Physica B 194–196 (1994) 1885–1886
North-Holland

PHYSICA B

MAGNETIC MEASUREMENTS ON Tl-2212 AND Bi-2212 SINGLE CRYSTALS: A COMPARATIVE STUDY

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We have compared the magnetic behaviour of two identicaly shaped single crystals, $Tl_2Ba_2CaCu_2O_8$ and $Bi_2Sr_2CaCu_2O_8$. The critical current density is found to decrease more rapidly with temperature in Bi-2212 although it is the highest in this material at low temperatures (T < 10K). I-V characteristic curves have been obtained from measurements of magnetic sweep rate dependencies of the hysteresis loops. We have found that the characteristic temperature at which flux motion becomes important is significantly higher in Tl-2212 than in Bi-2212. Hence the Tl-2212 has a larger effective pinning.

The $Bi_2Sr_2CaCu_2O_8$ (Bi-2212) and the $Tl_2Ba_2CaCu_2O_8$ (Tl-2212) oxides have a similar crystallographic structure and are both known to be extremely anisotropic. Furthermore in Tl-2212, as in Bi-2212, the superconducting behaviour is associated with CuO_2-double layers. Therefore, a magnetic comparison between them is interesting.

This paper concerns a magnetic comparative study between Tl-2212 and Bi-2212 single crystals. High quality single crystals of Bi-2212 and Tl-2212 have been grown as described in ref.1. The Bi-2212 single crystal was 0.6 x 0.6 x 0.04 mm^3 size with T_c=92K and the Tl-2212 single crystal was 0.5 x 0.5 x 0.04 mm^3 size with T_c=100K. The magnetic hysteresis measurements were carried out using an Oxford Instrument vibrating sample magnetometer.

Figure 1 shows the critical current density J_c versus magnetic field at different temperatures for Tl-2212 (fig.1a) and Bi-2212 (fig.1b) single crystals, as well as J_c versus temperature at a fixed magnetic field μ_0H=1T for both crystals (fig.1c). The critical current density is deduced within the phenomenology of the Bean critical state model[2]. Since the two crystals are nearly identical this comparison is valid. As can be seen from fig.1a and fig.1b, the field dependence of J_c is roughly the same for both crystals at temperatures T < 10K. For example, from μ_0H=1T to μ_0H=10T, the critical current is reduced by the same amount for both crystals: ~55% at 5K and ~65% at 10K. At higher temperatures, this statement is no longer valid as the critical current density decreases more rapidly with temperature in Bi-2212 than in Tl-2212. This is illustrated in fig.1c.

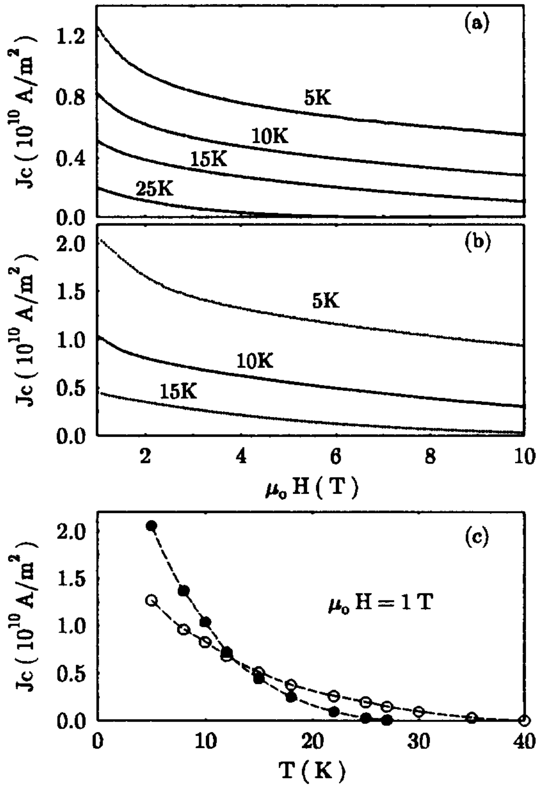

Figure 1: J_c vs μ_0H at the indicated temperatures: a) for Tl-2212 and b) for Bi-2212 single crystals. c) J_c vs T at the indicated fields: ● Tl-2212, ○ Bi-2212.

0921-4526/94/$07.00
SSDI 0921-4526(93)1574-6

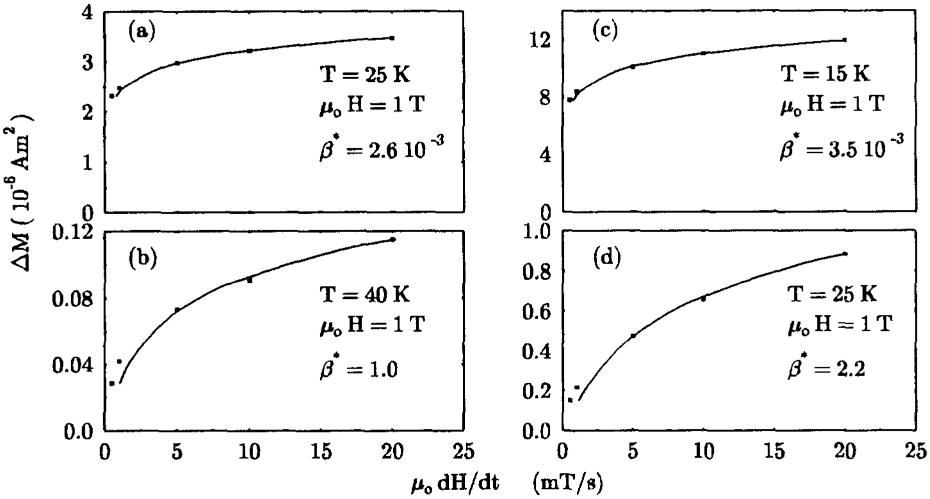

Figure 2: Magnetic hysteresis width (ΔM) versus magnetic sweep rate ($\beta=\mu_0$dH/dt) at the indicated temperatures, for Tl-2212 (a and b) and Bi-2212 (c and d). Lines represent a fit using eq.1.

Figure 2 shows sweep rate dependencies of the hysteresis width for both crystals. The lines represent a fit of our data using the following relation, between the hysteresis width (ΔM) and the magnetic sweep rate ($\beta=\mu_0$dH/dt), deduced by de Groot et al.[3] assuming thermally activated motion of vortices:

$$\frac{\Delta M}{\Delta M^*} = \sinh(\frac{\beta}{\beta^*}) \qquad (1)$$

where ΔM and β^* are constants taken as fitting parameters.
The fit is fairly good at low temperatures (lower than approximately 15K in the case of Bi-2212 and lower than around 25K in the case of Tl-2212). In the Anderson model[4], $\beta^* \propto \mu_0 H \exp(-U/kT)$, where U is the activation energy. Values of the fitting parameter β^* are given in fig.2. According to these values, both crystals show similar sweep rate dependencies of the hysteresis loops but at temperatures shifted in the case of Tl-2212 to higher values. This result suggests that the characteristic temperature at which flux motion becomes important is significantly higher in Tl-2212 than in Bi-2212. In high T_c materials, a transition of the vortex lattice to a vortex glass state is expected[5] and found to occur, for μ_0H=2T, at T_g=15K in Bi-2212 and T_g=20K in Tl-2212. These temperatures have been determined from relaxation measurements[6] following the method of ref.7. The shift in temperatures mentioned above could be possibly associated with the higher T_g value observed for Tl-2212.

In summary, we have compared the magnetic behaviour of Bi-2212 and Tl-2212. We have found that the critical current density is higher in Bi-2212 than in Tl-2212 at low temperatures (T<10K). However, J_c is shown to decrease more rapidly with temperature in Bi-2212 leading to a vanishing J_c at temperatures lower than those in the case of Tl-2212. Similarly, the magnetic sweep rate experiments (ΔM vs μ_0dH/dt) have shown that the characteristic temperature at which flux motion becomes important is significantly higher in Tl-2212 than in Bi-2212. Hence Tl-2212 has a larger effective pinning.

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