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EFFECT OF MAGNETISM IN ELECTRICAL TRANSPORTATION BETWEEN TWO SUPERCONDUCTING LAYERS

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ABSTRACT

To investigate the interplay between superconducting and magnetic material, a multilayer consisting of two superconducting YBa2Cu3O7 (YBCO) layers and sandwiched with magnetic Ni as a mediator was fabricated. The thin film of YBCO/Ni/YBCO on MgO substrate was prepared by pulsed laser deposition (PLD). The multilayer was initially characterized by XRD and then the morphology of surface was investigated by FESEM. Variation of resistivity via temperature was measured by DC electrical method with four point probe.

Keywords: YBCO; superconducting; pulsed laser deposition; multilayer; thin film

INTRODUCTION

Recently, more attention has been given to fabrication and characterization of multilayers based on perovskite oxides because it is a way to investigate materials with strong electron correlations [1]. A compound of superconductors (SC) and ferromagnets (FM) because of their mutually exclusive ground state properties, indicates a unique quantum phenomena is called π-junction effect[2,3]. The work on high temperature superconducting due to their potential for valuable applications such as power transmission, microwave devices, delay lines, resonant cavities, SQUIDs and etc, are believed to be susceptible in groups of perovskite oxides. One of the popular high temperature superconductors (HTS) is YBa2Cu3O7 because of its good behavior for coated conductor and high potential for SC/FM quantum states in multilayer structures. By controlling interfaces between two superconducting materials, it is possible to find out new physical phenomena not exhibited by that material alone. It is expected that magnetic correlations at the interface is an important factor in determination of the macroscopic properties of multilayer systems. The interaction between magnetic material and superconductors has attracted many studies due to interesting interplay between them in some new methods.[4-7]. In this work, we attempt to know more about the nature of magnetism as an interface between two superconducting layers and interplay of FM and SC order parameters. So we fabricated a multilayer of YBCO and Ni on MgO substrate. The use of MgO substrate which has stable physical and chemical properties and low dielectric constant, was a good idea to obtain an epitaxial growth of YBCO film[8]. This study was expected to provide a strong effect of magnetism on superconducting layer. Pulsed laser deposition method was used because it is a versatile technique and allows depositing different materials, such as high-temperature superconductors, oxides with high deposition rates. The pulsed nature of this method makes it possible to prepare multilayers and other complex polymer-metal compounds.

METHOD

The multilayer was prepared by PLD using a Nd:YAG class 4 laser system. The parameters of laser were adjusted as: 4.5 cm distance between target and MgO substrate, 1064 nm wavelength, 6 ns duration of pulse, and 600 µJ energy of laser. The first layer of YBCO was placed on MgO at a substrate temperature of 790°C in 300 mTorr oxygen atmosphere. Ni layer was deposited by using a Ni foil (99.9 %) at temperature 600°C and in presence of argon gas to prevent NiO formation. The upper layer of YBCO was deposited with similar conditions as same as the first one. A post-deposition annealing at 550°C was done for 1 hour and then the sample was cooled to room temperature at a slow rate. The crystallinity of the sample was characterized by x-ray diffraction (XRD) and its morphology was observed using a field emission scanning electron microscope (FESEM). Also the variation of resistivity with temperature was measured by DC electrical method with four point probe.

RESULTS AND DISCUSSIONS

PLD technique, as it is demonstrated in the literature, has the ability to grow YBCO films with good quality of epitaxy on different substrates such as MgO, STO, LAO, etc. Figure 1 shows the XRD patterns of the YBCO/Ni/YBCO thin film deposited on MgO with PLD method at 790°C. In Figure 1, the series of (00*l*) diffraction peaks for YBCO related to Y123 phase are seen, and some weak peaks such as NiO are also seen. To prevent the formation of this impurity, the annealing of Ni foil at 900°C in presence of a gas mixture consisting of 4% H2 and 96% Ar is useful [9]. With the exception of these poor diffraction peaks. It may indicates a good epitaxy quality of the YBCO multilayer, with a c-axis orientation. Also Figure 2 shows the diffraction peak of Ni (200). This is in good agreement with the previous results published by other researchers [10].

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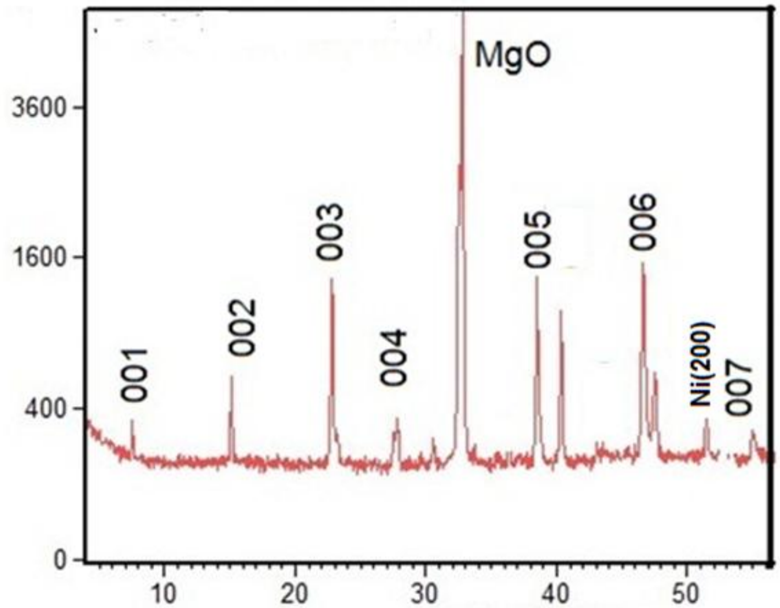

Figure 1: X-ray diffraction patterns of YBCO films on Ni/YBCO/MgO

Figure 2(a) shows the SEM micrographs of the first YBCO layer deposited on MgO substrate. The film has a good structure with a few cracks or pinhole. The particles are connected with each other during the annealing process. it seems that most of grains are in the same size of about 1 µm. Figure 2(b) displays the upper YBCO layer which is located on a thin Ni layer with the thickness of about 100 nm. It can be seen that The upper layer covered majority of the nickel interface with the minimum of defects.

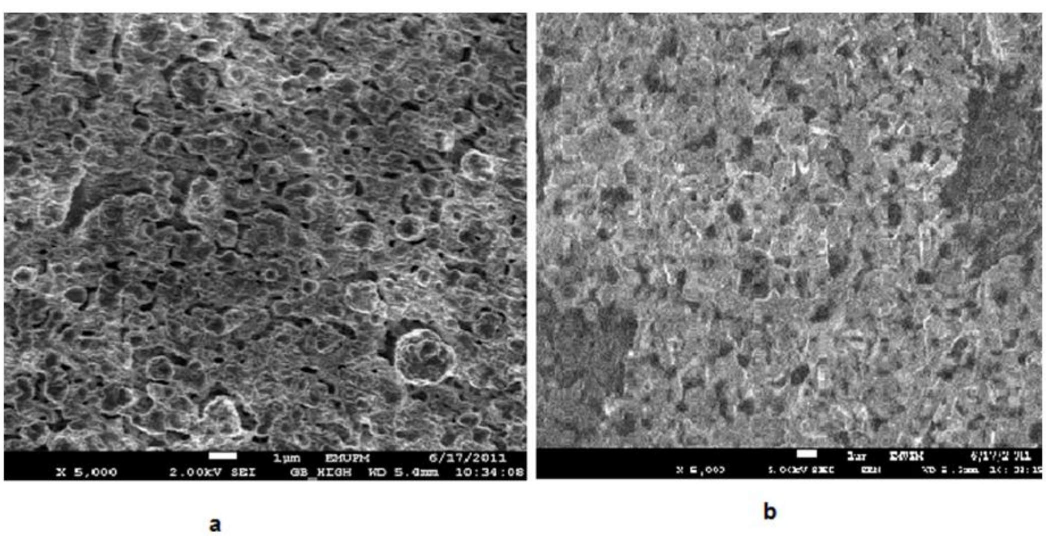

Figure 2: SEM micrograph of (a) the first layer of YBCO and (b) the upper layer of YBCO

The thin film was characterized with four point probe method in DC electrical resistance. Figure 3 shows the effect of applying a potential between two superconducting layers on resistivity of the sample in temperature range of 300 to 20K. The curve shows that the resistance of the sample is 2.24 ohm at room temperature, whereas for a single layer it is in the range of 0.1- 0.001 ohm and it decreases as temperature decreases to zero at 91 k. But as indicated from the curve, the minimum of resistivity of the sample reached to 1.44 ohm at 20K. It shows that by placing nickel mediator layer between the YBCO multilayers, the resistivity of the multilayer can be controlled.

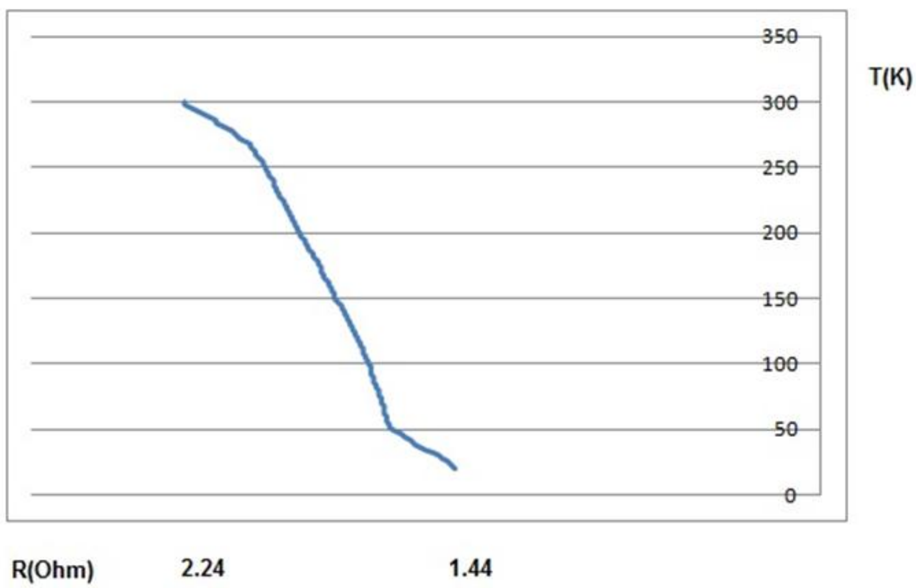

Figure 3: variation of resistivity-temperature

CONCLUSION

A multilayer of YBCO/Ni/YBCO/MgO thin film was prepared by PLD method. From figure 3 it is clear that by decreasing temperature, the resistivity between superconductor layers will be decreased. So, this magnetic layer has affected the Tc of superconducting layer and at 20K, the resistivity of the sample is 1.44 ohm.

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