58906-00-105, 85088-20-105

Conf-900817--3

PINNING IN TWIN BOUNDARIES OF $YBa_2Cu_3O_{7-\delta}$ SINGLE CRYSTALS*

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jmc

CONF-900817--3

DE91 006019

Submitted to LT-19 Satellite Conference on High Temperature Superconductivity, August 13-15, 1990, Queen's College, Cambridge, UK

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*Work supported by the U.S. Department of Energy, BES-Materials Sciences under contract #W-31-109-ENG-38 (WKK, SF, GWC) and the National Science Foundation-Office of Science and Technology Centers under contract #STC-8809854 (UW, KGV).

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Pinning in Twin Boundaries of $YBa_2Cu_3O_{7-\delta}$ Single Crystals

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Abstract. We present direct observation of Lorentz force induced flux motion and pinning by twin boundaries in single crystal $YBa_2Cu_3O_{7-\delta}$. From AC magnetoresistance measurements, we derive the effective pinning potential attributed to twin boundaries.

1. Introduction

The broad resistive transition in magnetic fields of the high T_c superconductors remains an intriguing subject of research. Several explanations, including thermally activated flux creep and flux flow (Malozemoff et al., 1989), Josephson junctions (Tinkham, 1988), superconducting fluctuations (T. Tsuneto, 1988), and flux line melting (Nelson, 1988, Fisher, 1989) have been proposed, but fail to quantitatively fit the experimental results satisfactorily. In a recent Letter (Kwok et al., 1989), we demonstrated that flux flow exists in the form of an excess angular dependent resistivity superimposed on an angular independent resistivity in a single crystal of $YBa_2Cu_3O_{7-\delta}$ with twins boundaries oriented only along one direction. In this paper, we report magnetoresistance measurements up to 8 Tesla on a high quality single crystal of $YBa_2Cu_3O_{7-\delta}$ which contains twin boundaries oriented along both the <110> and <1$\bar{1}$0> directions. We see the effects of flux flow as an excess angular dependent resistance which follows a $\sin^2(\theta)$ dependence. In addition, sharp decreases in resistances are found whenever the magnetic field is aligned along either the <110> or <1$\bar{1}$0> twin boundaries (TB). In order to separate the intrinsic pinning from pinning due to twin boundaries, we measured the temperature dependence of the resistance at several fields for H || TB where the sharp decrease in resistance was observed. From an Arrhenius plot representation of the data, we obtain the effective pinning potential U_{eff} of the twin boundaries.

2. Results and Discussion

The samples were prepared by a self flux method described elsewhere (Kaiser et al., 1987) and yielded platelet single crystals of average dimensions 1.2 x 0.5 x 0.04 mm^3. AC resistivity was measured by a four probe technique using gold wires attached to the sample with silver epoxy. Typical measuring current was 0.1 mA at a frequency of 17 Hz in the **ab** plane of the crystal. Angular dependent resistivity measurements at fixed temperatures and low fields H || **ab** were measured in a 1.5 Tesla transverse superconducting magnet. Measurements in higher fields up to 8 T (H || **ab**) were performed in the radial access transverse 8 T Bitter magnet at the Francis Bitter National Magnet Laboratory.

Figure 1 shows the resistive transition in a magnetic field of 1.5T in the **ab** plane for fields parallel (zero Lorentz force) and perpendicular (maximum Lorentz force) to the measuring

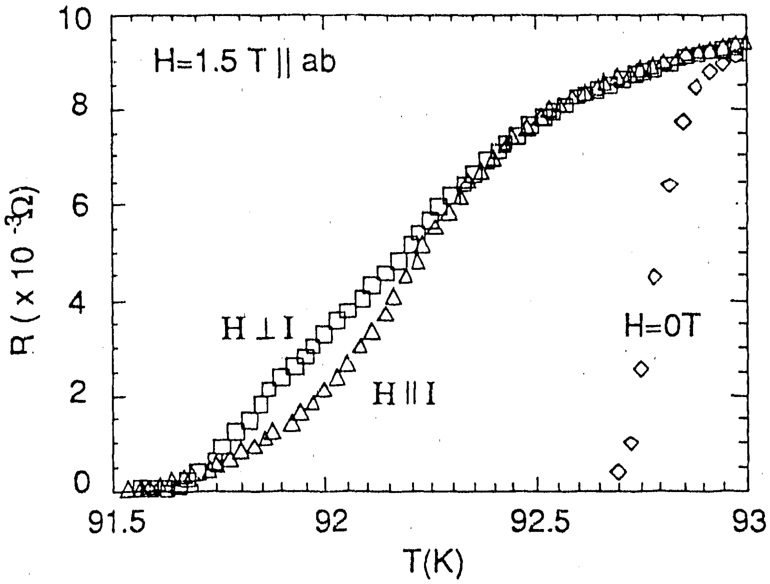

Fig. 1 Resistance versus temperature in a field of 1.5 Tesla for H parallel and perpendicular to the transport current. Both the current and magnetic field are parallel to the **ab** plane of the crystal.

current. The zero field transition is shown for comparison. In zero field, the resistive transition is very sharp with $T_{onset} \sim 92.9$ K and $T_{zero} \sim 92.6$ K. In the presence of a magnetic field, the anomalous broadening is evident even in the zero Lorentz force configuration (H || I). In the maximum Lorentz force configuration (H ⊥ I) there is an 'excess' resistance which follows a $\sin^2(\theta)$ behavior, as shown in Figure 2 for H=1.5T and T=91.89K.

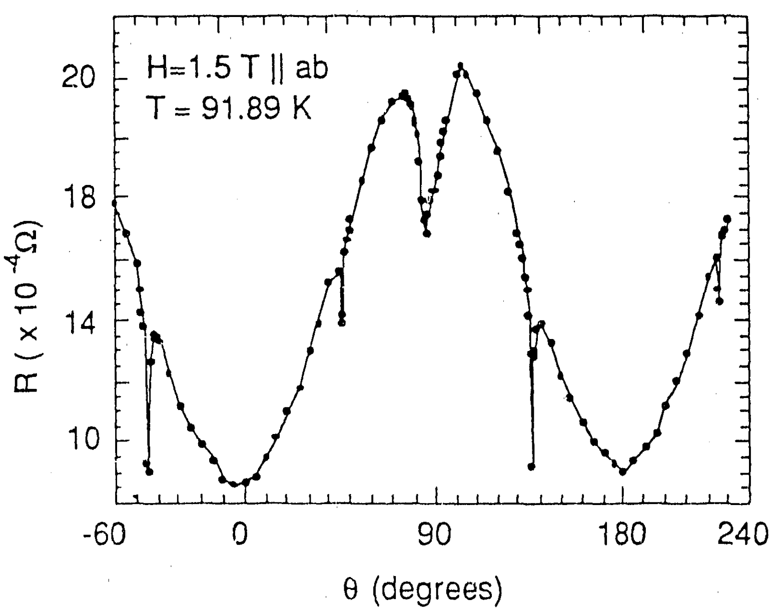

Fig. 2 Angular dependence of the resistance at H=1.5 T and 91.89 K. θ represents the angle between the magnetic field and transport current.

Minima are observed at 0 degrees and 180 degrees at the zero Lorentz force configuration (H || I) and a maximum is observed near 90 degrees. The pinning due to twin boundaries of both orientations <110> and <1$\bar{1}$0> is shown by sharp decreases, about 2° wide, in resistance at -45°, 45°, 135° and 225°.

In order to isolate the effect of pinning due to twin boundaries alone, we oriented the magnetic field parallel to the twin boundaries at 135 degrees. The Arrhenius plot of the temperature dependence of the resistance for this orientation in fields up to 7.35 T is shown in Figure 3. The slopes of the Arrhenius curves at low temperatures remain virtually constant in fields up to 7 Tesla. We obtain an effective $U_0/k = 8 \times 10^4$ K from fitting the low temperature linear region of the Arrhenius curves. This value is 5 times larger than that obtained from the Arrhenius curve for H=5.88 T, H ll I (zero Lorentz force) configuration, consistent with our earlier measurements (Kwok et al., 1990) on a single crystal with twin boundaries only along one direction. A substantial gain in pinning strength may be achieved, even in the presence of high magnetic fields with the introduction of more twin boundaries.

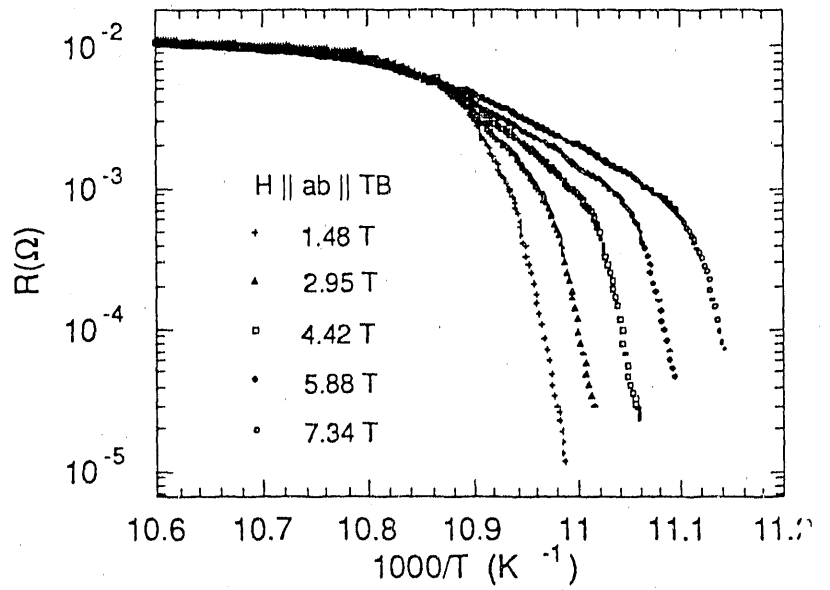

Fig. 3 Arrhenius plot of resistance versus 1000/T in different magnetic fields for H parallel to the twin boundaries.

3. Acknowledgements

We wish to thank the staff of the Francis Bitter National Magnet Laboratory for their hospitality and technical assistance. This work was supported by the U. S. Department of Energy, BES--Materials Science under contract #W-31-109-ENG-38 (WKK, SF, JZL, GWC) and the NSF--Office of Science and Technology Centers under contract #STC8809854 (UW, KGV) Science and Technology Center for Superconductivity). SF and KV acknowledge partial support from the Division of Educational Programs, Argonne National Laboratory.

4. References

Fisher M P A 1989, Phys. Rev. Lett. **62**, 1415

Kaiser D L, Holtzberg F, Chisholm M F, Worthington T K, 1987 J. Cryst. Growth **85**, 593

Kwok W K, Welp U, Crabtree G W, Vandervoort K G, Hulscher R, and Liu J Z, 1990 Phys. Rev. Lett. **64**, 966

Malozemoff A P , Worthington T K, Zeldov E, Yeh N C, McElfresh M W, Holtzberg F, 1989 in Springer Series in Physics: Strong Correlations and Superconductivity, edited by Fukuyama H, Maekawa S, Malozemoff A P, eds. (Springer-Verlag, Heidelberg) pp. 349

Nelson D R 1988, Phys. Rev. Lett. **60**, 1973

Tinkham M 1988, Phys. Rev. Lett. **61**, 1658

Tsuneto T 1988, J. Phys. Soc. Jpn. **57**, 3499

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