1 of 1

FLUX-PINNING RELATED DEFECTS IN $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ THIN FILMS GROWN ON MISCUT LaAlO_3 (001) SUBSTRATES

Z.L. Wang^{1*}, D.K. Christen², C.E. Klabunde², D.M. Kroeger¹, D.H. Lowndes² and D.P. Norton²

¹ Metals and Ceramics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

² Solid State Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831

* Presently at: Metallurgy Division, National Institute of Standards and Technology, Bldg. 223, Rm B123, Gaithersburg, MD 20899.

Measurements of critical current density in $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ (Y123) thin film grown on slightly (1.6 deg) miscut LaAlO_3 {001} substrates have shown an anomalous angular dependence of J_c . A strong, magnetic field-dependent peak in J_c is observed when the magnetic field is oriented between the c-axis (the film normal direction) and the a-b plane, an orientation where flux pinning normally is not strong. Scanning tunneling microscope images of the films showed tilted-platelet microstructures [1], suggesting that the films might contain highly oriented internal growth defects, induced by the miscut-aligned growth. This array of defects may be responsible for the strong flux pinning and high J_c . In this paper, high-resolution transmission electron microscopy (HRTEM) is applied to study the defect structure formed in the films.

HRTEM studies were performed at 300 kV in a Philips CM30 TEM/STEM with image resolution 2.3 Å. The {001} Y123 films of thickness ~ 0.5 µm were grown on miscut LaAlO_3 {001} substrates. Cross-sectional TEM specimens were prepared in order to examine the relationship between the substrate steps with the observed defects.

Low magnification TEM images (figure 1) have shown that nearly columnar defects penetrate through miscut-grown Y123 films. The diameters of the columnar defective regions are ~ 2 - 3 nm (figure 2). These defects are ideal to pin vortices in Y123 for which the vortex core diameter is ~ 3 nm. The defects were found to be oriented perpendicular or nearly perpendicular to the substrate, thus accounting for the observed anomalous pinning and high J_c with a magnetic field oriented at non-symmetry directions near the c-axis. HRTEM images show slight rotation of crystal orientation about the c-axis and a slight change in tilt of the a-b planes (figure 2). Numerous stacking faults have also been produced in the film and are lying in the a-b plane (figure 1). The stacking faults are produced by excess Cu-O layers in the (001) plane and can act as effective flux-pinner [2].

Images of the Y123-substrate interface revealed that some of the columnar growth defects initiate at the substrate steps (figure 3). The Y123 unit cells grown on the top and bottom terraces of the substrate step are shifted by $c/3[001]$, thus the Cu-O chains are broken, possibly resulting in the disappearance of superconductivity if the film thickness is less than 10 nm. Therefore, the supercurrent is carried by the Y123 material grown at distance more than 10 nm from the substrate, but the defects initiated from the interface are useful for pinning flux.

In conclusion, columnar defects are formed in the Y123 films grown on deliberately miscut substrates. The columnar defects and small diameter stacking faults in a-b plane can produce useful amounts of flux-pinning, at formerly low- J_c orientations (near the c-axis), resulting in the anomalous peak in J_c . Therefore, a proper control of the density of the columnar defects can optimize the critical current density when the magnetic field is between c-axis and a-b plane [3].

1. D.H. Lowndes et al., Appl. Phys. Lett. 17 (1992) 852.

2. Z.L. Wang, A. Goyal and D.M. Kroeger, Phys. Rev. B 47 (1993) 5373.

3. Research was supported by the U. S. Department of Energy, Office of Advanced Utility Concepts - Superconducting Technology Program, under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

The submitted manuscript has been authored by a contractor of the U.S. Government under contract No. DE-AC05-84OR21400. Accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes."

FIG. 1 -- Low magnification cross-section TEM image of Y123 film grown on miscut LaAlO_3 {001} substrate. Gold was coated on film for physical property measurements.

FIG. 2 -- Cross-section HRTEM image of columnar defect initiated from Y123- LaAlO_3 interface.

FIG. 3 -- Cross-section HRTEM image of Y123- LaAlO_3 interface showing defects produced by substrate step. Cu-O chains broken by defect are re-matched after film is thicker than 10 nm.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**DATE
FILMED**

6/10/94

END