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MOD-processed YBCO coated conductor on the IBAD-MgO template

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Abstract-- **We report the results of MOD-processed YBCO coated conductors on the IBAD-MgO template. The precursor solution was coated on the CeO_2-buffered IBAD-MgO template using a slot-die coating method, calcined at a temperature of 550°C, and fired at high temperatures for 2.5 h in a reduced oxygen atmosphere. The J_C value of YBCO coated conductors was found to be very sensitive to the microstructure, and thus higher J_C value could be achieved when the in-plane texture was higher and the difference in $T_{C,zero}$ was negligible. Optimally processed YBCO coated conductor exhibited J_C value of 0.75 MA/cm^2 at 77 K in self-field, which might be due to somewhat depressed $T_{C,zero}$ value of 87.3 K caused by possible Sm^{3+} substitution on the Ba^{2+} site.**

1. INTRODUCTION

Development of YBCO coated conductor with high critical current density over 1 MA/cm^2 offers a great promise in real applications. Among the various fabrication processes for coated conductor, a chemical solution method, including MOD (metal organic chemical deposition) and sol-gel processes, has drawn great attention as the promising alternative, since it is considered cost-effective compared with physical vapor depositions, such as pulsed laser deposition, e-beam co-evaporation, sputtering, and metal-organic chemical vapor deposition [1-2]. Recently, uniform YBCO coated conductors with I_C > 150 A/cm-width, produced by the TFA (trifluoroacetate)-MOD process on the RABiTS (rolling assisted biaxially textured substrates) and IBAD (ion beam assisted deposition)-GZO template, have been demonstrated over 50-m length [3-4]. Meanwhile, the IBAD MgO template is known to have a strong advantage in its processing time compared with YSZ (yttrium stabilized zirconia) and GZO template [5]. With $LaMnO_3$ as a buffer layer, high performance YBCO coated conductors have been reported over 100-m length by metal-organic chemical vapor deposition [6]. However, there are only a few reports for YBCO coated conductor on the IBAD-MgO template by the TFA-MOD process [7], which motivated present study.

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In this study, we applied the MOD process for YBCO coated conductor on the IBAD-MgO template, processing parameters were optimized to obtain high-J_C YBCO film.

2. EXPERIMENTAL DETAILS

Pulsed laser deposition was used to deposit 100 nm thick $LaMnO_3$ buffer layer and 200 nm thick CeO_2 cap layers on IBAD-MgO templates having a final architecture of CeO_2/$LaMnO_3$/ IBAD-MgO/ Hastelloy.

The YBCO films on the IBAD-MgO template were deposited by slot-die coating method using fluorine-free Y and Cu precursor solution with Sm-excess nominal composition. Slot-die coated gel films were calcined at 550°C for 2 h in humidified oxygen to form the oxy-fluorides films with a nominal composition of BaF_2, CuO, and Y_2O_3. The films were subsequently fired at 760 ~ 800°C for 2.5 h in a humidified Ar gas mixed with 100 ppm oxygen gas and finally oxygenated at 450°C for 1 h in a pure oxygen atmosphere. Ag protect layer of ~1.5 μm thickness was deposited on the YBCO film using dc-magnetron sputtering.

The phases were characterized by X-ray diffraction (XRD) using CuKα radiation. The in-plane texture was measured by high resolution X-ray diffraction (HR-XRD). The surface morphology and film thickness of samples were observed by field emission scanning electron microscopy (FE-SEM). Resistive T_C values were measured by the standard four probe method. I_C values were obtained measuring *I*-*V* curves at 77K in self-field.

3. RESULTS & DISCUSSION

Fig. 1 shows XRD θ-2θ scan of the YBCO film with 0.65 μm thickness, which was fired at 760-800°C for 2.5 h. The major peaks in the pattern correspond to the (00*l*) reflections of YBCO phase. The *a*/*b*-axis oriented peaks correspond to 2θ values of 23.274° and 46.725° are undetectable. The $BaCeO_3$ phase peak, which is usually formed by the reaction between YBCO film and CeO_2 cap layer, is also undetectable in Fig. 1. Since present samples are somewhat thick (thickness ~800 nm), the $BaCeO_3$ peak

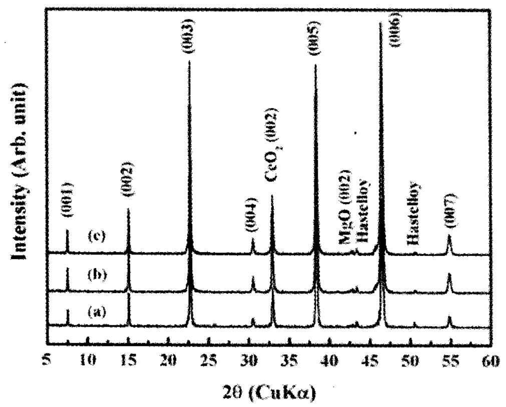

Fig. 1. XRD patterns of YBCO films on IBAD-MgO template with firing temperature: (a) 760°C, (b) 780°C, (c) 800°C for 2.5 h.

might be unobservable. Thus, further analysis by TEM is required to identify the existence of the $BaCeO_3$ phase.

The highly textured epitaxial MgO, CeO_2, and YBCO layers are confirmed by the X-ray φ-scans shown in Fig. 2. The in-plane textures for MgO and CeO_2 layers are 6.2° and 7°, respectively. With increasing the firing temperature from 760 to 800°C, FWHM values of (005) ω scan slightly decreased from 2.05 to 1.97°. Interestingly, however, the in-plane textures of YBCO layers are greatly enhanced compared with buffer layers. FWHM values of (103) φ scan for YBCO first decreased from 3.64 to 3.1° and then increased to 4.59° at 800°C and thus the lowest value of 3.1° could be obtained from the sample fired at 780°C for 2.5 h.

Characteristic microstructures are represented in Fig. 3. All films show the porous surface morphology, in comparison with MOD-processed YBCO films on the single crystal substrate. The grain size of YBCO film increased with increasing the firing temperature, while the *a/b*-axis oriented grains are hardly observed in all samples. It is also observed that YBCO films become denser (*i.e.*, less porous) with increasing the firing temperature from 760 to 780°C, but it becomes more porous at 800°C.

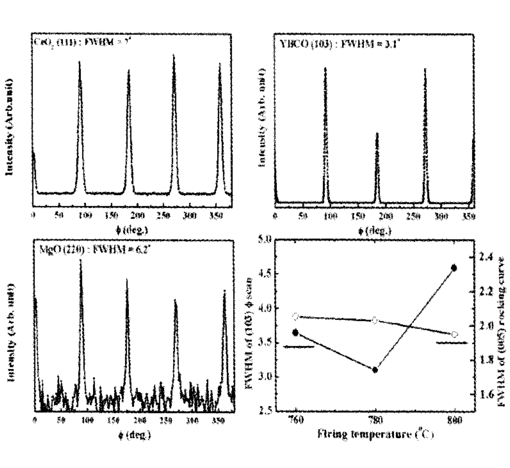

Fig. 2. XRD φ-scans of MgO, CeO_2, and YBCO film fired at 780°C for 2.5 h. FWHM values of (103) φ-scan and (005) ω-scan in YBCO films fired at 760°C-800°C.

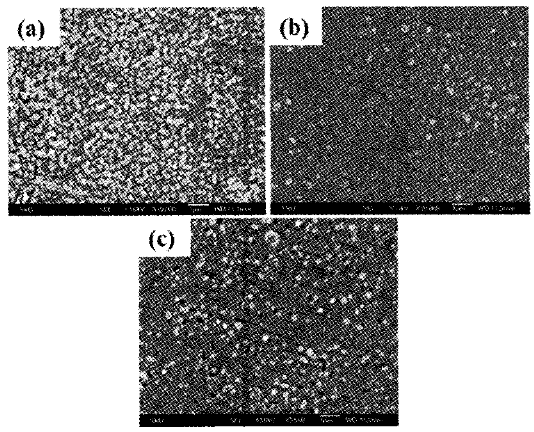

Fig. 3. Surface morphologies of YBCO films on the IBAD-MgO template fired at (a) 760°C, (b) 780°C, (c) 800°C for 2.5 h.

Fig. 4 (a) shows $T_{C,zero}$ and critical current density (J_C) of samples fired at temperature range of 760-800°C. These samples exhibited $T_{C,zero}$ values of 82 K-87.3 K. Depressed $T_{C,zero}$ values below 90 K might be originated from Sm^{3+} substitution on the Ba^{2+} site in the $Sm_{1+x}Ba_{2-x}Cu_3O_{7-\delta}$ solid solution. The highest $T_{C,zero}$ value of 87.3 K was obtained from YBCO film fired at 780°C for 2.5 h. I_C and J_C values for our samples were determined by measuring *I-V* curves. With increasing the firing temperature from 760 to 800°C, J_C value increased from 0.21 MA/cm^2 to 0.75 MA/cm^2 and then decreased to 0.2 MA/cm^2 at 800°C. Degraded J_C value for the sample fired at 760 °C is surely due to depressed $T_{C,zero}$ of 82 K. Lower J_C value of the sample fired at 800°C might be caused by a poor in-plane texture compared with that of the sample fired at 780°C. The highest J_C value of 0.75 MA/cm^2 corresponding to I_C value of 48 A/cm-width could be obtained from the YBCO film fired at 780°C for 2.5 h, as shown in Fig. 4 (b).

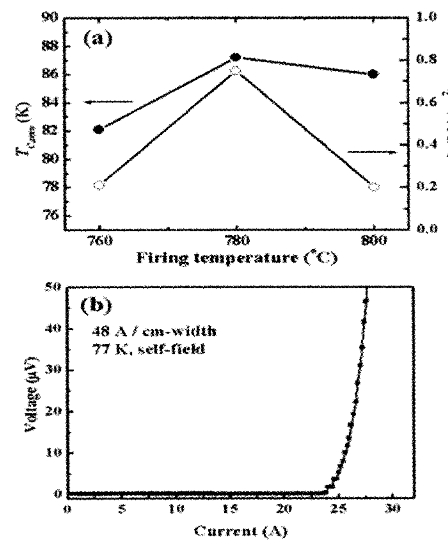

Fig. 4. (a) $T_{C,zero}$ and J_C values of YBCO films fired at temperature range of 760°C -800°C for 2.5 h. (b) *I-V* curve at 77 K for YBCO film fired at 800°C for 2.5 h on the IBAD-MgO template.

4. SUMMARY

We successfully fabricated YBCO films on the IBAD-MgO template with CeO_2 capping layer by the TFA-MOD process using fluorine-free Y and Cu solution with Sm-excess nominal composition. In the present experiments, it was difficult to achieve YBCO films with high-J_C above 1 MA/cm^2. The origin for this J_C suppression on the IBAD-MgO template is related with the degradation in $T_{C,\text{zero}}$ value which might be caused by Sm^{3+} substitution on the Ba^{2+} site. Optimally processed YBCO film (~650 nm thickness) exhibited the highest values of T_C and J_C were 87.3 K and 0.8 MA/cm^2 (77 K, self-field) from the sample fired at 780°C for 2.5 h, respectively. Microstructure and texture of YBCO thin films on the IBAD-MgO template were highly sensitive to the firing temperature. As expected, the higher J_C value could be obtained from the more highly textured YBCO film when $T_{C,\text{zero}}$ values were similar.

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