Journal of the Korea Institute of Applied Superconductivity and Cryogenics
Vol.5, No.3, (2003), pp.20~22

YBCO coated conductor with a single buffer layer of Yttrium Oxide

Chan Park, Dongqi Shi, Kyujeong Song, Rokkil Ko, Soojeong Choi, and Sang-Im Yoo[a]
Korea Electrotechnology Research Institute, Seoul National University[a]

cpark@keri.re.kr

***Abstract*-- Y_2O_3 films were pulsed laser deposited on cube textured Ni and Ni-W substrates to be used as a single buffer layer of YBCO coated conductor. Initial deposition of Y_2O_3 films was performed in a reducing atmosphere, and subsequent deposition was done in the base pressure of the chamber and oxygen atmosphere. The Y_2O_3 films have a strong cube texture (The full width at half maximum of the ϕ-scan of Y_2O_3 was 8.4 which was the same as that of metal substrate) and smooth crack-free microstructure. The biaxially textured YBCO films (The full width at half maximum of the ϕ-scan was 10.2) pulsed laser deposited on the Y_2O_3/metal exhibited Tc(R=0) of 86.5K and Jc of 0.7 MA/cm2 at 77K in self field, representing that the Y_2O_3 single buffer layer is an efficient diffusion barrier of Ni and thus very promising for the achievement of high-Jc YBCO coated conductor.**

1. INTRODUCTION

For the practical application of high temperature superconductor (HTS) in electric power devices and high field magnets, HTS has to be made in the form of wires/tapes with high critical current in the presence of magnetic field at the operation temperature and with cost-competitiveness compared to the conductors in use today such as copper and aluminum. Coated conductor is multi-layer hetero-epitaxial coating of oxides (one of the multi-layer is HTS which is mainly $YBa_2Cu_3O_7$) on either a textured substrate or a textured oxide layer deposited on a polycrystalline substrate, and it is expected to satisfy the requirements of practical application of HTS devices operating in liquid nitrogen temperature.

HTS films with high critical current densities (J_C) at 77 K have been achieved for epitaxial $YBa_2Cu_3O_7$ (YBCO) films on thermo-mechanically treated biaxially-textured metal substrates with the use of certain multi-layer buffer architecture between the substrate and HTS layer.[1,2] In order to realize coated conductor possessing a high critical current, the buffer layer architecture which serves as the seed for epitaxial growth of oxide films on metal, diffusion barrier, and the template for epitaxial deposition of superconducting layer, must satisfy a set of strict chemical and mechanical requirements. These objectives have required multi-layer combinations of various oxide buffer layers such as CeO_2/YSZ/CeO_2 or CeO_2/YSZ/Y_2O_3. This multi-layer structure of the buffer makes the fabrication process complicated and costly. Many results on the use of single buffer layer in coated conductor have been reported with yttria-stabilized zirconia [3], $La_2Zr_2O_7$ [4], $La_{0.7}Sr_{0.3}MnO_3$ [5], and $LaMnO_3$ [6,7].

Y_2O_3 is also an attractive candidate for the single buffer layer and the deposition of Y_2O_3 on textured metal substrate using evaporation and pulsed laser deposition to be used as a single buffer layer has been reported [8,9]. While the CeO_2 film deposited on textured metal tends to crack when it gets thicker than about 100 nanometer, the Y_2O_3 film which has better lattice match and chemically compatible with Ni, does not have cracking problems. (The lattice parameter (a) of Ni a(Ni) = 3.52A, a(CeO_2) = 5.41A, a(CeO_2)/square root of 2 = 3.83A, a(Y_2O_3) = 5.26A, a(Y_2O_3)/square root of 2 = 3.72A.) The critical currents of coated conductors with a single Y_2O_3 buffer layer reported so far are smaller than those obtained with multi-layer buffer structure. In this study, we report on the growth of epitaxial Y_2O_3 on a biaxially-textured metal and the properties of YBCO coated conductor with a single Y_2O_3 buffer layer.

2. EXPERIMENTS

The Y_2O_3 and YBCO films were deposited using pulsed laser deposition (PLD). The stoichiometric Y_2O_3 and YBCO ceramic targets of 2 inch diameter were ablated by an exicmer KrF pulsed laser with 248nm wavelength. The biaxially textured Ni and NiW substrates with the size of about $3\times10mm^2$ were attached with a silver paste on the target holder (also the heater) which was directly facing the target. The deposition temperature was measured by a thermocouple located in the heater block. The laser beam was brought to the target surface with an angle of 60° to the normal of target, target-substrate distance was 65mm, and the background pressure was $4x10^{-6}$Torr. The size of the laser spot on target was ~ $5\times1mm^2$, and the laser pulse energy density on the target was ~ 2 J/cm^2. The X-ray *diffraction system of D8 DISCOVER with GADDS* (general area detector diffraction solution) from Bruker was used to analyze the orientation of films with XRD θ-2θ scan, ω-scan and ϕ-scan with sample oscillation using a 1/4-circle Eulerian cradle xyz stage. The microstructure of the Y_2O_3 and YBCO films were examined using scanning electron microscope (SEM). The resistivity and transport critical current density (Jc) were measured using a standard four-probe technique. The voltage contact spacing was 4mm, and the Jc value was calculated using a 1 uV/cm criterion.

3. RESULTS AND DISCUSSION

Different deposition conditions were investigated to find out the deposition condition which leads to the bi-axial cube orientation of the Y_2O_3 film on the textured Ni or Ni-W alloy substrate. Table 1 shows the deposition condition used to deposit epitaxial Y_2O_3 film on textured metal substrate. Reducing atmosphere was used for both the heating of the substrate and the deposition of the 1st part of the Y_2O_3 film to prevent the native oxide in the surface of the metal substrate from influencing the epitaxial relation between the substrate and the growing film. The reducing atmosphere was followed by pumping to the base pressure of the system which was ~4 x 10^{-6}Torr, where additional 280nm thick Y_2O_3 film was deposited. The final deposition of Y_2O_3 was done in 0.1mTorr oxygen atmosphere. The 250nm thick YBCO film was deposited at a deposition temperature of 790°C in 200 mTorr oxygen pressure on the Y_2O_3 film.

Table 1. Deposition conditions used to deposit YBCO/ Y_2O_3 films on textured metal substrates. The single buffer Y_2O_3 was deposited in three different conditions.

	Depo Temp	Depo Pressure	Thickness	Laser prr
YBCO	790°C	200mTorr O_2	250nm	50Hz
	790°C	0.1mTorr O_2	25nm	
Y_2O_3	790°C	8 x 10^{-6} Torr	280nm	20Hz
	650°C	200mTorr 4%H_2/Ar	250nm	

θ-2θ XRD scans for YBCO/Y_2O_3 films deposited on textured Ni and Ni-W substrates at conditions in Table 1 are shown in Fig. 1 with the intensity of y-axis in log scale. Only 00*l* peaks of Y_2O_3 and YBCO are present in Fig. 1 together with that from cube textured metal. Along with a good c-axis texture of the Y_2O_3 and YBCO films, the pattern also shows that there is no detectable amount of NiO in the sample. Fig. 2 shows the ϕ-scans of YBCO (103), Y_2O_3 (222), and Ni (111) reflections. The in-plane texture of the Ni-W alloy substrate is transferred to YBCO through the Y_2O_3 single buffer layer. The fwhm (full width at half maximum) of the ϕ-scans were 10.2, 8.4, and 8.4 for the YBCO, Y_2O_3, and Ni-W, respectively.

The SEM images of 0.55um thick Y_2O_3 film deposited on Ni-W substrate (Fig. 3(a)) shows smooth surface without any evidence of microcracking. SEM image in Fig. 3(b) shows the smooth surface microstructure of YBCO

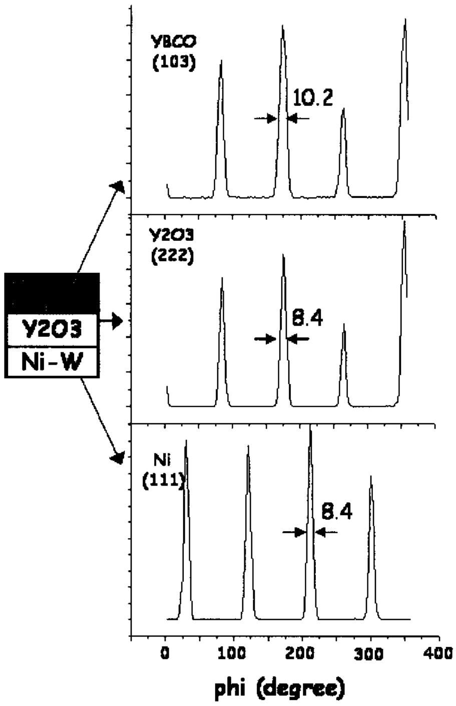

Fig. 2. XRD ϕ-scans for YBCO/Y_2O_3 film deposited on biaxially-textured Ni-W substrate in conditions listed in the Table 1.

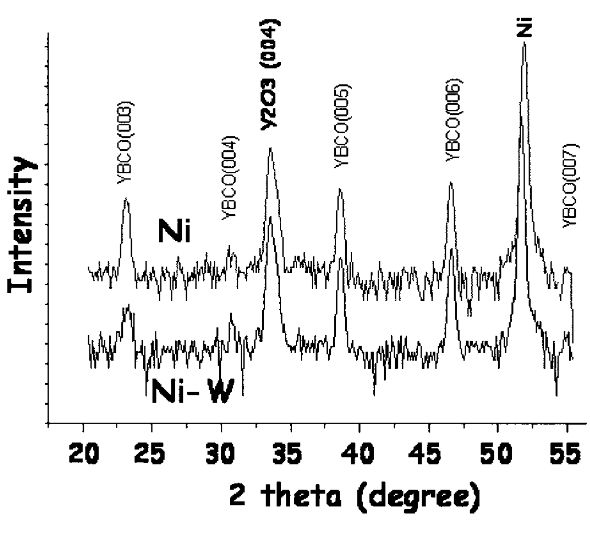

Fig. 1. XRD θ-2θ scans for YBCO/Y_2O_3 films deposited on biaxially-textured Ni and Ni-W substrate in conditions listed in Table 1.

Fig. 3. SEM images showing surface microstructures of (a) Y_2O_3/Ni-W and (b) YBCO/Y2O3/Ni-W.

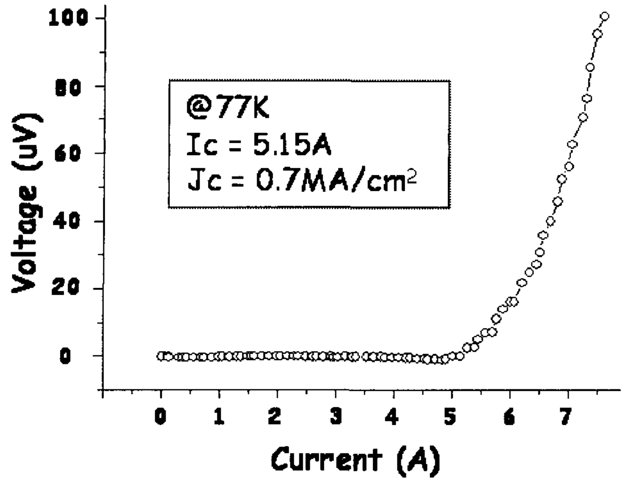

Fig. 4. The I-V curve of the YBCO coated conductor with an Y_2O_3 single buffer layer.

grown on Y_2O_3/Ni-W. The transition temperature (R=0) and J_C (77K, self field) of 250nm thick YBCO on Y_2O_3/Ni-W were 86.5K and 0.7MA/cm^2, respectively. The Tc(R=0) of 86.5K implies that the Y_2O_3 film is an efficient diffusion barrier of Ni in this coated conductor structure.

4. SUMMARY

Y_2O_3 film was pulsed laser deposited on cube textured Ni and Ni-W substrates to be used as a single buffer layer of coated conductor. Deposition of Y_2O_3 film started with reducing atmosphere followed by deposition in the base pressure of the chamber and oxygen atmosphere. The Y_2O_3 films have a strong cube texture (The full width at half maximum of the ϕ-scan of Y_2O_3 was 8.4 which was the same as that of metal substrate) and smooth crack-free microstructure. The biaxially textured YBCO films (The full width at half maximum of the ϕ-scan was 10.2) pulsed laser deposited on the Y_2O_3/metal has a Tc(R=0) of 86.5K and Jc of 700,000A/cm2 at 77K in self field. The Y_2O_3 film is an efficient diffusion barrier of Ni, and the YBCO coated conductor with a high Jc was realized with a single buffer layer.

ACKNOWLEDGMENT

This research was supported by a grant from Center for Applied Superconductivity Technology of the 21st Century Frontier R&D Program funded by the Ministry of Science and Technology, Republic of Korea.

REFERENCES

[1] D. P. Norton, A. Goyal, J. D. Budai, D. K. Christen, D. M. Kroeger, E. D. Specht, Q. He, B. Saffian, M. Paranthaman, C. E. Klabunde, D. F. Lee, B. C. Sales, and F. A. List, "Epitaxial YBa2Cu3O7 on biaxially Textured Nickel (001): An approach to superconducting tapes with high critical current density", *Science*, 274 (1996) 755.

[2] A. Goyal, D. P. Norton, J. D. Budai, M. Paranthaman, E. D. Specht, D. M. Kroeger, D. K. Christen, Q. He, B. Saffian, F. A. List, D. F. Lee, P. M. Martin, C. E. Klabunde, E. Hartfield, and V. K. Sikka, "High critical current density superconducting tapes by epitaxial deposition of YBa2Cu3Ox thick films on biaxially textured metals", *Appl. Phys. Lett.* 69 (1996) 1795.

[3] C. Park, DP Norton, DF Lee, DT Verebelyi, A Goyal, DK Christen, and JD Budai, Epitaxial yttria-stabilized zirconia on biaxially-textured (001) Ni for YBCO coated conductor, *Physica C*, 341-348 (2000) 2481.

[4] S. Sathyamurthy, M.P. Paranthaman, H.Y. Zhai, S. Kang, H.M. Christen, C. Cantoni, A. Goyal, and P. Martin, "Solution processing of Lanthanum Zirconate films as single buffer layers for high Ic YBCO coated conductors", *IEEE Transactions on Applied Superconductivity* 13[2] (2003) 2658-60.

[5] T. Aytug, M.P. Paranthaman, B.W. Kang, S. Sathyamurthy, A. Goyal, and D.K. Christen, "La0.7Sr0.3MnO3: A single, conductive-oxide buffer layer for the development of YBa2Cu3O7-d coated conductors", *Appl. Phys. Lett.* 79 (2001) 2205.

[6] M.P. Paranthaman, T. Aytug, S. Kang, R. Feenstra, J.D. Budai, D.K. Christen, P.N. Arendt, L. Stan, J.G. Groves, R.F. DePaula, S.R. Foltyn, and T.G. Holesinger, "Fabrication of high Jc YBa2Cu3O7-d tapes using the newly developed lanthanum manganate single buffer layers", *IEEE Transactions on Applied Superconductivity* 13[2] (2003) 2481.

[7] T. Aytug, M.P. Paranthaman, S. Kang, H.Y. Zhai, K.J. Leonard, C.E. Vallet, S. Sathyamurthy, H.M. Christen, A. Goyal, and D.K. Christen, "LaMnO3: a single oxide buffer layer for high Jc YBa2Cu3O7-d coated conductors", *IEEE Transactions on Applied Superconductivity* 13[2] (2003) 2661.