산화물 전구체 MOD공정에 의한 YBCO coated conductor 제조

Fabrication of YBCO coated conductor using oxide precursor-based MOD processing

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Abstract: MOD process using metal acetates or trifluoroacetates has been considered to be a strong candidate for a low cost fabrication process for coated conductor with high J_c. Recently, an economical MOD process has been developed for coated conductor with high I_c using low cost starting materials such as YBCO powders. YBCO thin films prepared by single coating on LAO substrate with this modified oxide-precursor solution gives transport I_c of 100A/cm-w and the J_c value of 2.9MA/cm^2 (77K, Self-field). The YBCO coated conductor prepared by single coating with CeO_2/IBAD-YSZ/SS tape gives transport I_c of 50A/cm-w in 2cm. Characterization with XRD, SEM shows that the YBCO layers were epitaxially grown and exhibit well-developed dense micro-structures. This newly developed oxide-precursor based MOD process will provide a low cost route to coated conductor with high J_c.

Key Words: MOD, YBCO, YBCO powder.

1. Introduction

The $YBa_2Cu_3O_{7-x}$ (YBCO)-based coated conductor is promising high temperature superconducting (HTSC) wire architectures for electrical devices[1]. Many efforts are in progress to develop long HTSC wire with high current carrying capacity by coated conductor architecture[1-3]. Among them, metal-organic deposition using trifluoroacetates (MOD-TFA) is attracting more interest because of its potential for scale-up and cost-effectiveness. MOD-TFA is chemical solution deposition process which is intrinsically non-vacuum approach and YBCO thin films with relatively high J_c (>1MA/cm^2) can be routinely fabricated by this process[4-7].

One of the most important issue in the fabrication of YBCO coated conductor with MOD-TFA process is the synthesis of MOD precursor solution. Precursor solution for MOD-TFA process is prepared by dissolution of metal-organic salts into aqueous solution of trifluoroacetic acid (TFA) followed by subsequent distillation to remove residual impurities and dilution with methanol. Since, however, the conventional MOD-TFA processing requires relatively expensive metal acetates or trifluoroacetates as starting precursors, more economical processing can be realized by substitution of cost-effective precursors.

In this study, we discuss the results obtained on processing of YBCO coated conductor by MOD process using low cost precursor materials. Instead of metal acetates, YBCO oxide powders are employed as starting precursors for MOD processing of YBCO thin films. Using YBCO oxide powders as precursor for MOD solution enables cost-effective processing and easy control of composition[8]. YBCO thin films were deposited on single crystal substrate using oxide-based precursor solution and analysis of microstructure and electrical property were performed. In order to show the applicability of oxide-precursor-based MOD solution in processing of YBCO coated conductor, a short sample of YBCO coated conductor was fabricated by deposition on a CeO_2/IBAD-YSZ/SS flexible tape.

2. Experimental

YBCO powders were employed as starting precursor for MOD processing of YBCO thin films. YBCO powders were dissolved in aqueous solution of TFA (trifluoroacetic acid) and refluxed for a few hours and the mixed aqueous solution of YBCO powders and TFA was distilled to remove residual impurities such as acetic acid, water, etc. Distilled residue appeared to be blue gel and dried gel was diluted with methanol and filtered to produce final coating solution.

(100)-oriented $LaAlO_3$ single crystals(LAO, 10mmx3.9mm) and CeO_2/IBAD-YSZ/SS flexible tape (IBAD tape, 20mmx4mm) were used as substrates for film growth. All substrates used in this study were cleaned with isopropanol and deionized water.

YBCO gel films were deposited by dip coating and dried on hot plates. Dried gel films were calcined at the optimized temperature and

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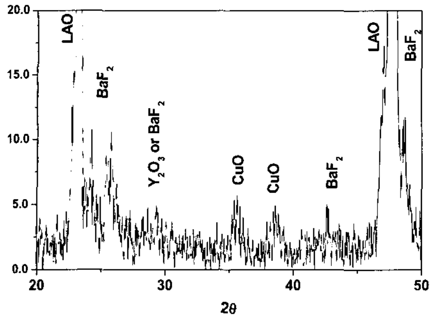

Fig. 1. X-ray diffraction result of calcined precursor film prepared by oxide-based precursor solution.

atmospheres. Annealing of calcined precursor films was performed in wet Ar/O_2 atmosphere to convert oxyfluoride to YBCO. The partial pressure of water in annealing atmosphere was set to 6.2%. Ag layer was deposited on YBCO surface by RF magnetron sputtering (KERI). Texture and microstructure of grown YBCO thin films are characterized with XRD, SEM, Raman spectroscopy, etc. Critical current was measured with conventional 4-probe method (77K, Self field)

3. Results and discussion

3.1. Fabrication of YBCO thin films on LAO substrates

MOD precursor solution prepared with YBCO powders shows good adhesion to substrates. As shown in Fig. 1, X-ray diffraction profile of the same film after calcination shows broad reflections and indicates existence of BaF_2, CuO or Y_2O_3 (Fig. 1(b)). These broad reflections indicate nanocrystalline nature of the calcined film. Existence of BaF_2, CuO or Y_2O_3 and nanocrystalline features of calcined film prepared by this oxide-based MOD solution is consistent with calcined film prepared by conventional MOD-TFA using metal acetates as starting precursors[9].

Fig. 2 shows microstructures of YBCO films single coated using oxide-based MOD solution on LAO substrates. Microstructure of YBCO film annealed at 750°C contains a large number of pores and shows sparse distribution of grains(Fig. 2(a)). However, YBCO annealed at 790°C shows dense microstructures and contains only small number of pores(Fig. 2(c)). In addition, grain linkage of YBCO was improved by annealing at high temperature. Cross-sectional observation shows 340nm-thick & dense YBCO film can be obtained after annealing at 790°C. However, further experiments are in progress to optimize annealing conditions. In this study, fabrication of YBCO film with dense microstructure is realized by this oxide-precursor-based MOD process.

Fig. 3 shows crystal texture of YBCO thin film deposited on LAO substrates. Only YBCO (00l) reflections are observed and not any trace of secondary phases are detectable in 2Θ-Θ scan profile.

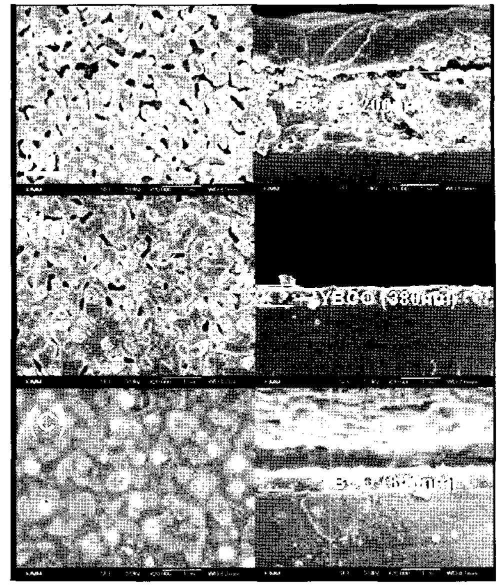

Fig. 2. Surface and cross-sectional view of YBCO thin film annealed at different temperature (a) 750°C, (b) 770°C, (c) 790°C.

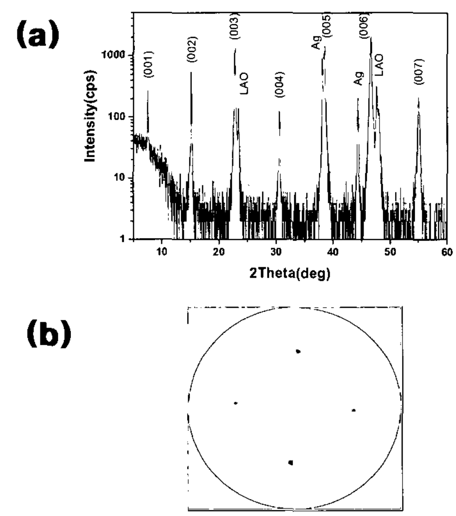

Fig. 3. X-ray diffraction profiles for the YBCO thin film annealed at 790°C. (a) 2Θ-Θ scan, (b) YBCO (102) pole figure.

In addition, existence of four discrete contours spaced by phi-angle of 90° in YBCO (102) pole figure indicates biaxial texture (Fig. 3(b)).

Fig. 4 shows the critical current value of YBCO thin film annealed at 790°C. YBCO thin film annealed at 790°C shows high Ic and Jc (I_c~100A/cm-w, J_c~2.9MA/cm^2). High Jc value of the YBCO thin film annealed at 790°C is consistent with dense and pore-free microstructure of same specimen as shown in Fig. 2. Thus, it is shown that YBCO film with good electrical property can be fabricated using oxide-based MOD process by single coating. Detailed analyses on the effect of annealing conditions are in progress to optimize processing parameters.

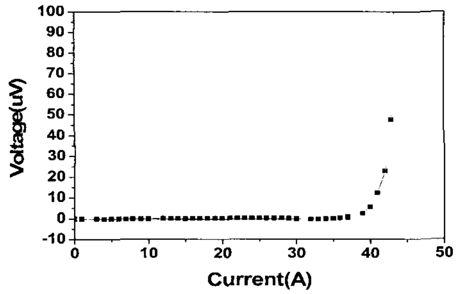

Fig. 4. I-V measurement for YBCO thin film annealed at 790°C.

3.2. Fabrication of the YBCO coated conductor on CeO_2/IBAD-YSZ/SS tape

As a trial to show feasibility of this oxide-precursor-based MOD process in the fabrication of YBCO coated conductor, YBCO coated conductor was prepared by oxide-based MOD precursor solution using 4mm-wide IBAD-templated flexible substrate (CeO_2/IBAD-YSZ/SS) after subsequent annealing at 790°C. Fig. 5(a) shows X-ray 2Θ-Θ diffraction profile of fully processed YBCO coated conductor using IBAD-templated tape. YBCO (00*l*) reflectionsare dominantly observed in the diffraction profile. In particular, trace of $BaCeO_3$ is detectable in the diffractogram. It is known that $BaCeO_3$ is usually formed at the interface between YBCO and CeO_2, but did not significantly deteriorate critical current density fatally[10]. Surface morphology of YBCO layer shows good grain linkage and existence of pores (Fig. 5(b)). Thickness of the YBCO layer was estimated to be 500nm from SEM photos.

Measured critical current is 50A/cm-w and Jc value estimated to be $1MA/cm^2$ (Fig. 6). In this study, it is shown that oxide-based MOD process can be applied to fabrication of YBCO coated conductor.

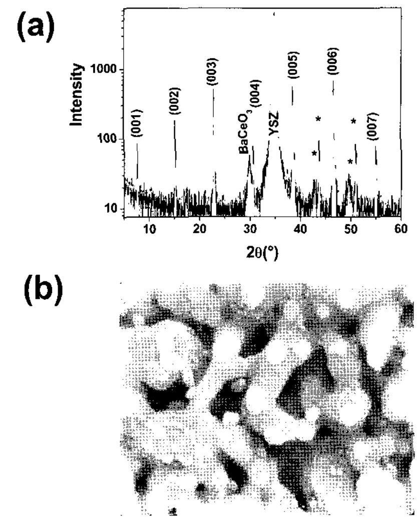

Fig. 5. (a) XRD profile and (b) microstructure of a YBCO layer deposited on IBAD tape and annealed at 790°C.(Asterisks{*} in XRD profile indicate reflections from the subsrate.)

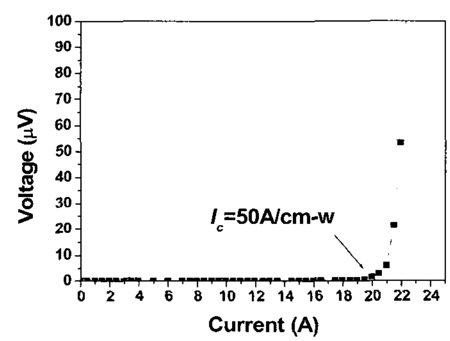

Fig. 6. I-V measurement for YBCO coated conductor annealed at 790°C.

4. Conclusions

In summary, YBCO thin film with high I_c has been successfully fabricated using oxide-based MOD process with single coating. It is shown that YBCO thin film with dense microstructure and high J_c (I_c~100A/cm-w, J_c~$2.9MA/cm^2$) can be fabricated by cost-effective "oxide-precursor-based MOD solution". Fabricated YBCO thin film shows well-developed biaxial texture and microstructure. A short sample of YBCO coated conductor was fabricated using IBAD-templated tape to show the feasibility of this oxide-precursor-based MOD process for fabrication of YBCO coated conductor. Although fully processed YBCO coated conductor contains small amount of $BaCeO_3$ phase, it shows good electrical property (I_c~50A/cm-w, J_c~$1MA/cm^2$). MOD process using oxide-precursor-based solution will provide a low cost route for fabricating YBCO coated conductor with high J_c.

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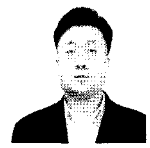

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