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MICROSTRUCTURAL CHARACTERIZATION OF YBCO THICK FILM COATED CONDUCTORS ON IBAD-YSZ AND MgO TEMPLATE LAYERS

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ABSTRACT

The microstructure of YBCO thick film coated conductors on IBAD-YSZ and IBAD-MgO has been characterized by transmission electron microscopy. The YBCO films show distinctly different microstructures, including grain size and distribution as well as inter-grain connection patterns. The differences are rationalized as a result of the microstructural differences in the underlying IBAD layers.

INTRODUCTION

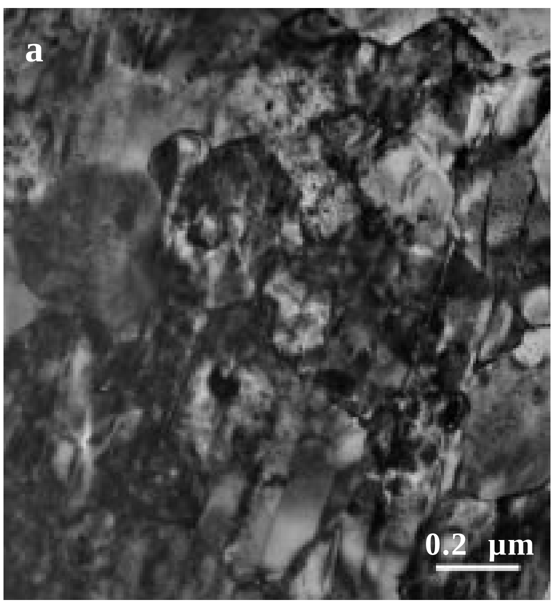
Future applications of high temperature superconductors (HTS) will require long lengths of superconducting materials with high critical current density at the operating temperatures and fields. It has been shown that the grain boundaries in polycrystalline conductors can severely degrade the transport properties, and the presence of magnetic fields further degrades the performance. The benefit of in-plane grain alignment has been documented in YBCO [1] in which high critical current density (Jc) has been observed across low angle grain boundaries, and deteriorates exponentially with grain boundary misorientation angles. The in-plane alignment can be obtained via the formation of a strongly textured template. The utilization of ion beam assisted deposition (IBAD) of a buffer layer [2] was proven to be effective in creating such a template. The two leading oxide layers used in the IBAD coated conductors are yttrium-stabilized zirconia (YSZ) and magnesium oxide (MgO). In this paper, the microstructure of YBCO grown on the two different oxide template layers will be compared. Emphasis has been placed on the grain shape and size distribution, and inter-grain alignment of the YBCO film. The difference in microstructure observed could be related to the differences in the IBAD template layers as discussed below.

EXPERIMENT

The deposition of YBCO coatings was conducted by first depositing an IBAD YSZ layer with a thickness of 0.5 µm - 1 µm, or alternatively an IBAD MgO layer with thickness of 10 nm on Inconel 625 alloy substrates. In the YSZ template layer case, this was followed by the deposition of a YSZ layer, a Y_2O_3 layer, and then the final coating of a 1-µm-thick YBCO layer by pulsed laser deposition (PLD). In the MgO case, additional YSZ and cerium oxide layers were deposited by PLD before the final YBCO coating. A detailed description of the facility, deposition parameters and superconducting properties characterization has been reported previously [3]. For plan-view TEM examination, 3mm discs were first punched out of the tape, and mechanically thinned from the substrate side to ~ 15 µm. Low angle Ar ion milling was then used to further thin the sample from the substrate side until perforation and electron transparency. A final ion polishing/cleaning from both sides was conducted to remove potential surface contamination during the ion thinning. TEM characterization was performed on a Philips CM30 analytical TEM, and a JEOL 3000F high resolution TEM, both were operated at 300 kV.

RESULTS AND DISCUSSIONS

Figure 1(a,b) shows plan-view bright field images of the YBCO film grown on YSZ and MgO template layers viewed along the c axis, respectively. The films were seen to consist of grains with near equi-axed shape and with an average grain size of ~0.5 µm in both cases. The presence of the {110} twins in the YBCO grains provides an internally calibrated axis and orientation marker, which can be used to estimate the misorientation between neighboring grains. In figure 1(a), the grain boundary misorientation angles, as estimated from the twin contrast, are of the low angle type with misorientation angles ≤ 7°. Some of the boundaries have such small in-plane rotation angles that periodic arrays of dislocations can be distinguished. Occasionally, grains with high misorientation angles were observed inter-dispersed among colonies of well-aligned grains. The YBCO grown on MgO template layers shows a distinctly different microstructure than the one with a YSZ layer. In figure 1(b) most of the neighboring grains have relatively high misorientation angles (≥ 10°), only occasionally a cluster of a few grains would exhibit well-aligned grain alignment. Even though the YBCO growth on MgO template layers has not been optimized at this stage, the lack of long-range grain alignment requires further analysis.



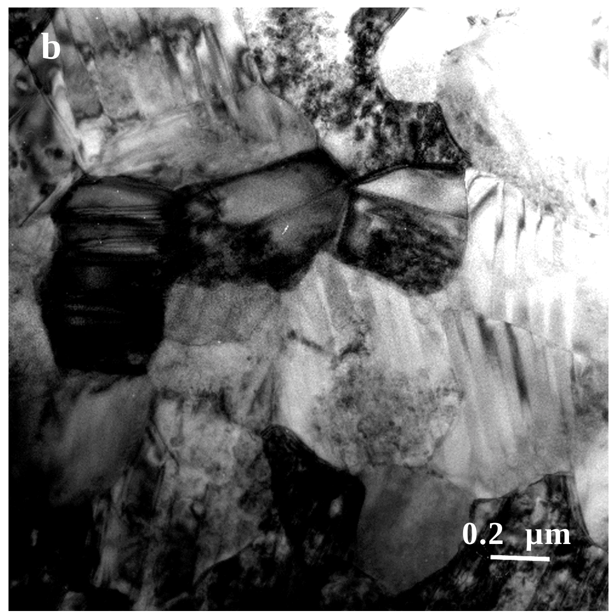


Figure 1(a,b) Plan-view TEM images showing the grain structure of the YBCO film grown on (a) the YSZ template layer, and (b) the MgO template layer.

Since the same growth condition of YBCO is used in the two cases, the difference in microstructure could result from the different template layers. Figure 2(a) shows a dark field (DF) TEM image of the MgO template layer grown on a metal substrate. The corresponding selected area diffraction pattern shown in the figure 2(b), shows the expected strong cube texture. The in-plane misorientation angle is estimated to be ~ 15° at FWHM. The DF image, which was formed by using one of the four {200} reflections, shows the size and distributions of domains consisting of grain clusters with orientation ± 5° of the <200> reflection. The domain size has been estimated to be in the range of 150 - 200 nm. This is much smaller than the domain size observed in the YSZ template, which is normally in the range of several µm in size, despite the similar in-plane misorientation angles of the two templates. Our preliminary study has shown that there is a correlation between the template domain size and the formation of colony structure in the subsequent YBCO film growth. The YSZ layer, which normally consists of large domains, would lend the template to the formation of colonies of well-aligned YBCO grains. In comparison, the

MgO template layer, containing a much smaller domain size, may not afford the sub-grain boundary development in a colony structure. The difference in the domain size between MgO and YSZ can then result in the distinctly different inter-grain connectivity observed in YBCO films grown on the two template layers.

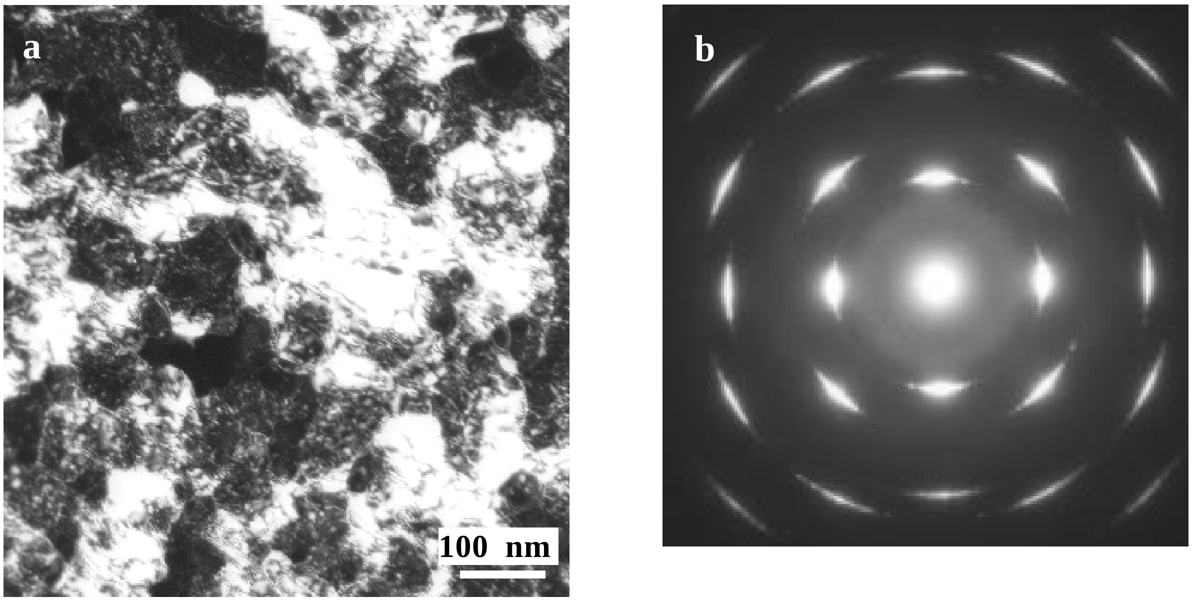


Figure 2(a) Dark field TEM image showing the domain structure in the MgO template layer. The bright contrast regions are oriented within ±5° of the diffracted beam. (b) Corresponding SAD pattern showing the strong <001> texture and the average in-plane misorientation.

CONCLUSION

The microstructure of YBCO films grown on IBAD YSZ and MgO template layers has been characterized by TEM. The distinctly different microstructure and the inter-grain connectivity can be linked to the different domain size in the template layers. The overall misorientation angles of the two templates are similar in magnitude, however, on the microscopic level, the YSZ sample has a much larger domain size than MgO. The larger the domain size, the easier it will be to form colonies consisting of well-aligned YBCO grains. Hence, the difference in microstructure of the template layers can influence the grain connectivity and microstructure of the YBCO layers.

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