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Preparation and characterization of $NdBa_2Cu_3O_{7-\delta}$ thin films on MgO substrates with Ba_2NdTaO_6 buffer layers

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We have prepared *c*-axis $NdBa_2Cu_3O_{7-\delta}$ (NBCO) thin films on (100) MgO substrates with Ba_2NdTaO_6 (BNTO) dielectric buffer layers by a pulsed laser deposition (PLD) method. Use of BNTO buffer layer enables cube-on-cube growth of NBCO on MgO without 45° -tilt grain boundaries, which was confirmed by XRD ϕ -scan measurement. NBCO/BNTO//MgO multilayer films reproducibly exhibited a critical temperature (T_c) of 91 K and a critical current density (J_c) at 77 K of 4.5 MA/cm^2. We have also measured the surface resistance (R_s) of the NBCO films at 38 GHz by a dielectric resonator method. The R_s value scaled to 10 GHz was 0.5 mΩ at 77 K. These results indicate that BNTO is a promising buffer layer between NBCO and MgO.

Key words: BNTO, NBCO, MgO, J_c, R_s

1.Introduction

Since the first discovery of high temperature superconductors [1], $YBa_2Cu_3O_{7-\delta}$ (YBCO) has been mainly used for various electronic device applications. $NdBa_2Cu_3O_{7-\delta}$ (NBCO) supercond -uctors have higher critical temperature (T_c) of 96 K and better surface morphology than those of YBCO [2-3]. Microwave device applications of this material would provide improved properties such as a lower surface resistance (R_s) at 77 K. We have tried to fabricate high quality NBCO thin films with the aim of microwave application. For the growth of high quality thin films, the choice of substrate is important. $SrTiO_3$ (STO) substrates have advantages such as good lattice matching and the perovskite structure similar to NBCO. It was reported that NBCO thin films on STO substrates had good crystallinity and an excellent flat surface [4]. However STO has high dielectric constant and loss tangent values, which restricts use as a substrate for microwave applications [5-6]. On the other hand, MgO is suitable for microwave devices because of its low dielectric constant and loss tangent values. NBCO films on the MgO substrates exhibited a degraded T_c and contained 45 ° in-plane misaligned grains[7]. It was also reported that an intermediate layer of barium salt was created at the interface between the NBCO and MgO [8]. Moreover, there is large between NBCO and MgO lattice mismatch (~7%). As one of the methods of solving these problems, we decided to use a buffer layer between MgO and NBCO superconductor. In this paper, we report the preparation and properties of NBCO thin films with BNTO as buffer layers on MgO substrates. BNTO has a perovskite structure and has moderate dielectric characteristic [9]. BNTO was found to have excellent chemical compatibility with NBCO superconductor [10]. Our results on the preparation and characterization of NBCO films on BNTO buffered MgO substrates are discussed in detail.

2.Experimental

In the present study, all films were prepared by a pulsed laser deposition (PLD) method using a Lambda Physik (compelx 201) KrF 248 nm excimer laser. Stoichiometric sintered targets of NBCO and BNTO were used for deposition of their films by PLD. First, the deposition chamber was pumped to a base pressure of 10^{-6} Torr, and then oxygen was introduced into the chamber before deposition. The deposition temperature was changed from 730 ℃ to 810 ℃. Other detailed deposition parameters are listed in Table Ⅰ. After the deposition, 700 Torr oxygen was introduced and the films were cooled to room temperature.

The crystal structures of the NBCO and BNTO films were examined by X-ray diffraction (XRD). The T_c and the J_c of the NBCO films, which were patterned by photolithography and argon ion milling method, were measured by a four-probe method. Though the size of the NBCO films was small, exact R_s of the NBCO films was measured using a 38 GHz sapphire dielectric resonator [11].

3.Results and Discussions

Fig.1 shows typical θ -2 θ XRD pattern of an NBCO thin film grown on a BNTO buffered MgO substrate. Only peaks of MgO substrate and peaks from (00*l*) reflections of NBCO are observed. This indicates that both BNTO and NBCO films have their *c*-axis perpendicular on the MgO substrate. In-plane alignment of the NBCO film grown on BNTO buffered MgO substrate was examined by XRD ϕ -scan measurements of (*a*) (103) reflection from NBCO, (*b*) (220) reflection from BNTO and (*c*) (101) reflection from MgO. The result is shown in Fig.2. All located the peaks of MgO, BNTO, and NBCO are at the same positions, and these diffraction peaks appear every 90° . These results show that both a BNTO and NBCO films have structures with cube-on-cube growth on the MgO substrate. Fig.3 shows the ϕ -scan XRD patterns of (*a*) (103) reflection from NBCO and (*b*) (101) reflection from MgO for the NBCO thin film on the MgO substrate without the BNTO buffer layer. Fig.3 clearly shows presence of 45° in-plane rotated grains. From the above results, it is found that the 45° in-plane misalignment of grains seen for films grown on MgO can be eliminated by using BNTO as a buffer layer on MgO.

Fig.4 shows the deposition temperature dependence of T_c for NBCO thin films grown on BNTO buffered MgO substrates, and the inset shows typical temperature dependence of resistance for an exceed NBCO thin films grown at 790 ℃ . T_c of the NBCO thin films exceeds 91K for all the deposition temperatures

Table Ⅰ. Deposition parameters used for *in situ* growth of BNTO and NBCO films on (100) MgO substrates by PLD.

	BNTO	NBCO
Deposition temperature (℃)	800	730~810
Oxygen pressure (mTorr)	200	250
Substrate-target distance (mm)	50	56
Laser pulse repetition rate (Hz)	10	5
Laser energy density (J/cm^2)	1.4	2.4
Film thickness (nm)	10	200
Deposition rate (nm/min)	10	7.5

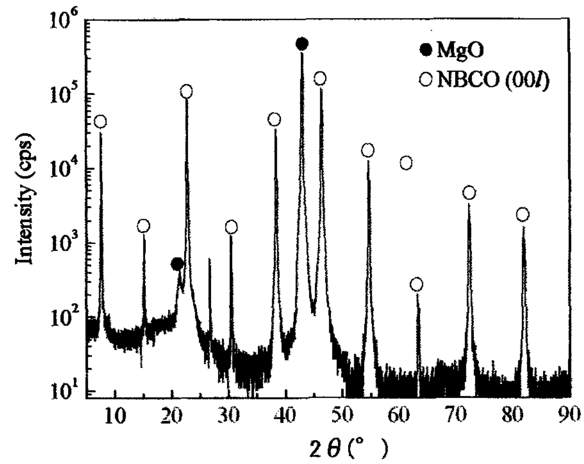

Fig.1 Typical θ -2 θ XRD pattern of an NBCO thin film grown on a BNTO buffered MgO substrate by PLD.

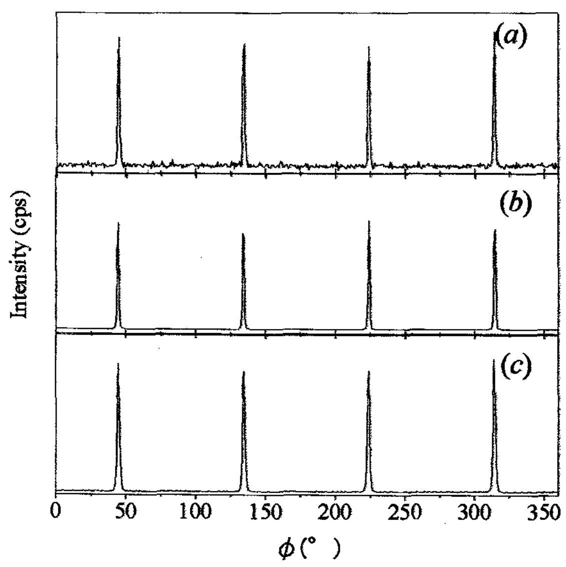

Fig.2 ϕ -scan XRD patterns of (*a*) (103) reflection from NBCO, (*b*) (220) reflection from BNTO and (*c*) (101) reflection from MgO for an NBCO thin film grown on a BNTO buffered MgO substrate by PLD.

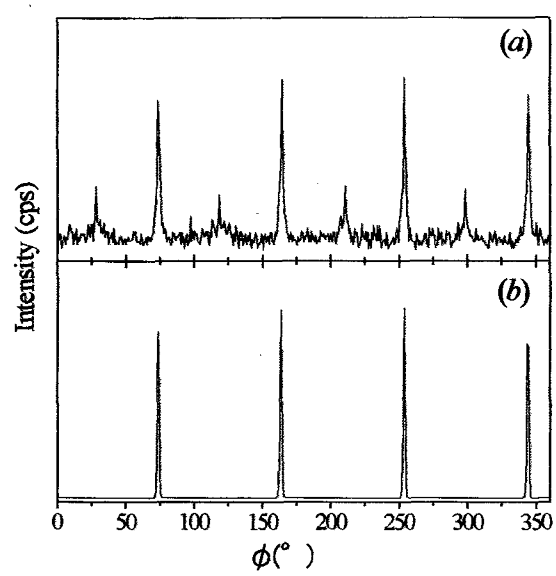

Fig.3 ϕ -scan XRD patterns of (*a*) (103) reflection from NBCO and (*b*) (101) reflection from MgO for an NBCO thin film on MgO substrate without a buffer layer of BNTO by PLD.

examined, and this result is sufficiently reproducible

Fig.5 shows the deposition temperature dependence of J_c at 77 K for NBCO thin films grown on BNTO buffered MgO substrates, and the inset shows a temperature dependence of J_c for the NBCO thin film deposited at 790 ℃. As the deposition temperature is raised, J_c of the NBCO thin film increase. This is probable, because connection of grains of NBCO becomes strong by raising the deposition temperature. The J_c value of the NBCO thin films deposited at 790 ℃ is higher than 4.5 MA/cm^2 at 77 K.

Fig.6 shows the temperature dependence of R_s for a NBCO thin film grown on a BNTO buffered MgO substrate. The R_s value at 38GHz was 7 mΩ at 77 K. The R_s value scaled to 10 GHz was 0.5 mΩ at 77 K. Even when we made a film thickness of the BNTO buffer layer as this as, we succeeded in obtaining NBCO thin films of equivalent quality.

4. Conclusions

By using Ba_2NdTaO_6 buffer layers on MgO substrates, *c*-axis $NdBa_2Cu_3O_{7-\delta}$ thin films with cube-on-cube growth of NBCO on MgO and without 45° -tilt grain boundaries, have been successfully obtained by PLD. $NdBa_2Cu_3O_{7-\delta}$ thin films on MgO substrates with Ba_2NdTaO_6 dielectric buffer layers reproducibly exhibited a T_c of 91 K and a J_c at 77 K of 4.5 MA/cm^2. We have also measured the R_s of the NBCO film at 38 GHz by a dielectric resonator method. The R_s value scaled to 10 GHz was 0.5 mΩ at 77 K. There results indicate that Ba_2NdTaO_6 is a promising buffer layer between $NdBa_2Cu_3O_{7-\delta}$ and MgO.

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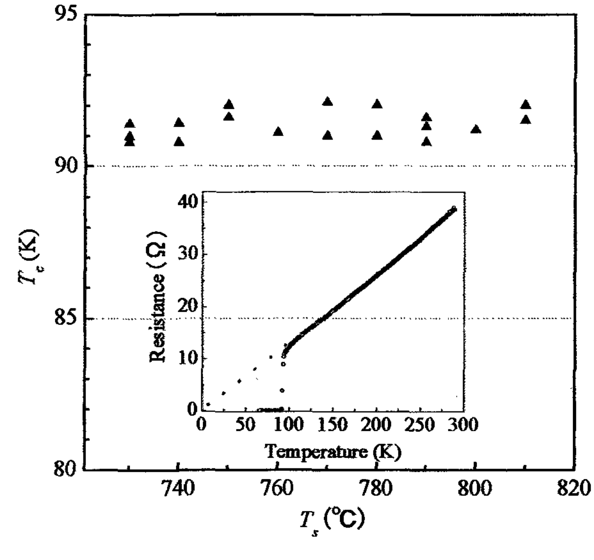

Fig.4 Deposition temperature dependence of T_c for NBCO thin films grown on BNTO buffered MgO substrates by PLD. The inset shows the temperature dependence of resistance for the NBCO thin film grown at 790 ℃.

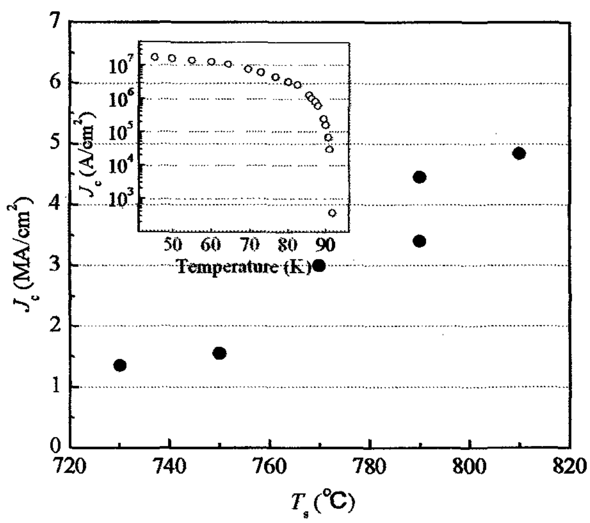

Fig.5 Deposition temperature dependence of J_c from NBCO thin films grown on BNTO buffered MgO substrates by PLD. The inset shows the temperature dependence of J_c for an NBCO thin film grown at 790 ℃.

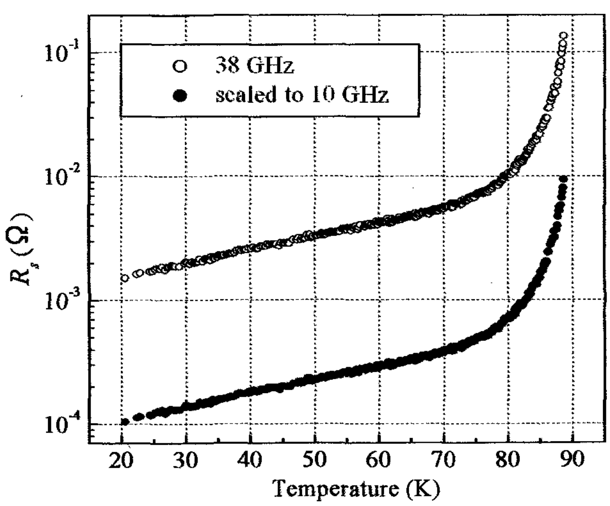

Fig.6 Temperature dependence of R_s for an NBCO thin film grown on BNTO buffered MgO substrate grown at 790 ℃ by PLD.

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