

Transmission Electron Microscopy Study of $Y_xGd_{1-x}Ba_2Cu_3O_y$ Layers with $BaZrO_3$ Particles Fabricated by Metal Organic Deposition

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Many research teams have attempted to introduce nano-sized non-superconductive particles to act as artificial pinning centers in yttrium-based superconducting layers on a metallic substrate with a textured buffer layer. These coated conductors with high critical current (I_c) values in high magnetic fields are indispensable to develop industrial applications. In particular, it has been demonstrated that nano-sized $BaZrO_3$ (BZO) particles can be successfully distributed in yttrium-based superconductive layers fabricated by trifluoroacetates-metal organic deposition (TFA-MOD) [1,2]. In the TFA-MOD process, a precursor solution containing zirconium salt was synthesized. The metallic substrate was dipped into the solution and then dried. Thus, the dipping and drying processes were repeated 9 times (calcination process). Finally, the calcined film was heated up in humid conditions (crystallization process). Recently, a two-step crystallization process in the TFA-MOD has been developed [3]. The two-step crystallization process was carried out as follows; a calcined film was kept at 848 K for 3 hours, followed by heating up to 1038 K in humid conditions. Fig. 1 shows the field angular dependence of I_c of $Y_xGd_{1-x}Ba_2Cu_3O_y$ (YGdBCO) coated conductors with BZO particles fabricated by the two-step crystallization process and the conventional single-step process at 77 K under a magnetic field of 3 T. Round symbols correspond to the sample of the two-step process, and square symbols correspond to that of the conventional process in Fig. 1. The critical current values of the YGdBCO with BZO particles fabricated by the two-step process are enhanced compared with those by the conventional process at all field angles. In this study, we characterized nanostructures of the YGdBCO coated conductors with the BZO particles fabricated by the both processes in detail using transmission electron microscopy (TEM) to investigate the relationship between the superconductive properties and the nanostructure.

Figures 2 (a) and (b) show cross-sectional electron micrographs of the YGdBCO layer with BZO particles on a CeO_2 buffer layer fabricated by the two-step crystallization process and the conventional process, respectively. These YGdBCO layers are mainly composed of *c*-axis oriented YGdBCO grains. The YGdBCO layer formed by the two-step process is dense as shown in Fig. 2 (a). On the contrary, larger elliptical pores are formed in the YGdBCO by the conventional process in Fig. 2 (b). Though some of the BZO as well as secondary phase are formed in the YGdBCO layers, all these grains are not defined in the micrographs in Fig. 2 because of their random orientation [2]. Therefore, EDS elemental mapping was carried out to identify those grains. Fig. 3 shows the result of EDS elemental maps of the YGdBCO layer fabricated by the two-step process. Figs. 3 (a)-(e) show Y, Gd, Ba, Cu, Zr maps and (f) the corresponding region of a high angle annular dark-field (HAADF) image. Fig. 4 shows the result of EDS elemental maps of the YGdBCO layer by the conventional process. In these Y and Gd maps, bright contrast regions correspond to the $(Y,Gd)_2Cu_2O_5$ (225) grains. Bright contrast regions in the Cu maps reveal CuO grains. These 225 and CuO grains with a size of 100-200 nm are distributed in the YGdBCO layers. Furthermore, a large number of BZO particles with an average size of 20 nm are distributed in the

YGdBCO layers as shown in Fig. 3 (e) and Fig. 4 (e). Though some of the BZO particles in the YGdBCO layer fabricated by the two-step process, shown in Fig. 3 (e), are aligned parallel to the GdBCO/CeO₂ interface, these particles are homogeneously distributed in the GdBCO layer. On the other hand, BZO particles in the YGdBCO layers fabricated by the conventional process are coagulated together, as shown in Fig. 4 (e). This difference in distributions of BZO particles and pores in the YGdBCO layers would correspond to the difference in their I_c properties at 77 K under a magnetic field of 3 T. In order to clarify the reasons why such layered nanostructures of YGdBCO layer are formed, we plan to observe the nanostructural changes taking place at intermediate stages during the two-step crystallization process.

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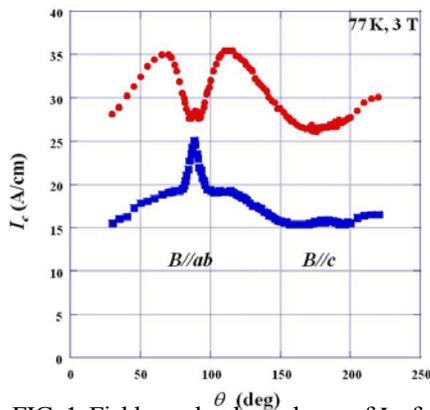


FIG. 1. Field angular dependence of I_c of YGdBCO coated conductors with BZO fabricated by the two-step crystallization process (●) and the conventional single-step crystallization process (■) at 77 K under a magnetic field of 3 T.

References

- [1] Miura et al., Appl. Phys. Express, **1** (2008) 51701.
- [2] T. Kato et al., J. Electron Microscopy, **59** (2010) S101.
- [3] Y. Takahashi et al., Abstracts of 24th International Symposium on superconductivity (ISS2011), WT-8 (2011) 119.

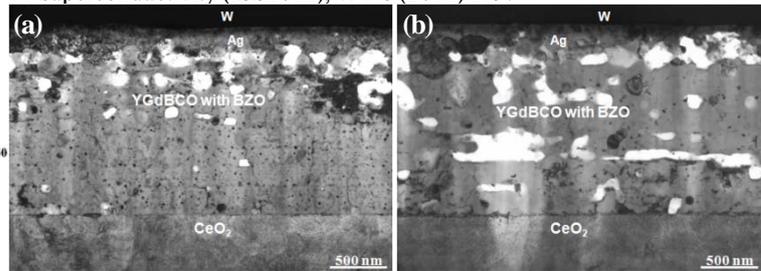


FIG. 2. Cross-sectional electron micrographs of the YGdBCO layer with BZO particles fabricated by (a) the two-step crystallization process and (b) the conventional single-step crystallization process.

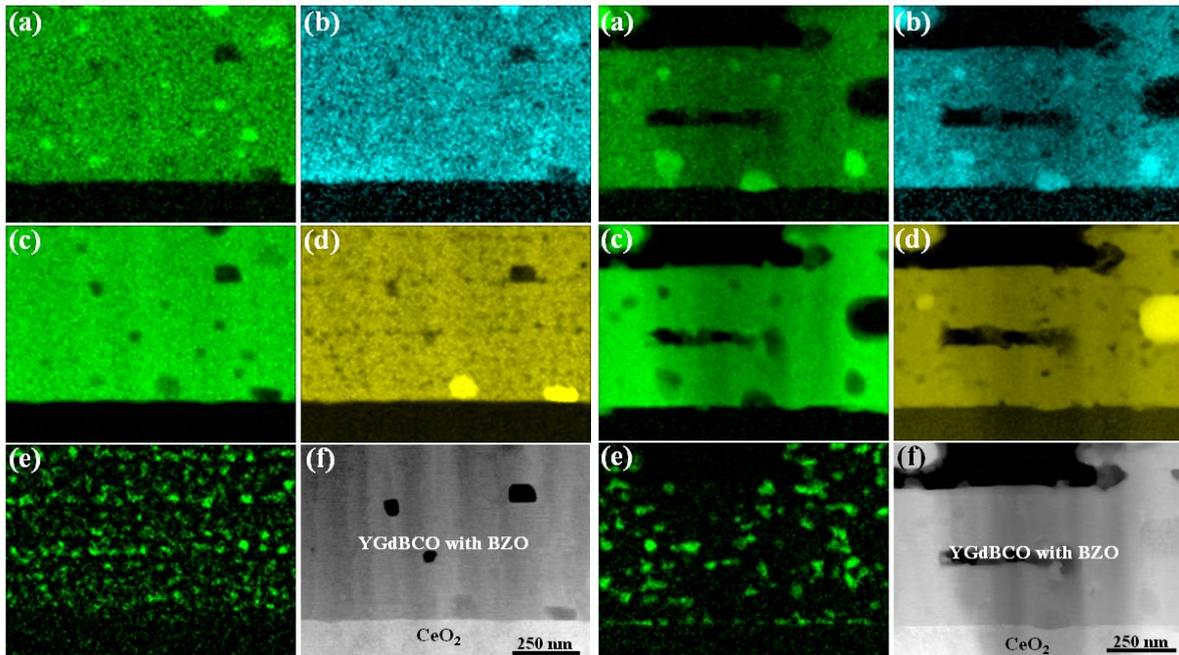


FIG. 3. Result of EDS elemental maps of the YGdBCO layer fabricated by the two-step crystallization process. (a) Y, (b) Gd, (c) Ba, (d) Cu, (e) Zr map and (f) corresponding region of HAADF image.

FIG. 4. Result of EDS elemental maps of the YGdBCO layer fabricated by the conventional single-step crystallization process. (a) Y, (b) Gd, (c) Ba, (d) Cu, (e) Zr map and (f) corresponding region of HAADF image.