EFFECT OF FABRICATION CONDITIONS ON PROPERTIES OF BI-2212 THIN FILMS

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Abstract

High-quality epitaxial c-axis oriented Bi-2212 thin films were deposited on single crystalline (100) MgO substrate using Pulsed Laser Deposition. The results show that these films are good quality with *c*-axis orientation and epitaxial growth, good electrical and magnetic properties. The critical current density J_c was found to be strongly dependent on the temperature and magnetic field. The critical current density for the film growth with the best deposition conditions (Jc=6,3x10^6 A/cm^2 in 0.5T magnetic field at 5 K).The onset temperature for superconducting transition $T_{c\text{-onset}}$ = 95K and the temperature for zero resistivity $T_{c\text{-zero}}$ =80K.

INTRODUCTION

High-temperature superconducting (HTS) thin films have a large critical current density Jc and small surface resistance Rs in the microwave and millimeter wave region compared with that of normal conducting films. It can be used to design high-performance passive microwave devices, for example, filters, antennas, resonators, and delay lines [1-5]. The $Bi_2Sr_2CaCu_2 O_{8+y}$ system is one of the most promising high -Tc superconducting compound to be used in applications ranging from power transmission cables to Josephson -junction -based electronic devices [10].

Therefore, Bi-2212 thin films are very important for submillimeter wave devices. Several fabrication techniques of Bi-2212 films have been performed, such as pulse laser deposition (PLD), a molecular beam epitaxy (MBE) [7], a liquid phase epitaxy (LPE) [8], a metal chemical vapor deposition (MOCVD) [9]. The PLD method suitable for fabricating films with complex stoichiometry.

Pulsed laser deposition (PLD) or laser ablation is one of the most often used techniques for production of high-quality BSCCO thin films. The ablation process results in con-servation of the target stoichiometry in the initially ablated cloud [6]. Ablated species from a target come into oxygen environment and transfer to the substrate. A relatively high oxygen background pressure can be used with this technique. This allows for the fabrication of oxide films with nearly perfect stoichiometry.

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In this paper, we report the deposition of $Bi_2Sr_2Ca_1Cu_2O_{8+y}$ (BSCCO) thin films on MgO substrate prepared by the PLD method. Electrical properties such as the superconducting transition temperature (Tc) and the transport critical current density (Jc), surface morphology, crystal structure were investigated.

EXPERIMENTAL DETAILS

Precursor powder with Bi_2O_3, $SrCO_3$, $CaCO_3$ and CuO were prepared by solid state reaction. The powders were calcined at 835^0C for 24 hours in air. The calcinations were repeated three time at 835^0C for 24 hours in order improve the homogeneity by intermittently grinding the powder. The calcined powder was compressed into a disk of 15 mm in diameter and 4mm. We have used the polyvinyl alcohol as a binder. The compacted powder disk was heat-treated at 845^0 C for 160 hours.

The $Bi_2Sr_2Ca_1Cu_2O_{8+y}$ (BSCCO) thin films in this study were prepared by pulsed laser deposition (PLD). Before deposition, the (100) MgO substrate was washed. The excimer laser (λ = 248 nm) was operated at 300 mJ/pulse (the laser frequency is 3 Hz) for 30 min for each deposition. The temperature of the substrate which was mounted on the heater in the cross- area of the plume caused by the beam was 730^0C. The oxygen pressure was kept at 0.2 mbar. After deposition the films were annealed in situ a temperature at 680 ^{0}C for about 2 hours and cooled down to room temperature for in 3 hours in an ambient oxygen pressure of 800 mbar. The thin films T84, T92 and T93 were ex situ annealed at 845^0C for 3 hours, 2 hours and 1 hour. The films thickness was about 272 nm. The crystallographic texture of the film was studied by X-ray diffraction. SEM and FESEM. Superconducting transition properties were measured by resistance, MVSH, and inductive measurements. The critical current density Jc of the film was calculated by model Bean: $J_c = \dfrac{60a|\Delta M|}{b(3a-b)}$; where a and b are the length and width (a>b, in cm) of the sample plane perpendicular the applied magnetic field. ΔM is the difference of the magnetization (emu /cm^3) between the field-up and field-down branches.

RESULTS AND DISCUSSION

Flatness of the thin films is important in fabrication of layered structures and for research of basic properties of a few unit cell thick superconducting layers. SEM was used to investigate the influence of the energy of the laser pulses, the oxygen pressure and the temperature of the substrate on the surface morphology of the films. The SEM image of a film deposition on MgO at 0.2 mbar O_2, E = 300 mJ/pulse and substrate temperature Ts is about 730 ^{0}C is shown in figure 1. Figure 1 shows a SEM image of the Bi-2212 film on MgO, with a smooth and dense microstructure.

The presence of the *(00l)* peaks in the XRD patterns of the thin film corresponds to a well-crystallized single orthorhombic phase and *c*-axis-oriented film, as shown in figure 2. It shows that the BSCCO thin films of high structural quality have been epitaxially grown on single crystalline (100) MgO substrate. This reflects the perfection of the orientation of the different *c*-axis-oriented blocks of the film relative to the normal to the substrate.

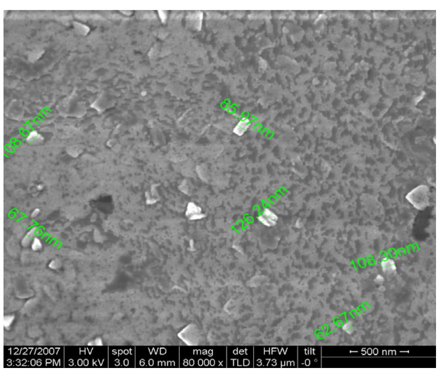

Figure 1: SEM micrograph of the surface appearance of the BSCCO film on MgO substrate.

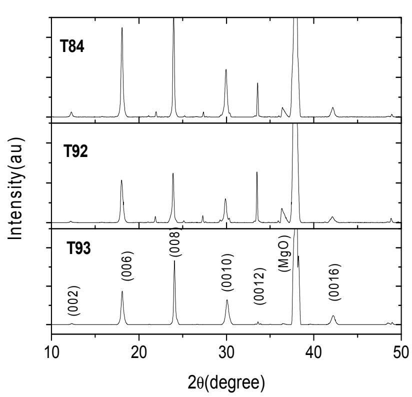

Figure 2: XRD patterns of the Bi 2212 thin films on MgO substrate; T93, annealing at 845^{0}C/1h; T92 annealing at 845^{0}C/2h; T84 annealing at 845 ^{0}C/3h.

The temperature dependent resistance, R(T), is shown in figure 3. The film exhibited good superconducting properties with $T_{c\text{-onset}}$ = 95 K and $T_{c\text{-zero}}$=80K. The value of T_c-$_{onset}$ increase with increasing the time of annealing.

The transport critical current density Jc is given by equation by model Bean: Jc = 60a ΔM / b(3a-b) = 6.3x10^6 A/cm^2 (where d=272 nm is the film thickness; and b=2.5 mm is the width of film, a= 2.8 mm is length of films).

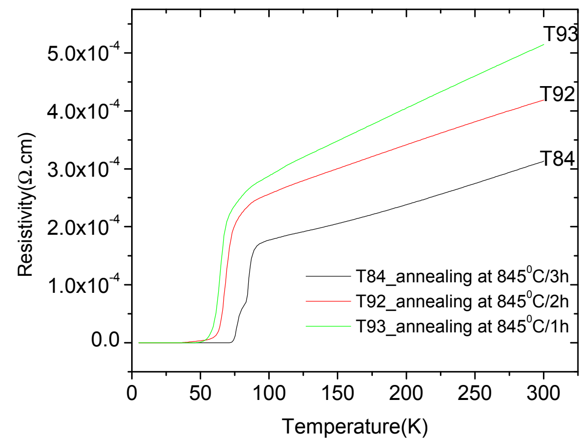

Figure 3: The temperature dependent resistivity of Bi-2212 thin film on a MgO substrate.

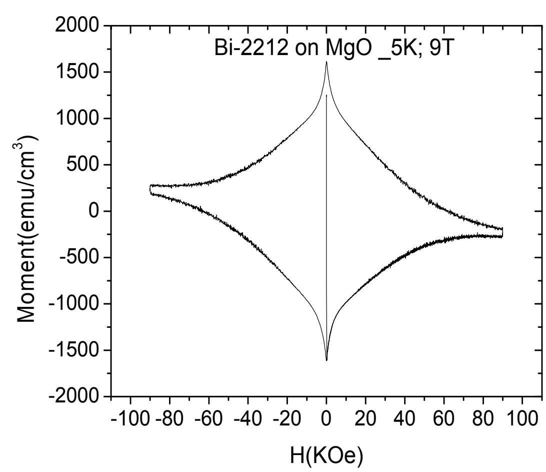

Figure 4: Moment depend about magnetic field of thin film Bi-2212 on MgO substrate at 5K.

Figure 5 shows the increase of Jc with decreasing magnetic field. The results also indicate the enhanced H_{c1} values in these BSCCO samples. At magnetic field is 0.5T, J_c achieves maximum value is 6.3x10^6 A/cm^2 at 5K in 0.5T

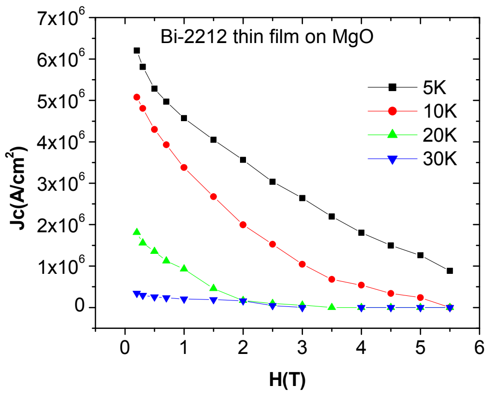

Figure 5: Current density of T84 thin film on MgO substrate depend on magnetic field at difference temperature.

In the levitation effect of superconductors, two of the more important properties are critical current density J_c and the lower critical field H_{c1}. The repulsive force of sample depends on the value of J_c, and H_{c1} is the field of magnet. Because of J_c is achieved maximum at 0.5T, when the superconductor exhibits pinning force [9].

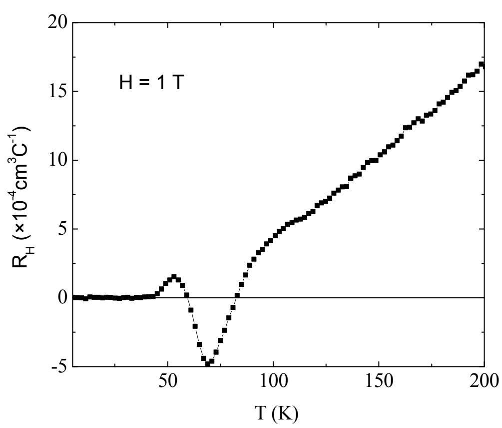

Figure 6: Hall coefficient of Bi-2212 thin film.

CONCLUSIONS

High quality epitaxial Bi-2212 thin films have been grown ex situ annealing by pulsed laser deposition (PLD) on single crystalline (100) MgO substrate. Our results show that the PLD method can be very useful in making Bi-2212 thin films with a smooth surface and good properties superconductivity, such as the transition temperature $T_{c\text{-onset}}$ = 95 K; $T_{c\text{-zero}}$=80K, and critical current density Jc = 6,3x10^6 A/cm^2 in 0.5T magnetic field at 5 K, which are essential for the production of various superconducting devices with high performance.

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