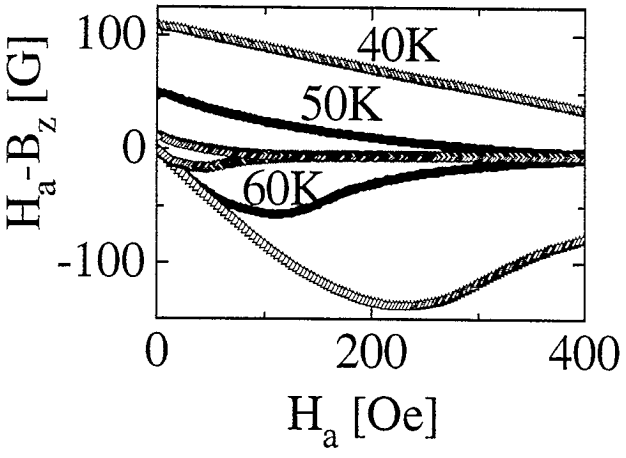

Fig. 1 Magnetization curves (taken by one of the probes of the Hallprobe array) of 1at.% Ti-doped Bi-2212. Temperatures are indicated.

These data show that at all temperatures a smooth flux penetration is seen; a signature of bulk pinning, rather than edge pinning. Furthermore, we did not observe *a)* the presence of a step in the magnetization associated with a first-order melting- or sublimation transition, and *b)* a clear second magnetization peak (see figure 2, magnetization curves on two different locations above the specimen) associated with a 3D-2D crossover of the vortex lattice (both are observed in undoped Bi-2212 crystals [3]). The presence of the planar defects thus creates correlated disorder analogous to columnar defects introduced by heavy ion irradiation [3].

Figure 3 shows the induction profile across the crystal at 50K. The figure reveals a Bean-like profile. This evidences that the magnetic irreversibility at 50K is caused by bulk pinning.

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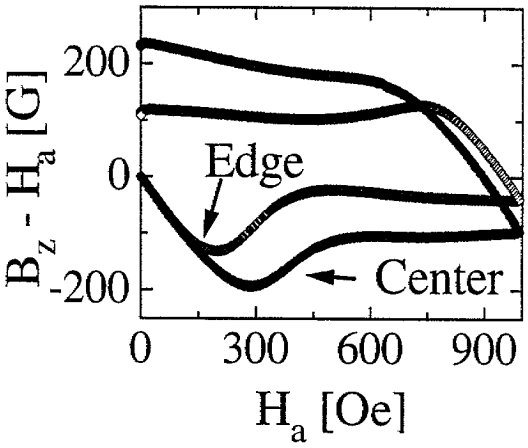

Fig. 2 Magnetization curves of two probes (positions are indicated) at 24K on the 1at. % Ti-doped sample.

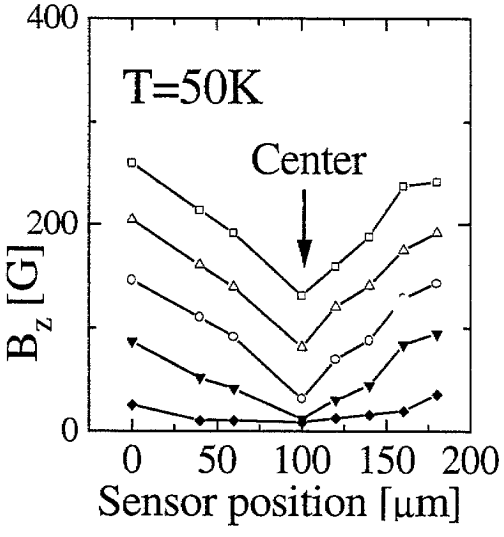

Fig. 3 Induction profiles at different applied fields (ranging from 100Oe(♦) to 300Oe(□) in steps of 50Oe) in 1at.% Ti-doped Bi-2212 measured by the Hallprobe array. T=50K

We note that in undoped Bi-2212 (measured at similar conditions) bulk pinning becomes exponentially small at temperatures above 25K (leading to dome-shaped induction profiles positioned around the center of the sample) [3]. The magnetic irreversiblity is then mainly determined by surface- and geometrical effects [3]. Two magneto-optical images (T=15 and 62.5K) of the remanent induction in the Ti-doped crystal are shown in figure 4 (light areas appear as high field regions). The flux is trapped at the edges of the specimen in the low temperature image, evidencing bulk pinning, whereas at 62.5K the flux profile (at the outer parts of the crystal) possesses a dome-shape (checked by taking intensity profiles). The same outer parts (which are separated from the middle part by defects perpendicular to the long edges) shows a crossover from bulk pinning to edge pinning at T~60K in contrast to undoped Bi-2212 where the crossover appears at much lower T. This reflects the enhanced pinning due to the presence of the Ti-induced planar defect structure. Figure 4 also reveals an inhomogeneous pinning center density (at 62.5K): the outer parts of the sample exhibit a dome-shape induction profile while the middle part still possesses a Bean-like profile. High resolution electron microscopy studies indeed confirmed [2] an inhomogeneous distribution of the Ti-induced defects.

4. References

[1] T.W. Li *et al.*, Physica C, vol. 274, issue 384, (1997)

[2] C. Traeholt *et al.*, to be published (also appearing in this issue) (1997)

[3] For a review see: P.H. Kes *et al.*, J. Phys. I, France, **6**, 2327, (1996) and references therein.

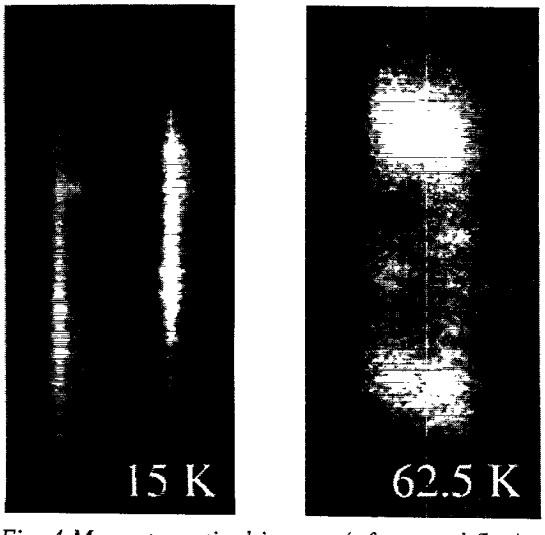

Fig. 4 Magneto-optical images (of trapped flux) of a 1 at.% Ti-doped sample at 15 and 62.5K. The applied fields are 27Oe and 15Oe respectively