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Josephson Property and Magnetoresistance in $Y_1Ba_2Cu_3O_{7-x}$ and $La_{0.2}Sr_{0.8}MnO_3$ Films on Biepitaxial $SrTiO_3$/(MgO/)Al_2O_3($11\bar{2}0$)

$SrTiO_3$/(MgO/)Al_2O_3($11\bar{2}0$) 위에 쌍에피택설하게 성장한 $Y_1Ba_2Cu_3O_{7-x}$와 $La_{0.2}Sr_{0.8}MnO_3$ 박막의 조셉슨 및 자기저항 특성연구

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Biepitaxial $Y_1Ba_2Cu_3O_{7-x}$ (YBCO) and $La_{0.2}Sr_{0.8}MnO_3$ (LSMO) thin films have been prepared on $SrTiO_3$ buffer layer and MgO seed layer grown on Al_2O_3($11\bar{2}0$) substrates by dc-sputtering with hollow cylindrical targets, respectively. We charaterized Josephson properties and significantly large magnetoresistance in YBCO and LSMO films with 45^0 grain boundary junction, respectively. The observed working voltage (I_cR_n) at 77 K in grain boundary junction was below 10 μV, which is typical I_cR_n value of single biepitaxial Josephson junction. The field magnetoresistance ratio (MR) of LSMO grain boundary junction at 77K was enhanced to 13%, which it was significant MR value with high magnetic field sensitivity at a low field of 250 Oe. These results indicate that inserting the insulating layer instead of the grain boundary layer with metallic phase can be possible to apply a new SIS Josephson junction and a novel magnetic device using spin-polarized tunneling junction.

I. Introduction

Grain boundary junctions work well at temperatures close T_c, have reasonably high working voltage (I_cR_n) products, and show behavior explained by a resistively shunted junction (RSJ) model with a relatively uniform current density[1]. The Josephson junction of successful biepitaxial grain boundaries in high-T_c superconducting (HTS) YBCO film by controlling their in-plane epitaxy using seed and buffer layers deposited r-plane sapphire substrates can be operated at and above 77 K and used on a random position and a wide variety of substrates, although they have low I_cR_n because of 45^0 grain weak-link geometry[2].

On other side hand, the study of colossal magnetoresistance (CMR) in manganese oxide materials in the last few years is not only of scientific interest in these metallic oxides but also of technological interest as potential candidate for magnetic sensors and magnetic recording devices [3]. The perovskite-like crystal structure of La-(Ca, Ba, Sr)-manganese oxides has antiferromagnetic and ferromagnetic ordering along the all axes [3,4]. The manganese oxide CMR films, very useful half-metallic materials with a complete spin-polarization of 100%, could be used in spin-dependent tunneling (SDT) junction devices. Large values of MR at high fields (of order a few Tesla) have been achieved for the manganite epitaxial thin film within a narrow temperature range around the ferromagnetic transition [6-8]. However, a large MR effect at small fields could be achieved by controlling the crystallinity and defect constitution in CMR materials [9].

In this paper, in order to study in-plane grain boundary effects and Josephson properties and MR properties, we have made artificial 45^0 angle grain boundaries in the HTS and CMR layer using biepitaxial YBCO and LSMO thin film growth techniques, respectively.

II. Experimental Procedure

Biepitaxial multilayer structures are used to fabricate well-defined and reproducible high-T_c superconducting Josephson junctions [1,2,10,11]. We used a biepitaxial a YBCO film and LSMO film. About 2000 Å and 5000 Å thick cuperite and manganite oxide films on $SrTiO_3$ buffer layer/(MgO seed layer/)Al_2O_3 substrate were deposited by using dc -sputtering with an inverted cylindrical magnetic source, respectively. The films, YBCO and LSMO, were deposited in an argon-oxygen atmosphere at a total pressure of 300 mTorr, respectively. The films were biepitaxially grown at a substrate temperature of 700~900℃ on (100)-oriented surfaces of $SrTiO_3$/(MgO/) $Al_2O_3(11\bar{2}0)$. The cooling to room temperature in 0.7 atm. of oxygen gas without post annealing was *in-situ* process. Fig. 1(a) and (b) show the schematic diagrams of two types of biepitaxial YBCO and LSMO structures, respectively, which are composed of a MgO seed layer (100 Å) and a $SrTiO_3$(1000 Å) buffer layer on r-plane sapphire substrates.

As shown schematically, biepitaxial boundaries with an artificial 45^0 in-plane rotation of the [100] axes were formed in YBCO and LSMO films. Every layer shown in Fig. 1 is grown epitaxially and this is confirmed by X-ray diffraction $\theta/2\theta$ and ϕ-scan , and surface morphology observation by atomic force microscope (AFM).

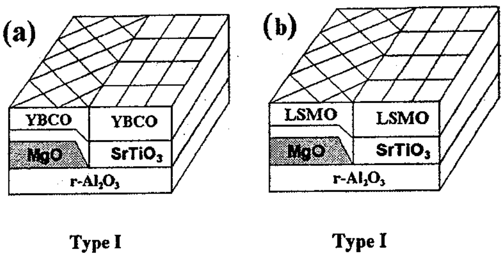

Fig. 1. The schematic structures of biepitaxial grain boundary multilayers. (a) YBCO/$SrTiO_3$/(MgO/) $Al_2O_3(11\bar{2}0)$ and (b) LSMO/$SrTiO_3$/(MgO/) $Al_2O_3(11\bar{2}0)$.

To investigate the effects of an in-plane grain boundary on the Josephson and magnetotransport properties of YBCO and LSMO, a bridge pattern with a width of 20 ㎛ and 1 ㎜ was formed by conventional photo-lithography and wet etching (see Fig. 2(b) and 3(b)), respectively. The resistance-temperature curve and MR curve value of the films was measured using a standard four-probe method with a current of 100 ㎂ in the film plane and I_c and R_n are defined by a conventional criterion limit from I-V characteristic curve. The magnetic field was in the plane of the film parallel to the grain boundary junction (∥).

Ⅲ. RESULTS AND DISCUSSION

We patterened a microbridge across 45^0 grain boundary junction with 20 ㎛ and 0.5 ㎛ YBCO film thick by photolithography and wet etched with EDTA (Fig. 2(b)). The current-voltage characteristics of biepitaxial grain boundary junction at 77 K, which exhibits RSJ Josephson junction behavior is shown in Fig. 2(a). The critical current of about at 77 K translated to about 2×10^2 A/㎠. The temperature dependence of critical current and the resistance of the junction is displaced in Fig. 2(c). The I_cR_n product of the junctions is from about 14 ㎶ at 65 K to about 2 ㎶ at 77K. The critical current disappears nonlinearly as the critical temperature is approached. This result is different to that of grain boundary junctions of YBCO, by K. Char. et al., which leads their to speculate that the temperature dependence may be a general property of YBCO interfaces[2].

Without an external magnetic field, the temperature dependence of the resistance of the biepitaxial LSMO layer is shown in Fig. 3(a). The sample was *in-situ* annealed at 900℃ for 20 min at oxygen atmosphere of a 500 Torr. The transition temperature from semiconductor and ferromagnetic mixed phases to ferromagnetic metallic phase in the LSMO layer is about 300 K. Fig. 2(c) shows the MR curves (∥) measured at 77 K. Here the magnetic field was in the film plane and parallel to the grain boundary. The MR ratio in the "A" or "B" epitaxial regions at 77 K is very small, however, the maximum MR ratio across the grain boundary junction is 13%. LSMO films

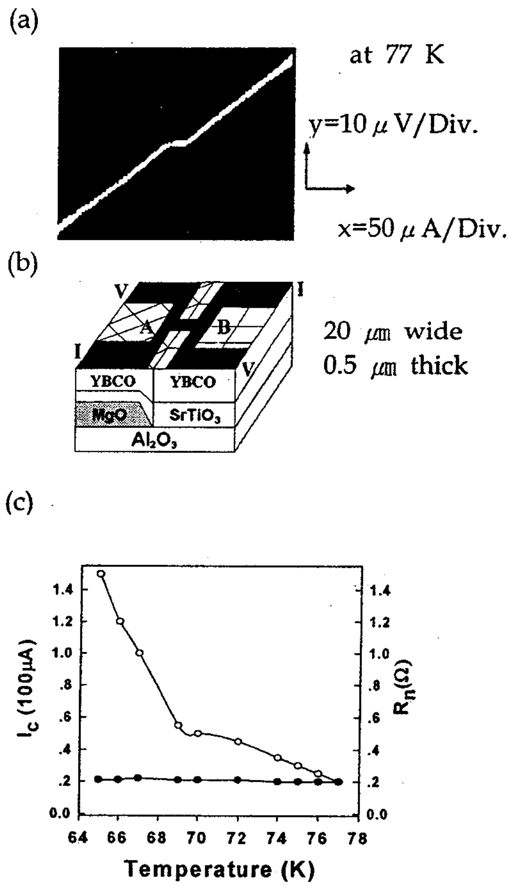

Fig. 2. (a) Voltage (vertical)-current (horizontal) characteristics of $YBCO/SrTiO_3/(MgO/)Al_2O_3(11\bar{2}0)$ films with a microbrige of 20 ㎛ wide and 0.5 ㎛ thick, as showm in (b). (c) Temperature dependence I_c and R_n of biepitaxial junction.

with a 45^0 grain boundary show hysteretic behaviour as well as an enhanced MR at value at a low magnetic field of 250 Oe. It is a significantly enhanced MR value at low saturated magnetic field of 350 Oe.

In case of field direction (⊥) the MR ratio decreases to 6%, but the saturated coercive field increases to over a few kOe. It seems that the adjacent grains are not exchange coupled, and their relative orientation is changed in a small field, because of ferromagnetic spin-polarization ordering in ab-plane of biepitaxial LSMO films. Therefore, this result implies that

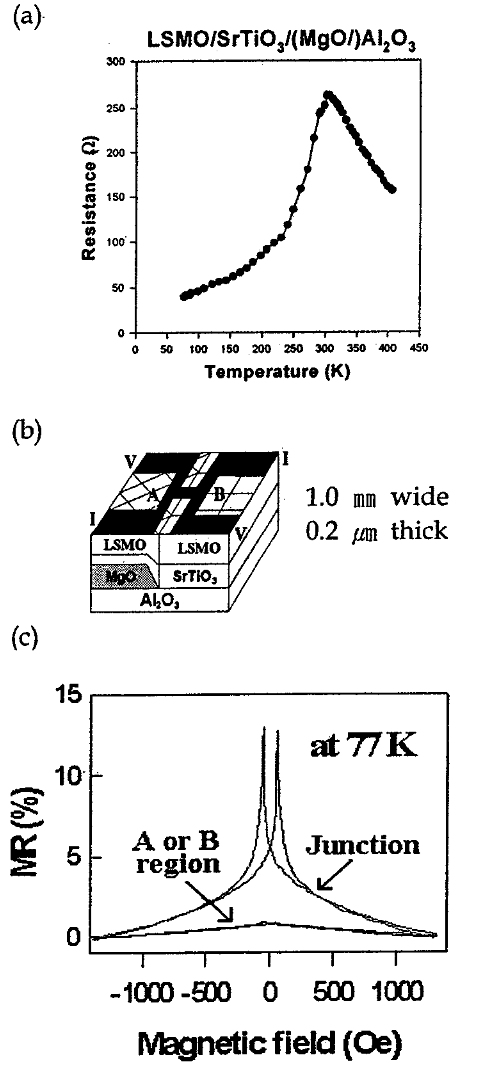

Fig. 3. (a) Resistance vs temperature curves of bieptaxial LSMO/$SrTiO_3$/(MgO/)Al_2O_3($11\bar{2}0$) films with a bride of 1 mm wide and 0.2 μm thick, as shown in (b). (c) Low field MR curves of biepitaxial LSMO grain boundary junction at 77 K.

biepitaxial LSMO films with insulating barriers inserted or formed between in-plane 45^0 angle can be used for fabricating the spin-dependent tunneling junction across grain boundary.

Ⅳ. CONCLUSIONS

The biepitaxial grain boundary junction of YBCO/$SrTiO_3$/(MgO/)Al_2O_3($11\bar{2}0$) and LSMO/$SrTiO_3$/(MgO/)Al_2O_3($11\bar{2}0$) films was fabricated using the deposition techniques by means of rf-sputtering and e-beam evaporation and dc-sputtering. Josephson properties of biepitaxial YBCO films across a grain boundary junction line were J_c = 2×10^2 A/㎠. I_cR_n = 2~14 μV at 65 K~77 K. In case of biepitaxial LSMO films, the low field MR of 13% at 77 K is because of the 45^0 grain boundary effect. This result is due to biepitaxial LSMO films with ferromagnetic spin-polarization ordering in ab-plane at grain boundary junction.

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