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Transmission Electron Microscopy Study of $Y_xSm_{1-x}Ba_2Cu_3O_y$ Coated Conductors Containing $BaZrO_3$ Particles

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Second-generation $YBa_2Cu_3O_y$ coated conductors with high critical current (I_c) values have been developed [1]. The length of the coated conductors can reach up to 1 km with their I_c values more than 300 A/cm at 77 K under self-field. These coated conductors are thus promising candidates for industrial applications [1]. However, for the applications it is important to enhance the I_c values in high magnetic fields. Therefore, many research teams have recently attempted to introduce nano-sized non-superconductive particles to act as artificial pinning centers in the superconducting layers. In particular, it has been demonstrated that nano-sized $BaZrO_3$ (BZO) particles can be successfully distributed in $Y_{1-x}Sm_xBa_2Cu_3O_y$ (YSmBCO) superconducting layers fabricated by trifluoroacetates-metal organic deposition (TFA-MOD) [2]. In this study, we characterized nanostructures of the YSmBCO coated conductors with the BZO particles in detail using transmission electron microscopy (TEM).

YSmBCO layer containing the BZO was fabricated on a Hastelloy with a textured $CeO_2/Gd_2Zr_2O_7$ buffer layer using the TFA-MOD process, including precursor synthesis, coating, calcinations and crystallization. The starting solution was substoichiometric with respect to Ba [2]. We introduced zirconium oxide-naphthenate into the solution. The molar contents of zirconium oxide in the YSmBCO composite was 1 wt%. The layer was thinned in a HITACHI FB2100 FIB system at an accelerating voltage of 10-40 keV to form an electron transparent cross-sectional TEM specimen. The specimen was further milled using a Gatan Dual Ion Mill at an accelerating voltage of 2.0 keV to remove FIB damaged layers formed on the TEM specimen. The specimen was examined in a TOPCON EM-002B TEM at an accelerating voltage of 200 keV.

Figure 1 shows the field angular dependence of critical current density (I_c) of YSmBCO coated conductors containing BZO and without BZO at 77 K under a magnetic field of 1 T. The I_c values of the coated conductors containing BZO are higher than those of pristine YSmBCO at all field angles. In addition, the coated conductor containing BZO has a much flatter I_c-B-θ profile with a ratio $I_{c,min}/I_{c,max}$ of 0.91 at 77 K and 1 T.

Figure 2 shows a cross-sectional electron micrograph of the YSmBCO coated conductor with (i)-(iv) selected area diffraction patterns corresponding to the region of A-D in the micrograph. The YSmBCO layer is comparatively dense and predominantly composed of *c*-axis oriented grains. In addition, $(Y,Sm)_2Cu_2O_5$ (225) grains with size of 200-100 nm, as well as a large number of particles with an average diameter of 20 nm, are homogeneously distributed in the layer. Some $BaCeO_3$ has also formed at the interface between the superconductive layer and CeO_2. Fig. 3 (a)-(e) shows EDS elemental map of Zr, Y, Sm, Ba, Cu, and (f) the corresponding region, respectively. The zirconium map shows the distribution of nano-sized particles in the layer containing zirconium. Bright regions of the yttrium and the samarium maps (Figs. 3(b) and (c)) correspond to the 225 phase, while that of the copper map (Fig. 3(e)) corresponds to copper oxide. Fig. 4 (a) shows a particle with approximately 15 nm in diameter (indicated by an arrow), Fig. 4 (b) the Zr map corresponding to the region (a), Fig. 4 (c) a higher magnification image of the particle in (a) and (b), and Fig. 4 (d) the nano-beam diffraction pattern corresponding to the particle. The Zr-map indicates that the particle contains zirconium. In addition, the nano-beam diffraction pattern confirms an incident bean direction of the [110] for BZO. On this basis, the nano-sized particles containing zirconium can be identified as BZO. Therefore, the homogeneous distribution of the BZO particles in the YSmBCO layer should work as three-dimensional pinning centers at 77K and a magnetic field of 1T, and could create the much flatter I_c-B-θ profile compared with that of pristine YSmBCO in Fig. 1.

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References

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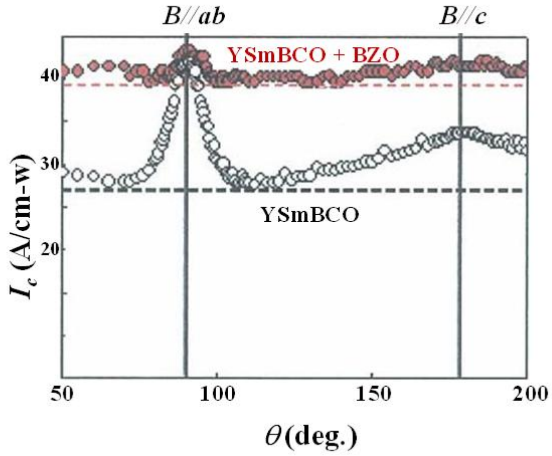

FIG. 1. The field angular dependence of I_c of YSmBCO coated conductors with and without BZO at 77 K under a magnetic field of 1 T.

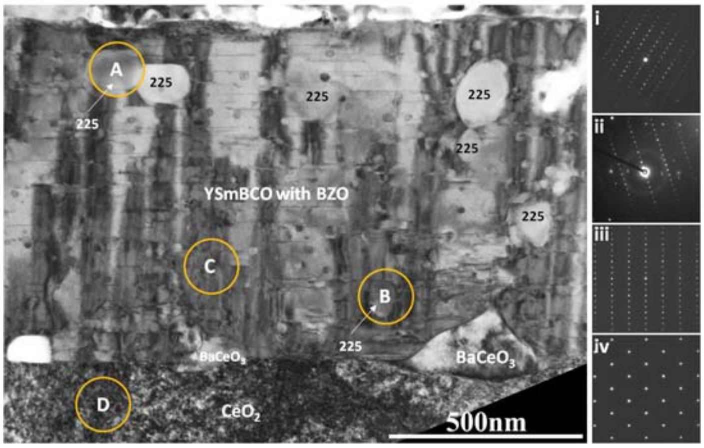

FIG. 2. Cross-sectional electron micrograph of the YSmBCO coated conductor with (i)-(iv) selected area diffraction patterns corresponding to the region of A-D in the micrograph.

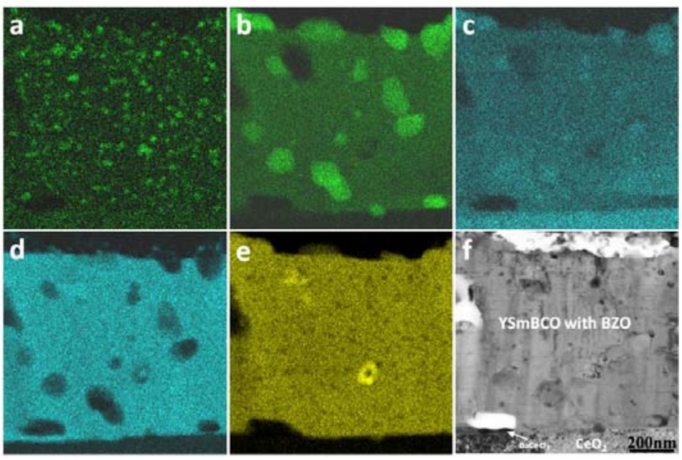

FIG. 3. EDS elemental map (a) Zr, (b) Y, (c) (d) Sm, (d) Ba, (e) Cu and (f) the corresponding region.

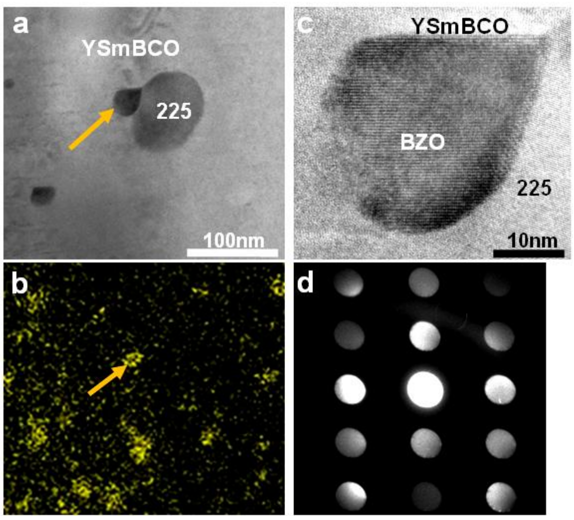

FIG. 4. (a) a BZO particle in YSmBCO indicated by an arrow, (b) Zr-map correspond to the region (a), (c) higher magnification image of the BZO in (a), and (d) nano-beam diffraction pattern along the BZO [110] zone axis for the BZO in (c).