

CRITICAL CURRENTS IN MELT-TEXTURED $\text{YBa}_2\text{Cu}_3\text{O}_x$ *

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ANL/CP--72561

DE91 016523

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Proceedings of the 3rd International Conference on Materials and Mechanisms of Superconductivity High-Temperature Superconductors ($\text{M}^2\text{S-HTSC III}$) Kanazawa, Japan, July 22-26, 1991 (to be published in a special issue of *Physica C*).

*Work supported by the U.S. Department of Energy, BES-Materials Sciences under contract #W-31-109-ENG-38

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CRITICAL CURRENTS IN MELT-TEXTURED $\text{YBa}_2\text{Cu}_3\text{O}_x$

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$\text{YBa}_2\text{Cu}_3\text{O}_x$ bars and wires textured by partial-melt-growth and zone-melting methods have been characterized. Specimens exhibited critical current densities (J_c) greater than 10^4 A/cm² at 77 K in a 2 T field. The high J_c values were related to the presence of low-angle grain boundaries and high concentrations of crystal defects. These defects were found to be effective flux-pinning centers.

1. INTRODUCTION

Melt-textured $\text{YBa}_2\text{Cu}_3\text{O}_x$ (123) can have very high J_c values in large magnetic fields.¹⁻³ The flux creep behaviors and the microstructural features that influence J_c and flux creep of 123 textured by zone-melting and partial-melt-growth techniques have been studied.

2. EXPERIMENTAL DETAILS

The 123 specimens were sintered from 123 powder.^{2,3} Wires were zone-melted by heating the entire lengths in air to near 1000°C. A resistance coil was added to partially melt the wires locally. The molten zones were passed along the wires.² Melt-textured bars were heated in air to 1150°C, held for 0.2 h, and cooled rapidly to a maximum temperature on the bar of 1050°C. A gradient of 1°C/mm was established and the bars were cooled to 930–980°C at 0.5–2°C/h. On some bars, a thin coating of Ag was applied to the surface to promote melting.³ To investigate the effects of dislocations and stacking faults on J_c and flux pinning, partial-melt-growth bars were ground to a powder at liquid N_2 temperature. Half of the powder from each specimen was given an anneal in air at 880°C for 80 h to remove dislocations and faults. All of the powders were given a final anneal in O_2 at 450°C. J_c values were calculated from the Bean model⁴ and the average sizes of the powders.

Transmission electron microscopy (TEM) of the specimens was performed on a Philips 420. A superconducting quantum interference device (SQUID) was used for the magnetic relaxation and J_c measurements. Transport J_c was also measured by a four-probe method.²

3. RESULTS AND DISCUSSION

Each specimen contained long, well-aligned grains of 123 separated by low-angle grain boundaries. Depending on the rate at which the temperature gradient was passed along a specimen, the preferred orientation of the grains persisted for ≈10 to 50 mm. Slower rates of gradient motion promoted better alignment.

The zone-melted specimens contained large Y_2BaCuO_5 (211) precipitates (Fig. 1a). The 211 was nearly absent from the partial-melt-growth specimens, which were processed over periods of 1–4 days. This slower rate of solidification allowed time for the 211 to react more fully with the Ba- and Cu-rich liquid to form 123. Both types of specimen contained low-angle grain boundaries (Fig. 1a) and high concentrations of dislocations and planar faults (Fig. 1b). The melt-textured bars exhibited transport J_c values of 4.4×10^4 A/cm² at 77 K in a 1.8 T field.

The J_c in field of the melt-textured (MT) powder that was annealed at 880°C was comparable to that of sintered 123; sintered 123

has relatively low concentrations of dislocations. The MT powder that was not given the 880°C anneal exhibited a much higher J_c . Thus, it appears that dislocations and planar faults are effective at pinning flux lines.

We assumed that the flux creep was thermally activated and that the relaxation obeyed the Anderson–Kim model,⁴ and then calculated apparent activation energies (U_0). The U_0 versus temperature plots revealed important effects (Fig. 3): (1) U_0 increased with temperature, which suggested that a distribution of pinning potentials exists, and that different pinning centers dominate at different temperatures; (2) pinning was most effective perpendicular to the crystal c -axes (i.e., between Cu–O layers); and (3) the U_0 values were larger for melt-textured powders than for sintered powders, which is consistent with the assertion of flux pinning from defects such as dislocations.

ACKNOWLEDGEMENTS

We thank P. J. McGinn and A. C. Biondo for providing specimens. This work was supported by the U.S. Department of Energy, Basic Energy Sciences–Materials Science, under Contract W-31-109-Eng-38. S.S.S. was also supported by a fellowship from Fundação de Ampara a Pesquisa do Estado de São Paulo, Brazil.

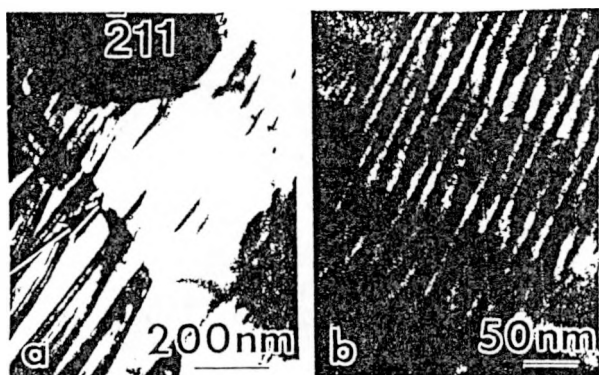


FIGURE 1
TEM of zone-melted specimen: (a) grain boundary and 211 and (b) dislocation array.

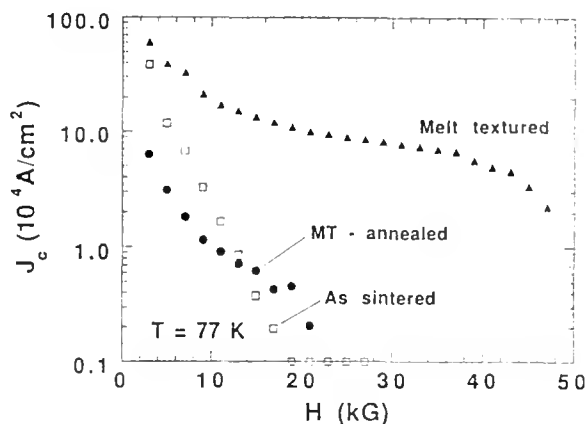


FIGURE 2
Magnetization J_c of powdered samples.

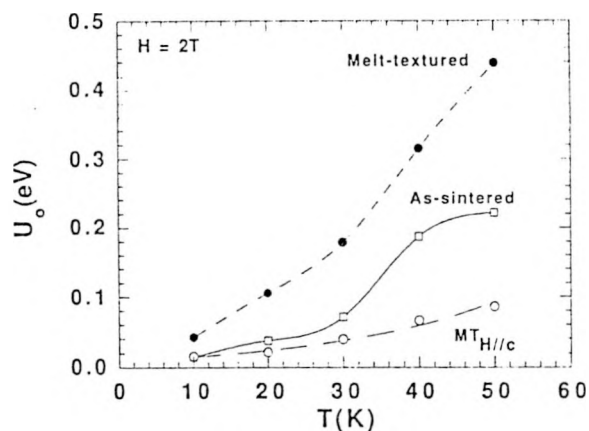


FIGURE 3
 U_0 values of zone-melted (Melt-textured), sintered (ST), and zone-melted with field parallel to the c -axes (MT_{H//c}) powdered samples.

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