Preparation and Characterization of Bi-2212 thin film using Pulsed Laser Deposition.

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Abstract

High-quality c-axis oriented Bi-2212 thin films have been grown ex situ on single crystal (100) surface of MgO substrates was produced by PLD. The properties of Bi-2212 thin films have been investigated. The films were characterized by SEM, FESEM, X-ray diffraction, resistivity, MVSH, and transport properties. 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. In optimized growth conditions the transport critical current density Jc=6.3x10^6 A/cm^2 in 0.5T magnetic field at 5 K, superconducting transition temperature $T_{c\text{-onset}}$ = 95K and $T_{c\text{-zero}}$ =75K are obtained.

Keywords: *Bi-2212 thin film, pulsed laser deposition, superconductors*.

1. Introduction

High-temperature superconducting (HTS) thin films have a large critical current density Jc and small surface temperature 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 $Bi_2Sr_2Ca_{n-1}O_x$ system is thought to be one of the most promising high -Tc superconductor compounds use in applications ranging from power transmission cables to Josephson-junction -based electronic devices [10].

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 conservation 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. 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.

In this paper, we report the result 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.

2. Experimental details

Precursor powder with Bi_2O_3, $SrCO_3$, $CaCO_3$ and CuO were prepared by solid satte reaction. The powders were calcined at 830^{0}C for 24 h in air. The calcinations were repeated three time at 830^{0}C for 24 h in order improve the homogeneity by

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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 h.

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 solution in an ultrasonic cleaner and subsequently by deionized water, acetone and ethanol and annealing at 800^0C. 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 substrate is mounted on the heater in the cross- area of the plume caused by the beam and its temperature (Ts) was in the 730^0C. The ambient oxygen pressure was kept at 0.2 mbar. The films were in situ annealed at 680 ^{0}C for about 2 h and cooled down to room temperature for about 3 h in the ambient oxygen pressure of 800mbar. The thin films T84 , T92 and T93 were ex situ annealing at 845^0C for 3h, 2h and 1h. 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:

$J_c = \frac{60a|\Delta M|}{b(3a-b)}$; 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.

3. Results and discussion

Flatness of the thin films is importance 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.

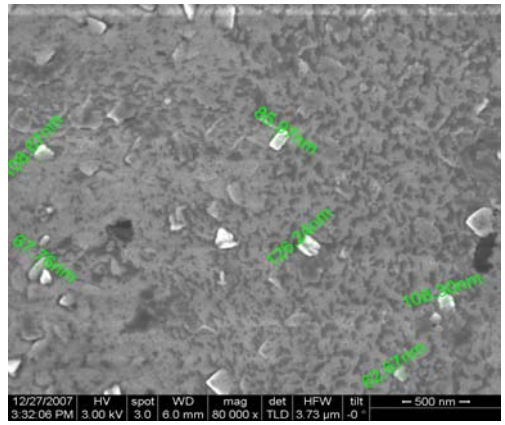


***Figure 1**. SEM micrograph of the surface appearance of the BSCCO film on MgO substrate*

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.

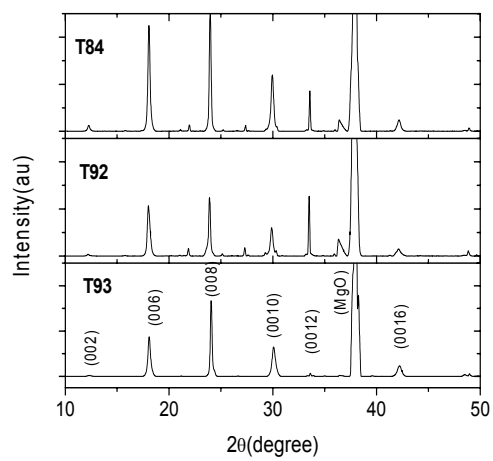


***Figure 2**. XRD patterns of the Bi 2212 thin films on MgO substrate; T93 annealing at 845^0C/1h; T92 annealing at 845^0C/2h; T84 annealing at 845 ^{0}C/3h*

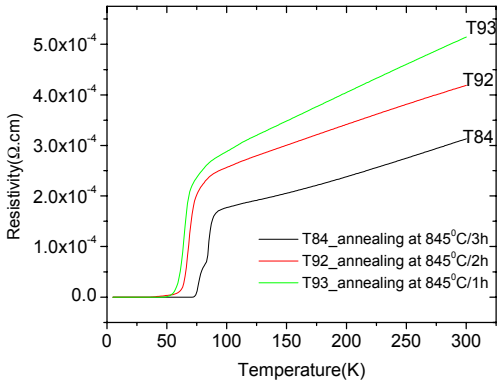
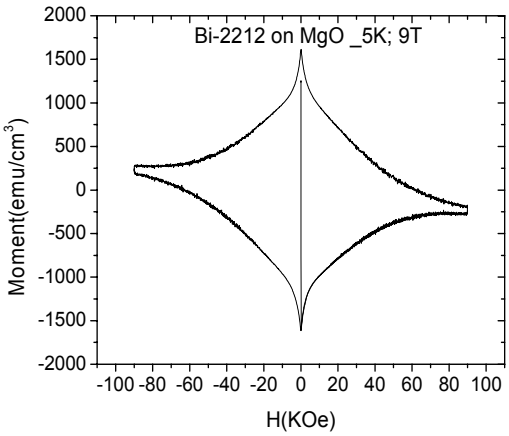


Figure 3. *The temperature dependent resistivity of Bi-2212 thin film on a MgO substrate*

The temperature dependent resistance, R(T), is shown in figure 3. The film exhibited good superconducting properties with $T_{c\text{-onset}}$ = 95K and $T_{c\text{-zero}}$=75K. When increasing time annealing, we find that value of $T_{c\text{-onset}}$ increasing.

The transport critical current density Jc is given by equation by model Bean: Jc = 60a ΔM / b(3a-b) = $6.3\text{x}10^6$ 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).



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

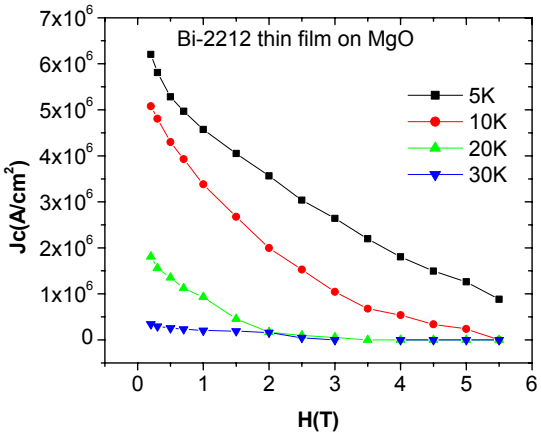


Figure 4. *Current density of Bi-2212 thin film on MgO substrate depend on magnetic field at difference temperature*

This figure shows that the J_c values were found to increase initially with the decreasing of 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 $6.5\text{x}10^6$A/cm^2 at 5K in 0.5T

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].

4. 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 electrical, such as the transition temperature $T_{c\text{-onset}}$ = 95K and $T_{c\text{-zero}}$=75K, and critical current density Jc = $6.3\text{x}10^6$ 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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