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Nanostructural Characterization of $Y_{1-x}Sm_xBa_{1.5}Cu_3O_y$ Coated Conductors with $BaZrO_3$ Particles by Transmission Electron Microscopy

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Second-generation YBa_2Cu_3Oy coated conductors with high critical current (I_c) values have been developed. The length of the coated conductors is more than 500 m or 1 km and the I_c values of the coated conductors are more than 300 A/cm at 77 K, self-field. These coated conductors are very promising candidates materials for industrial applications, such as superconductor cables, transformers, superconducting magnetic energy storage (SMES) systems. However, for these applications it is important to enhance the critical current density (J_c) in high magnetic fields and to improve the magnetic field angular dependence of the J_c values of the coated conductors. Therefore, many research efforts have attempted to distribute nano-sized non-superconductive particles to act as artificial pinning centers (APCs) in superconductor layers to resolve those problems. In particular, nano-sized APC can be successfully distributed in $Y_{1-x}Sm_xBa_{1.5}Cu_3O_y$ (YSmBCO) superconducting layers fabricated by trifluoroacetates-metal organic deposition (TFA-MOD) [1]. Fig. 1 shows the field angular dependence of J_c of YSmBCO coated conductors with and without APCs at 77 K and a magnetic field of 1 T. The J_c values of the coated conductor with APCs increase at all field angles compared with those of YSmBCO on its own. In addition, the coated conductor with APCs has a much flatter J_c-B-θ profile with a ratio $J_{c,min}/J_{c,max}$ of 0.91 at 77 K and 1 T. In this study, we characterized nanostructures of the YSmBCO coated conductor with APC in detail using transmission electron microscopy (TEM).

The APCs-containing YSmBCO layer was deposited on 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. We introduced zirconium oxide-naphthenate into the organic solution. The molar content of zirconium oxide in the YSmBCO composite was 1 wt% [1]. The layers were thinned in a HITACHI FB-2100 FIB system at an accelerating voltage of 10-40 keV to prepare the cross-sectional TEM specimen. The cross-sectional TEM specimen was further milled using a Gatan Dual Ion Mill at an accelerating voltage of 1.5-2.0 keV to remove FIB damaged layers formed on the TEM specimen. The specimens were examined in a TOPCON EM-002B TEM at an accelerating voltage of 200 keV.

Fig. 2 shows a cross-sectional electron micrograph of the YSmBCO coated conductor and (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 a few 100 nm in diameter, 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 layer and the CeO_2. Fig. 3 (a)-(g) shows EDS elemental maps of Zr, Y, Sm, Ba, Cu, O, Ce, O and (h) the mapping region, respectively. The zirconium map indicates the distribution of nano-sized particles in the layer containing Zr. 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 correlponds to copper oxide. Fig. 4 shows a selected diffraction pattern from the YSmBCO layer and the plane indexes of the 225 phase and $BaZrO_3$ (BZO). The nano-sized particles containing zirconium can be identified as BZO. Furthermore, according to the diffraction pattern the orientations of both the BZO particles and the 225 phase are random. The BZO particles in the YSmBCO layer should act as pinning centers in high magnetic fields, and the distribution of the particles in the YSmBCO could enhance its J_c values for all magnetic field orientations.

References

[1] Miura et al., Appl. Phys. Express **1** (2008) 51701.
[2] This work was supported by New Energy and Industrial Technology Development Organization (NEDO) as the project for Development of Materials & Power Application of Coated Conductors.

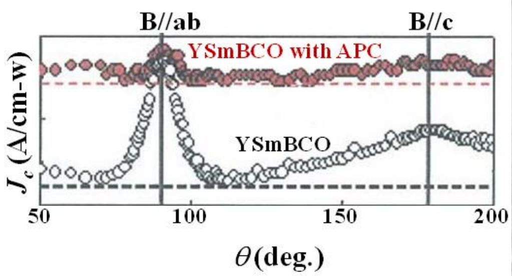

Fig. 1 Field angular dependence of J_c of YSmBCO coated conductors with and without APCs at 77K and a magnetic field of 1T.

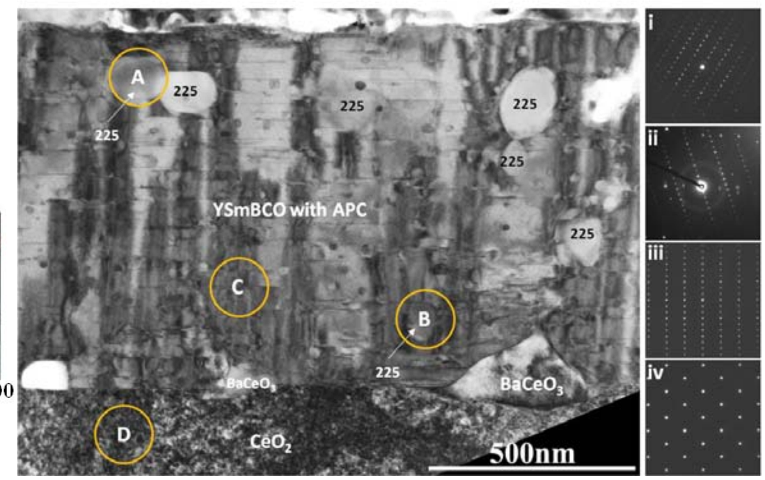

Fig. 2 Cross-sectional electron micrograph of the YSmBCO coated conductor and (i)-(iv) selected area diffraction patterns corresponding to regions of A-D in the micrograph.

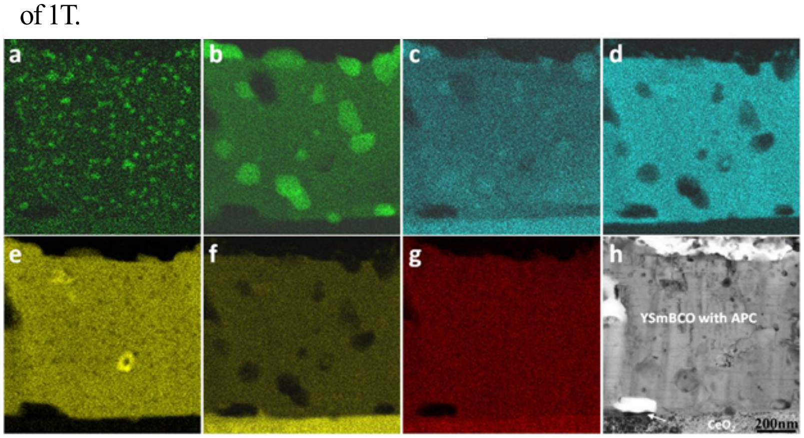

Fig. 3 EDS elemental maps of (a) Zr, (b) Y, (c) Sm, (d) Ba, (e) Cu, (f) Ce, (g) O and (g) the mapping region.

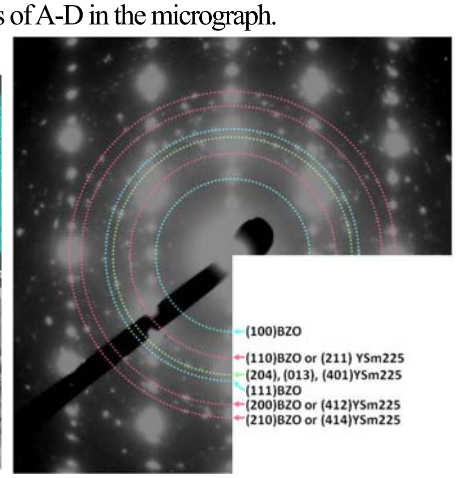

Fig. 4 Selected diffraction pattern from the YSmBCO layer showing the plane indexes of the 225 and BZO phase.

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