사파이어 기판 위에 펄스-증착법으로 성장한 YBCO/CeO2 박막의 초전도성과 표면 모폴러지

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Superconductivity and Surface Morphology of YBCO/CeO2 Thin Films on Sapphire Substrate by Pulsed Laser Deposition

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Abstract - The crystal structure and properties of $YBa_2Cu_3O_{7-x}$(YBCO) and CeO_2 thin films deposited on *r*-plane (1$\bar{1}$02) sapphire substrate by pulsed- laser deposition(PLD) have been in- vestigated. C-axis oriented epitaxial YBCO thin films with critical temper- ature (*Tc*) of 88 K were routinely grown on (200) oriented CeO_2 buffer layers with thickness in the range between 20 to 80 nm. When the thick -ness of the (200)oriented CeO_2 buffer layer increases over than 80 nm, the superconducting properties of YBCO thin films on that were deteriorated. The decrease in *Tc* of YBCO thin films was explained by the microcrack for- mation in CeO_2 buffer layer. These results indicate that the thickness of the (200) oriented CeO_2 buffer layer is critical to the epitaxial YBCO thin film growth on *r*-plane(1$\bar{1}$02) sapphire substrate.

1. INTRODUCTION

Owing to the good crystalline per- fection, mechanical strength, low die- lectric constant and losses, *r*-plane (1012) sapphire substrate is recog- nized as a very promising for the deposition of epitaxial YBCO films for microwave device applications.

However, due to the large lattice mismatch between YBCO and sapphire and the diffusion of Al atoms from sapphire into YBCO during film depo- sition conditions, buffer layers such as $SrTiO_3$[1], YSZ[2], CeO_2[3] are used to overcome these problems. Among them, CeO_2 is recognized as a desired buffer layer for the epitaxial growth of superconducting YBCO thin films on sapphire substrate[4-8]. Most previous studies centered on the epitaxial growth of CeO_2 thin films on various substrates by using different deposi- tion technique. In addition, the relati- onship between the thin film proper- ties of CeO_2 buffer layer and superco- nducting properties of YBCO thin film has not been investigated in detail.

In this study, we report on the growth of (200) oriented CeO_2 buffer layers and YBCO thin films on r-plane (1012) sapphire substrate. By optimi- zing the (200) oriented CeO_2 film growth, YBCO thin films with high quality c-axis orientation could be deposited on r-cut plane(1012) of sap- phire substrate by pulsed laser depo- sition

2. EXPERIMENTAL PROCEDURE

Both the CeO_2 and YBCO thin films were deposited on *r*-plane (1$\bar{1}$02) sapphire substrate by pulsed laser deposition technique. The 248 nm out- put from a KrF excimer laser of 3 J/cm^2 was focused onto the rotating target at an incident angle of 45^o and a repetition rate of 5 Hz. During the CeO_2 buffer layer deposition, substrate temperature was fixed at 750 ^oC and oxygen pressure was maintained at 180 mTorr. The detailed YBCO thin film growth conditions are described elsewhere[9,10]. The structure of the as-grown YBCO thin films was exa- mined by X-ray diffractometer (XRD) with *CuKa* radiation. Surface morpho- logies were observed by scanning electron microscopy (SEM). Resistance -temperature(R-T) characteristics were measured by a conventional four-probe method.

3. RESULTS AND DISCUSSION

The crystalline orientation of CeO_2 thin films was strongly affected by the deposition temperatures. Figure 1 sho- ws the XRD patterns for the 300 nm thick CeO_2 thin films deposited at various deposition temperatures. For the case of CeO_2 thin films deposited above 750°C, only the CeO_2(200) peak was dominant. However, with decreas- ing the deposition temperature into 750°C, the CeO_2 (111) peak was obse- rved in addition to CeO_2 (200) peak.

At 650°C deposition temperatures, the CeO_2 (111) was dominant. From these results, in order to use as a buffer layer for the YBCO thin film growth on sapphire substrate, we fixed the growth temperature of CeO_2 buffer layer to 750°C.

The superconductivity of YBCO thin films with 430 nm thick was de- pended significantly on the thickness of the (200) oriented CeO_2 buffer layer. Influence of the (200) oriented CeO_2 buffer layer thickness on T_c of YBCO thin film is shown in Fig. 2. The T_c of the YBCO thin film directly deposited on a sapphire substrate was 63 K. When the (200) oriented CeO_2 buffer layer thickness is in the range of 20 to 80 nm, YBCO thin films with a T_c of about 88K are obtained repro- ducibly. For the thickness of the (200) oriented CeO_2 buffer layer incre- ases over 80 nm, YBCO thin films showed a T_c of 83 K. From these results, it is considered that the effective thickness of CeO_2 as buffer layers for YBCO thin film growth on sapphire substrate are 20 to 80 nm.

Figure 3 shows the SEM images of YBCO thin films deposited on (200) oriented CeO_2 buffer layer with thick- ness in the range from 0 to 450 nm. YBCO thin films deposited directly on sapphire substrate show the surface morphology composed of large-island shape grains with a low connectivity, high density of grain boundaries and pores. As the (200) oriented CeO_2 buffer layer thickness increases from 0 to 160 nm, YBCO thin films have a smooth surface and the pore size decreased. However, when the (200) CeO_2 oriented buffer layer thickness increases near to 450 nm, YBCO thin film has a surface morphology with high density of grain boundaries, micro-size pores, and microcracks. In order to explain the porous surface morphology of YBCO thin film depo- sited on (200) oriented CeO_2 buffer layers with 450 nm thickness, we examined the CeO_2 surface morpho- logies with various thicknesses.

As shown in Fig. 4, The (200) ori- ented CeO_2 buffer layers with a thick- ness below 80 nm have a smooth surface. However, as the thickness of the CeO_2 buffer layer increases to 160 nm, microcracks were observed. These microcracks could be seen clearly in the (200) oriented CeO_2 buffer layer with 450 nm thickness. These micro- cracks seem to be originated from the mismatch of lattice constants and the thermal expansion coefficients of sapp- hire, CeO_2 and YBCO[11]. From these results, we could understand that the porous surface morphology and low T_c values of YBCO thin film deposited on (200) oriented CeO_2 buffer layers with 450 nm thickness are due to the microcrack formation in (200) oriented CeO_2 buffer layer.

4. CONCLUSIONS

We have investigated the influence of the CeO_2 buffer layer thickness on the superconducting and microstruc- ture properties of YBCO thin films on *r*-plane $(1\bar{1}02)$ sapphire substrates de- posited by PLD technique. The (200) oriented CeO_2 buffer layer growth was notable for the deposition temperature above 750°C. The (200) oriented CeO_2 buffer layers deposited below 80 nm thickness showed smooth surface mor- phology. However, the (200) oriented CeO_2 buffer layer with 450 nm thick- ness showed rough surface morphology composed of rectangular shape grains with microcracks.

High quality c-axis oriented YBCO thin film with T_c of 88K and a smooth surface were routinely obtained on (200) oriented CeO_2 buffer layer with a thickness in the range between 10 to 80 nm. When the thickness of the (200) oriented CeO_2 buffer layer incre- ases over than 80 nm, the supercond- ucting properties of YBCO thin films were deteriorated. These results were considered due to the microcrack form- ation in YBCO and CeO_2 buffer layer films. As a results of the investiga- tion, it was found that (200) oriented CeO_2 buffer layer deposited at 750°C with a thickness of about 40 nm is best buffer layer conditions for YBCO thin film growth on *r*-plane $(1\bar{1}02)$ sapphire substrate.

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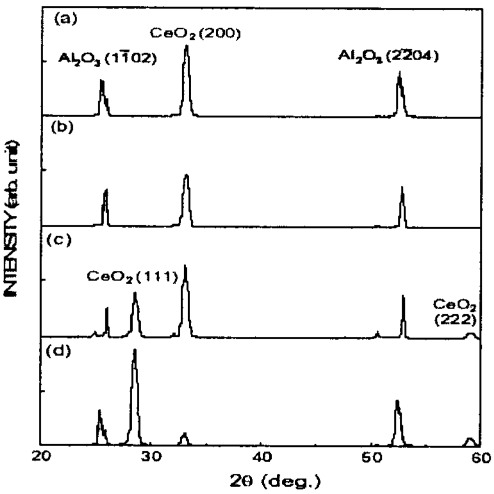

Fig. 1. X-ray diffraction patterns for the CeO2 buffer layers deposited at various deposition temeratures of (a)800oC, (b)750oC, (c)700oC, and (d)650 oC.

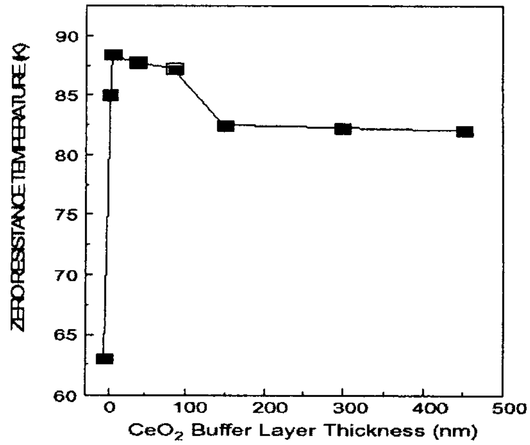

Fig. 2. Resistance vs. temperature characteristics of YBCO thin films deposited at 750oC with different as a function of the (200)oriented CeO2 buffer layer thickness.

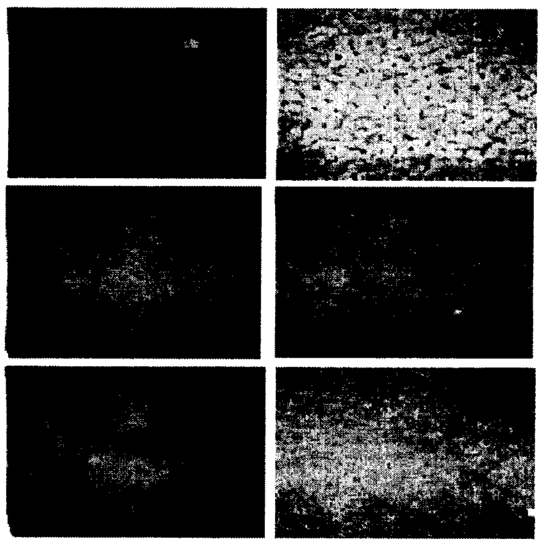

Fig. 3. Scanning electron micrographs for YBCO thin films deposited on the (200) oriented CeO2 buffer layer of (a) 0 nm, (b) 10 nm, (c) 40 nm, (d) 80 nm, (e) 160 nm, and (f) 450 nm.

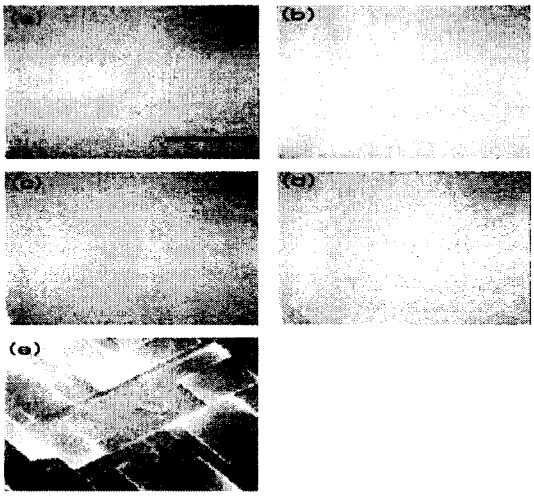

Fig. 4. Scanning electron micrographs for the (200) oriented CeO2 buffer layers deposited at 750oC with differ- ent thickness of (a)20 nm, (b)40 nm, (c)80 nm, (d)160 nm, and (e)450 nm.