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Texture influence on critical current density of YBCO films deposited on (100)-MgO substrates

M. Pernet [a], D. Chateigner [a], P. Germi [a], C Dubourdieu [b], O. Thomas [b], J.P. Sénateur [b], D. Chambonnet [c] and C. Belouet [c]

[a] *Laboratoire de Cristallographie CNRS-UJF, BP166, 38042 Grenoble Cedex 09, France.*
[b] *LMGP, ENSPG BP 46, 38042 St Martin d'Hères Cedex, France.*
[c] *Alcatel-Alsthom Recherche, route de Nozay, 91460 Marcoussis, France.*

The texture of two series of YBCO films deposited on (100) MgO substrates by Pulsed Laser Deposition or Metal Organic Chemical Vapour Deposition was analysed using the X-ray pole figure technique. The effect of misorientations on the critical current density is studied.

1. INTRODUCTION

For the application of high-temperature superconducting films in microwave devices, substrates with low dielectric losses must be used. MgO is the must widely used substrate for microwave applications. The dependence of the critical current density J_C on the grain boundary angle has been reported [1]. To achieve high critical current densities, a well aligned epitaxial growth of the YBCO grains on the substrate is required.

The objectives of this study are to obtain a quantitative characterization of the crystallite orientation or "texture" and to find the effect of misorientations on the J_C value.

2. EXPERIMENTAL

YBCO films were grown on (100) MgO substrates using the well known pulsed laser deposition (PLD) or Metal Organic Chemical Vapor Deposition (MOCVD) techniques [2,3] with thicknesses ranging between 150 and 280 nm.

The crystalline texture of the films was analyzed by X-ray pole figure measurements. Pole figures were obtained with the Schulz method using a special diffractometer with a rotating anode CuKα source. A graphite monochromator was installed on the incident beam to prevent artifacts from the substrate [4]. The pole sphere was scanned by 0.45° steps in both tilt χ and φ angles. Corrections for defocusing were made with a special procedure [5].

The J_C values, at T=77 K without an external magnetic field, were obtained from direct transport measurements or were determined using the third harmonic response of the AC susceptibility measurements [6] then calibrated with transport measurements.

3. RESULTS AND DISCUSSION

In the present X-ray pole figure analysis made for ten YBCO films it was found that principally the film grows with it's c axis perpendicular to the substrate surface (c⊥ orientation). The a and b axes of the YBCO are aligned along the (100) and (010) directions of the substrate. In addition to this "epitaxial" growth orientation (c⊥0) in plane misorientations with angle of 45° were found (c⊥45). The YBCO c-axis was oriented perpendicular to the substrate, and a- and b-axes were aligned to the MgO <110> axis in the plane parallel to the substrate surface.

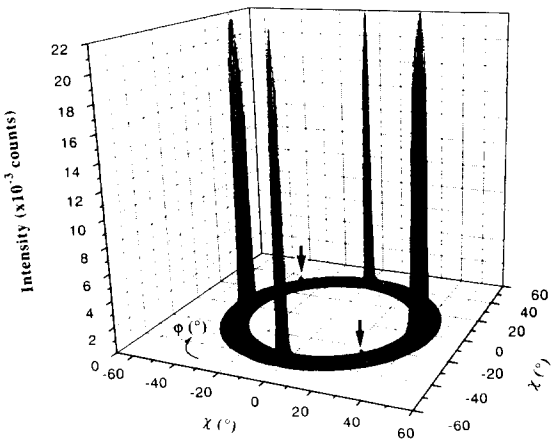

Figure 1: 3D representation of (103) pole figure of a YBCO-film.(Note the small misorientations c⊥45 indicated by arrows).

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Figure 1 shows an example of the (103/013) pole figure for one YBCO film in which the epitaxial orientation (strong peaks) plus 45° misorientation (weak peaks) are observed. The 4 distinct strong peaks correspond to the c⊥0 orientation. The volume fraction of 45° misaligned grains (i. e., the intensity ratio of the peaks at φ=45° and 0°) is about 2.7 % in the presented sample.

Else φ scan of the (103) peak reveals that some of the films have weak in-plane misorientations with angles ranging between 20 and 35° (Figure 2). Due to the high lattice mismatching to the MgO substrate these YBCO misorientations may be explained by the near-coincidence site lattice theory.

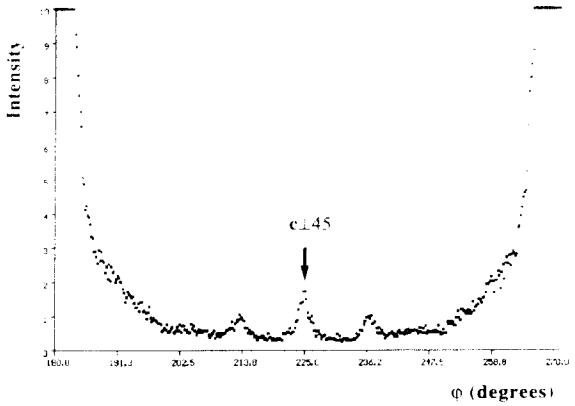

Figure 2: φ scan of the (103) peak for YBCO.

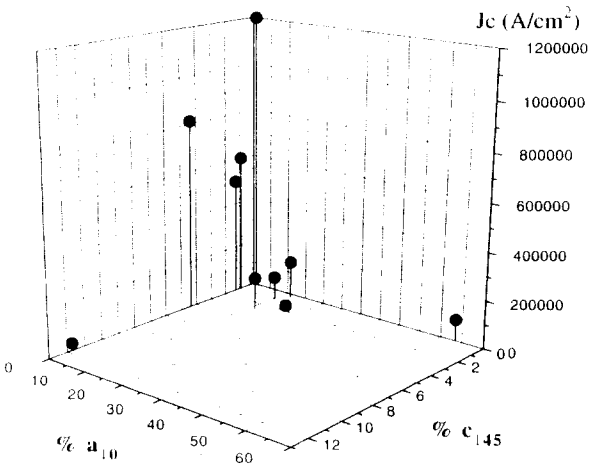

Figure 3: Jc versus misorientations.

Some c-oriented films exibit a-orientation i. e. a-YBCO axis perpendicular to the surface substrate (a⊥). Using the (102) pole figure it was possible to evaluate the ratio a⊥/c⊥.

The effect of misorientations on the Jc value is represented on Figure 3. Only the two major misorientations c⊥45 and a⊥ are taken into account. A reduction of about two times in the Jc was observed as the mixture ratio of c⊥45/c⊥0 was varied from 0 to 2%.

In MOCVD deposited films, CuO inclusions were detected and these inclusions were found textured. It is interesting to notice that comparable Jc values were measured on this type of sample with misorientations and on a sample without misorientations. The CuO inclusions seem to act as pinning centers.

4. CONCLUDING REMARKS

The most significant results of this work may be summarized as follow. It was found in c-oriented films that there were principally two in-plane epitaxial states in which the a or b YBCO-axis was parallel to either the <100> direction or the <110> direction of the substrate. The mixture ratio of the two states influence the Jc value. It confirms that large angle grain boundaries in a-b planes had very weak superconducting coupling.

ACKNOWLEDGEMENTS

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