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Nanostructural Characterization of $YBa_2Cu_3O_{7-x}$ Layers with $BaZrO_3$ Rods Fabricated by Pulsed-Laser Deposition

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Recently $YBa_2Cu_3O_{7-x}$ (Y123) wires have been developed from an 1 cm to more than 100 m long, and have a high critical current (I_c) more than 100 Acm^{-1} at 77 K and 0 T. However, critical current density (J_c) values of the Y123 layers still decrease in magnetic fields and are strongly dependent on magnetic field angle due to its anisotropic crystal structure and short coherent length. In order to develop superconductive coils and superconductive instruments using the Y123 wires, it is necessary to enhance the J_c values of the Y123 layers in magnetic fields. This suggests the importance of formation of strong vortex pinning centers in the superconductive layer. Therefore, recent research efforts have been made attempts to form high density defects or to distribute non-superconductive particles to play the role of the vortex pinning in the superconductive layer. In particular, formation of nano-sized non-superconductive particles in Y123 layer is known to be highly effective for J_c enhancement of the Y123 layer in high magnetic fields [1,2]. In this study, we characterize the nanostructures of the Y123 layer with the nano-sized particles by transmission electron microscopy (TEM).

Two thicknesses of Y123 layer were deposited on a Ni-based alloy (Hastelloy) with buffered $CeO_2/Gd_2Zr_2O_7$ multilayer by pulsed-laser deposition (PLD). One was a 150 nm-thick Y123 layer and the other was 1.8 μm-thick. In the formation of the Y123 layers, a 2vol%YSZ-Y123 was used as a target material. These Y123 layers were thinned by focused ion beam (FIB) for the cross-sectional TEM specimen. The TEM specimens were further milled by Ar ion milling to remove FIB damaged layers formed on the TEM specimen. The specimens were examined in a TOPCON EM-002B TEM.

A cross-sectional electron micrograph of a Y123 layer on CeO_2 by PLD using the 2vol%YSZ-Y123 target is shown in Fig. 1. The thickness of the Y123 layer is 150 nm. Y123 layer is composed of c-axis oriented grains, in which many continuous dark dots aligned in the [001] of the Y123 are observed, and these continuous dots are distributed homogeneously. Fig. 2 shows a selected area diffraction pattern (SADP) from the Y123 and plane indexes of reflection spots. According to the SADP, those continuous dark dots in the Y123 are identified as $BaZrO_3$ (BZO), and the BZO is formed in the Y123 film kept the cube-on-cube orientation relationship. The orientation relationships between the Y123 and BZO are as follows; (001)Y123//(001)BZO and (100)Y123//(100)BZO. Because of these orientation relationships, these BZO are imaged as moiré fringes as shown in Fig. 1. Therefore, the BZO in the Y123 are formed as nano-rods of about 5nm in diameter. In the PLD process for the formation of the Y123 layers, YSZ particles from the target material were considered to react with Y123 and to change to be BZO. The J_c values of the layers in a magnetic field parallel to the substrate normal were higher than those of Y123 layers without BZO rods. Figure 3(a) shows a low magnification electron micrograph of a 1.8 μm-thich Y123 layer with BZO rods, and Fig. 3(b) and (c) show the surface region and near the CeO_2 interface, respectively. As shown in the micrographs, BZO rods are formed from the CeO_2 interface to the surface region of the Y123 layer. Fig. 4 shows a SADP from the surface region of the Y123. Reflection spots of the <110> from the BZO rods in Fig. 2 is sharp, on the other hand, those in Fig. 4, indicated by allows, have streaks. This result indicates that the orientations of the BZO rods formed beyond the CeO_2 (>1 μm) are distributed along the [001] of Y123. These distributions of the BZO rods in the Y123 films are considered to improve the J_c values and the magnetic field angle dependency in high magnetic fields.

References

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[3] This work was supported by the New Energy and Industrial Technology Development Organization (NEDO).

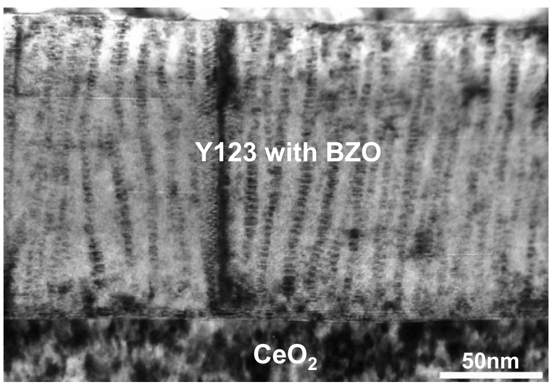


Fig. 1 Cross-sectional electron micrograph of 150 nm-thick Y123 with nano-sized BZO rods on CeO_2

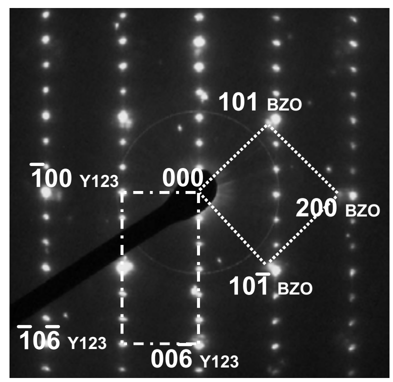
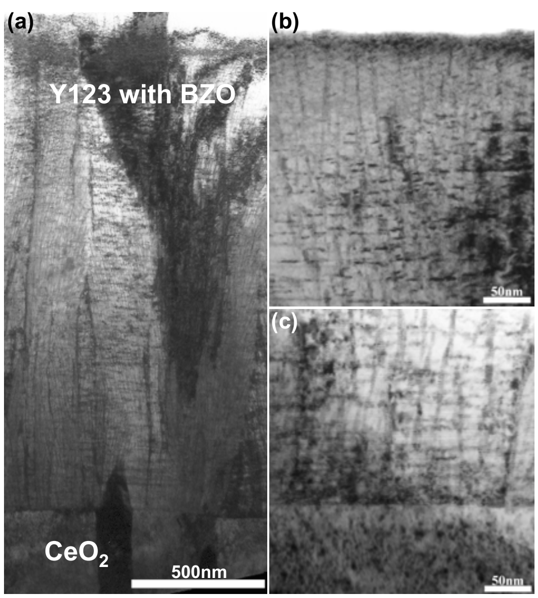


Fig. 2 SADP from the 150 nm-thick Y123 with BZO and plane indexes of each reflection spots from Y123 and BZO.



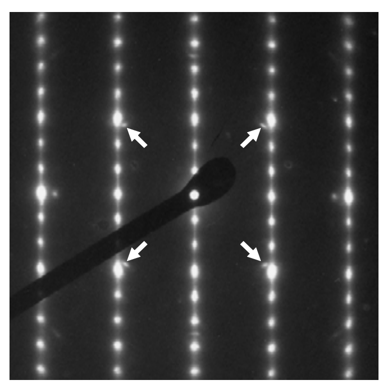


Fig. 4 SADP from the 1.8 μm-thickY123 with BZO. Arrows indicate reflection spots of the <110> of BZO.

Fig. 3(a) Low magnification electron micrograph of 1.8 μm-thick Y123 with nano-sized BZO rods on CeO_2. (b) the surface region and (c) near the CeO_2 interface of the Y123.

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