Journal of the Korea Institute of Applied Superconductivity and Cryogenics
Vol.8, No.4, (2006), pp.8~11

The Study of Different Buffer Structure on Ni-W Tape for SmBCO Coated Conductor

T. H. Kim [1,3], H. S. Kim [1], S. S. Oh [1], R. K. Ko [1], D. W. Ha [1], K. J. Song [1], N. J. Lee [1], J. S. Yang [1],
Y. H. Jung [2], D. J. Youm [2], K. C. Park [3]

[1] Korea Electrotechnology Research Institute, Changwon, Kyungnam 641-120, KERI
[2] Department of Physics, KAIST, Daejeon 305-701, Korea
[3] Department of Materials science and Metallurgy, Kyungpook National Univ., Daegu 702-701, Korea

tktwo@keri.re.kr

Abstract-- **High temperature superconducting coated conductor has various buffer structures on Ni-W alloy. We comparatively studied the growth conditions of a multi buffer layer (CeO_2/YSZ/CeO_2) and a single buffer layer(CeO_2) on textured Ni-W alloy tapes. XRD data showed that the qualities of in-plane and out-of-plane textures of the two type buffer structures were good. Also, we investigated the properties of SmBCO superconducting layer that was deposited on the two type buffer structure. The SmBCO superconducting properties on the single and multi buffer structure showed different critical current values and surface morphologies. FWHM of In-plane and out-of-plane textures were 7.4°, 5.0° in the top CeO2 layer of the multi-buffer layers of CeO_2/YSZ/CeO_2, and 7.3°, 5.1° in the CeO_2 single buffer layer. 1㎛-thick SmBCO superconducting layers were deposited on two type buffer layer. I_c of SmBCO deposited on single and multi buffer were 90 A/cm, 150 A/cm and corresponding J_c were 0.9 MA/cm^2, 1.5 MA/cm^2 at 77K in self-field, respectively.**

1. INTRODUCTION

Recently, developing deposition technologies of coated conductors promote their practical applications[1]. Usually textured Ni-W alloy tapes are used for the substrates of coated conductors. Since the superconducting layer can be grown at temperatures over 700℃, buffer layers are necessary as diffusion barrier between the superconducting layer and Ni-W substrate[2]. Additionally, buffer layer must have the following functions in 2G HTS. First, texture of Ni-W substrate is transferred to superconducting layer. Second, the stress induced by crystal lattice mismatch between superconducting layer and Ni-W substrate should be relaxed.

Various appropriate materials for those buffer layers were reported [3]. Among them, the well-known buffer layer is the multi oxide layer (CeO_2/YSZ/CeO_2) or single oxide layer (CeO_2). The buffer layers can be grown epitaxially on Ni-W substrate by means of the sputtering and e-beam evaporation technique. The induction thermal evaporation method using a metallic lump of Ce in W crucible is not popular for the depositions of CeO_2 films but, using this method, one can get faster deposition rate than any other deposition method.

In the thermal evaporation of Ce, It is important to prevent the metallic substrate surface from oxidation during buffer depositions. This can be easily done by thermal reactive depositions of CeO_2 films. When metallic lumps of Ce were evaporated under low pressures of water vapor, Ce reacts on the water vapor to be oxidized for CeO_2 formation and the water vapor was decomposed H_2 gas [4].

In this study, we reported the results of the comparative studies on the growth textures, roughness, morphologies, and superconducting properties for single and multi-buffer films.

2. EXPERIMENT

We used biaxially textured Ni-W alloy substrates which were manufactured and supplied by EVICO with a size of 80㎛-thick, 10mm-width, deposited by reel to reel system. In the CeO_2/YSZ/CeO_2 structure, the top and bottom CeO_2 layers were deposited by induction thermal evaporation method, while the YSZ film was deposited by DC reactive sputtering technique which was shown in Fig. 1.

In the CeO_2 single buffer architecture, the film was deposited by induction thermal evaporation.

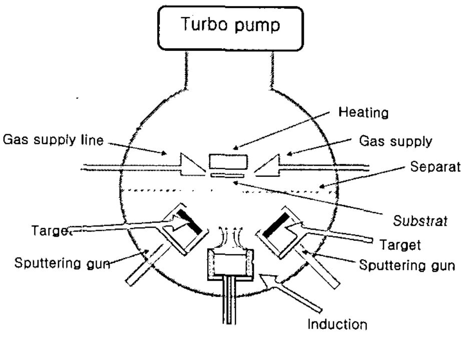


Fig. 1. Schematic layout of buffer films deposition chamber.

SmBCO superconducting layers were deposited on the two type buffer layers using batch type co-evaporation process as evaporation using drum in dual chambers (EDDC) in shown Fig. 2.

To study the crystalline alignment of the substrate, buffer layers and superconducting film, XRD θ-2 θ scans, ø-scans, ω-scans were conducted to examine the texture of samples. A digital instruments atomic force microscope (AFM) and SEM were used to more fully characterize the surface roughness and morphologies of buffer layers. Electrical properties characterizations of the sample were done using a standard four-probe technique with 1μV /cm criterion to determine the critical current (I_c) as well as the transition temperature (T_c).

Prior to deposition, substrate were heated 800℃ in 200mTorr atmosphere of forming gas, Ar+10%H_2 gas mixture, to deoxidize the native NiO layer on the surface of the Ni-W alloy substrate, and prevent its oxidation.

The reducing atmosphere was followed by pumping to the base pressure of the system which was ~1 x 10^{-6}Torr, and then the seed layer of CeO_2 films was deposited by induction thermal evaporation. The film was deposited with the deposition condition of the substrate temperature of 700°C, water vapor pressure of 6 x 10^{-5}Torr, and deposition rate of 6 Å /second. Second YSZ film was deposited with the deposition condition of the substrate temperature of 800°C, water vapor pressure of 1mTorr, Ar gas pressure of 4mTorr and deposition rate of 3 Å/second. In the last process, a cap layer of CeO_2 films was deposited with the deposition condition of the substrate temperature of 700℃, oxygen pressure of 3 x 10^{-5}Torr and deposition rate of 5 Å/second. The single buffer layer of CeO_2 films was deposited with the same deposition condition of the seed layer of multi-buffer layer.

SmBCO superconducting films were deposited using the batch type co-evaporation process (EDDC) method. Schematic diagram is shown in Fig. 2 The horizontal drum sample holder tightly was rotated by 45RPM in a reaction chamber filled with 3 x 10^{-3}Torr oxygen gas.

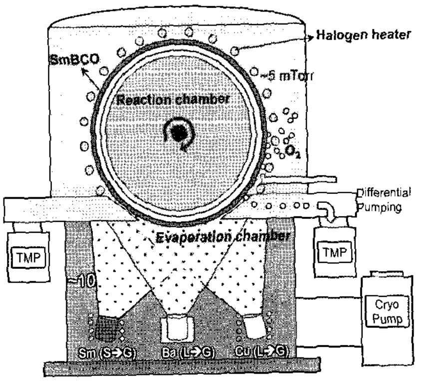


Fig. 2. Schematic layout of superconducting films deposition EDDC chamber.

The reaction chamber was connected to an evaporation chamber though an opening. The vapors of co-evaporated Sm, Ba, Cu were supplied through the opening deposition area and deposited on the tape. The vacuum in the evaporation chamber was less than 5 x 10^{-5}Torr, which was due to effectively blocking the oxygen gas leak by the narrow gap between the drum type sample holder and the opening frame, and differential pumping. The temperature of the tape during deposition was 700℃. To adjust the compositional ratios of Sm:Ba:Cu, we regulated the deposition rates of each element by QCM(quartz crystal microbalance).

3. RESLUTS AND DISCUSSION

Fig. 3 shows θ-2θ scans for SmBCO/CeO_2films and SmBCO/ CeO_2/YSZ/CeO_2films deposited on textured Ni-W substrate. X-ray θ-2θ scans on the intermediate buffer layers of single CeO_2 and CeO_2/YSZ/CeO_2films architecture showed sharp (00L) peaks indicating excellent c-axis texture in the buffer layers which was carried over to the superconducting SmBCO layer.

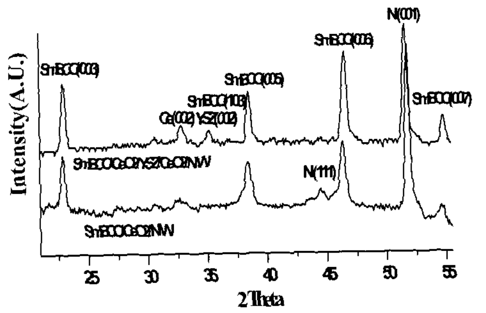


Fig. 3. Typical θ-2θ scans for SmBCO/CeO_2 films and SmBCO/CeO_2/YSZ/CeO_2 films deposited on textured Ni-W substrate.

In Fig. 4, XRD ø-scans, ω-scans of SmBCO/CeO_2films and SmBCO/CeO_2/YSZ/CeO_2 films were conducted to examine the texture of samples.

The ø-scans and ω-scans of Ni-W substrate, single CeO_2films, multi CeO_2films were 7.5°/5.3°, 7.3°/5.1°, and 7.2°/5.0° respectively. Fig. 5 shows the I_c and T_c plots of the SmBCO films with thickness of 1μm. In this case, the deposition rate was about 16nm/min. The critical current of the two type samples were 45A, 75A which is equivalent to a J_c of 0.9 MA/cm^{-2}, 1.5 MA/cm^{-2} at 77K and self-field. The critical temperatures of both samples showed the same value of 91K.

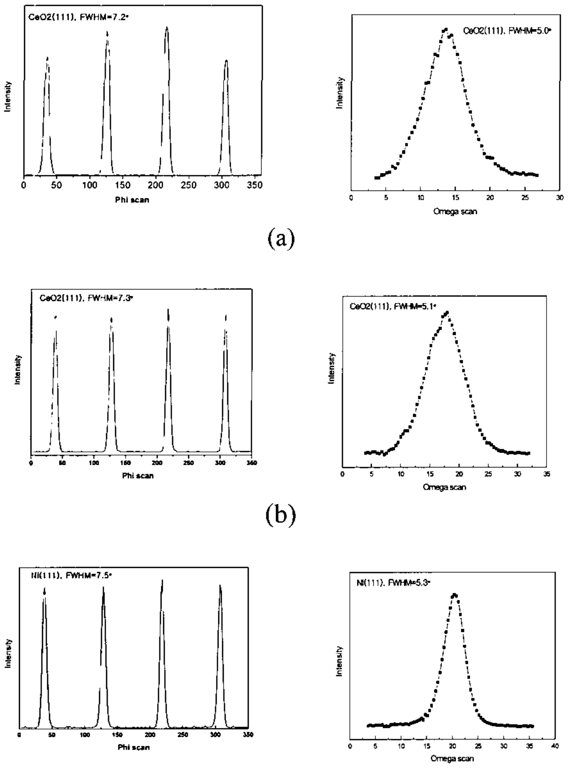
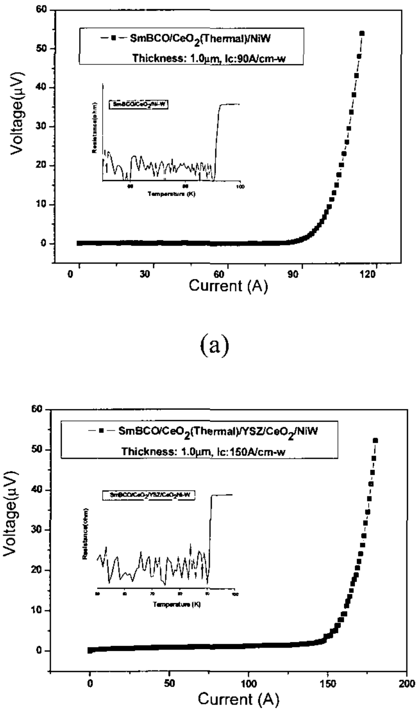


Fig. 4. XRD ø-scans, ω-scans (a) multi-buffer (b) single buffer (c) Ni-W substrate of SmBCO/CeO_2films and SmBCO/CeO_2/YSZ/CeO_2 films.

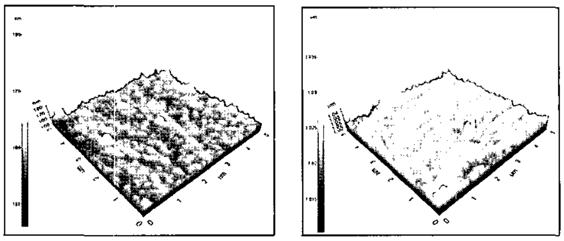


(a)

(b)

Fig. 5. The I_c and T_c measurements SmBCO films of (a) single buffer (b) multi-buffer deposited on textured Ni-W substrate.

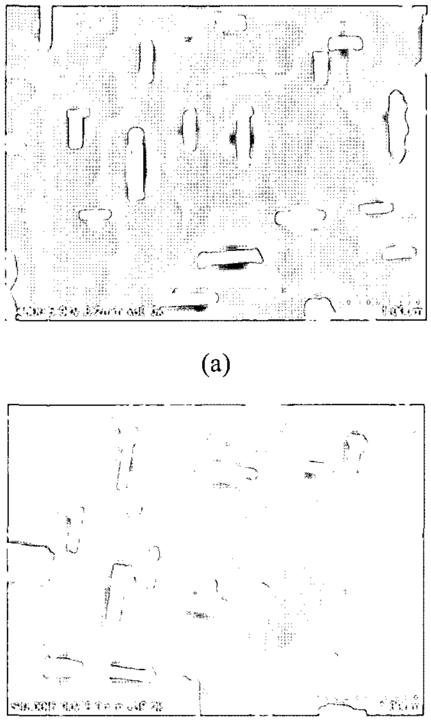
The surface morphology and roughness was investigated by AFM. Fig. 6 is the AFM image of CeO_2 film on top of the buffer layers. The AFM scan on single buffer and multi-buffer gave a root-mean-square roughness (RMS) of about 8.5nm, 6.2nm over a 5㎛ X 5㎛ area. This indicated that single buffer is rougher than multi-buffer. In multi-buffer case, the roughness of an intermediate YSZ film was less than that of single CeO_2film. Generally the surface roughness of sputter method is better than that of thermal evaporation method.



(a) (b)

Fig. 6. AFM images showing the CeO_2 films surface morphology and roughness of (a) single buffer (b) multi-buffer deposited on textured Ni-W substrate.

Fig. 7 shows the SEM surface image of SmBCO films on single and multi-buffer films. There is flat precipitate within the films. The size of this precipitate was about 0.5㎛. This precipitate was identified as crystallized Cu_2O [5]. The SmBCO film on multi-buffer was denser than that of SmBCO film on single buffer.



(a)

(b)

Fig. 7. SEM images of SmBCO films surface morphologies (a) single buffer (b) multi-buffer deposited on textured Ni-W substrate.

4. SUMMARY AND CONCLUSION

We comparatively studied the deposition properties of the single and multi buffer on the textured Ni-W substrate.

Single CeO_2 buffer film and multi $CeO_2/YSZ/CeO_2$ buffer film showed sharp (00L) peaks in XRD-2θ measurement indicating excellent c-axis texturing which was transferred to the superconducting SmBCO layer. The critical current (I_c) of SmBCO superconducting films was 45A, 75A at liquid nitrogen temperature which is equivalent to a J_c of $0.9MA/cm^{-2}$, $1.5MA/cm^{-2}$ at 77K and self-field. The T_c of the samples was 91K. The superconducting properties of SmBCO film on multi-buffer architecture were better than that of SmBCO film on single buffer architecture. But CeO_2 single buffer layer architecture is a promising candidate for the fabrication of SmBCO coated conductor.

ACKNOWLED GMENT

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] Nicolas Martin, Christophe Rousselot, "Use of a theoretical model to investigate RF and DC reactive sputtering of titanium and chromium oxide coatings", Surface and Coatings Technology, Vol. 110, pp.158, 1998.

[2] T.J Jackson,B.A.Glowacki, J.E.Evetts, "Oxidation thermodynamics of metal substrates during the deposition of buffer layer oxides", Physica C, Vol. 296, pp.215, 1998.

[3] X. Cui, F.A.List, D.M. Kroeger, A. Goyal, D.F. Lee, J.E. Mathis, "Continuous growth of epitaxial CeO_2 buffer layers on rolled Ni tapes by electron beam evaporation" Physica C, Vol 316, pp.27-33 1999.

[4] K. Sudoh, Y. Yoshida, Y. Takai, "Effect of deposition conditions and solid solution on the $Sm_{1+\chi}Ba_{2-\chi}Cu_3O_{6+\delta}$ thin films prepared by plused laser deposition" Physica C, Vol 384, pp.178-184, 2003.

[5] S.Lim, H. Kim, K. Chungm B. Lee, D. Youm, "Comparative studies on the growth conditions of CeO_2 and Y_2O_3 buffer layers on NiW tapes" Physica C, Vol 384, pp.178-184, 2003.