Temperature Dependence of Vortex–Twin-Boundary Interaction in $YBa_2Cu_3O_{6+x}$

Two recent Letters[1,2] have reported studies of flux-vortex pinning by twin boundaries in single crystals of the high-temperature superconductor $YBa_2Cu_3O_{6+x}$ (with x near 1) containing predominantly one twin-boundary (TB) orientation. Although both investigations report a measurable effect of TB's on flux pinning, they present opposite conclusions concerning the nature of the vortex-TB interactions. One investigation[1] showed by magnetization measurements that flux-vortex pinning at 10 K was greater when the applied magnetic field (H) was perpendicular to the TB's (compared with parallel or at 45° to the TB's). In contrast, the other investigation[2] studied resistivity near the superconducting transition temperature (~93 K) and demonstrated that pinning was greatest with the field parallel to the twin planes (compared to the full range of **H**-TB orientations). We present evidence here that both results are correct, with the apparent contradiction arising entirely from the different temperatures employed in the two investigations.

The geometry used in our experiments is shown in the inset of Fig. 1. The crystal and measurement methods were identical to those reported in Ref. 1. The crystal was first cooled in zero field and the magnetization as a function of field was then measured with the field applied either parallel or perpendicular to the TB's. The measurements were carried out to field values in excess of H_{c1}. Figure 1 shows that at 80 K the curve for **H**∥TB lies below that for **H**⊥TB, whereas at 60 and 40 K the relative positions of the two curves are reversed (as was found at 10 K, Ref. 1). Thus for temperatures below about 70 K, pinning is greater when vortices are perpendicular to the TB's (**H**⊥TB), whereas above ~70 K pinning is greater when vortices are parallel to the TB's (**H**∥TB).

In the present work and both previous studies[1,2] the arrangement of a vortex with respect to the TB's remains constant as it moves within the sample. Vortex pinning by TB's is therefore likely to be associated with imperfections of the TB, such as steps or impurity clusters. In any case, pinning by TB's will be greatest for those vortices with the largest effective TB-interaction volume. If the formation energy for vortex-TB interactions is positive (i.e., for **H**∥TB, since vortices are able to completely avoid intersection with TB's in this orientation. On the other hand, if the formation energy is negative (i.e., attractive), there will be a greater interaction volume and hence higher pinning for **H**∥TB. Our results (Fig. 1) suggest that the interaction energy between flux vortices and TB's changes sign from negative to positive as the temperature is lowered. For small applied fields ($H < 2H_{c1}$) the crossover temperature is approximately 70 K. This crossover temperature is not a fixed value, as it depends upon details of the crystalline imperfections, field alignment, and field magnitude.

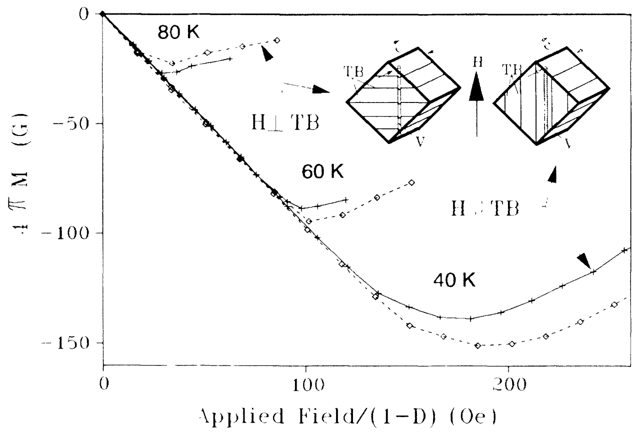

FIG. 1. Magnetization vs applied field for two orientations of a nearly cubic single crystal of $YBa_2Cu_3O_{6+x}$ with predominantly one twin-boundary variant. The data were taken after cooling in zero field to the temperatures indicated. The diamonds and dotted lines indicate H parallel to the twin boundaries (TB's), and the crosses and solid lines indicate H perpendicular to the TB's. The applied field has been corrected for demagnetizing factors (using $D=\frac{1}{3}$).

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[1] L. J. Swartzendruber, A. Roitburd, D. L. Kaiser, F. W. Gayle, and L. H. Bennett, Phys. Rev. Lett. **64**, 483 (1990).
[2] W. K. Kwok, U. Welp, G. W. Crabtree, K. G. Vandervoort, R. Hulscher, and J. Z. Liu, Phys. Rev. Lett. **64**, 966 (1990).