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Magnetoresistance effects in $La_{1-x}Sr_xMnO_3$/Nb-$SrTiO_3$/Co junctions

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1. Introduction

Recently, the areal density of the hard disk drives (HDD) is increasing rapidly, and HDD with areal density of 200 Gbit/ in^2 have been successfully fabricated by using high sensitive tunnel magnetoresistance (TMR) devices [1]. However, to achieve higher areal density, much lower resistance-area products (RA) and higher MR ratio should be coexist in MR devices. In the case of TMR devices, it is not easy to achieve both large MR ratio and low RA because of the high resistivity of insulating tunnel barriers. The barrier layer thickness must be reduced for reduction of lower RA. However, there's limitation of the thickness reduction of the tunnel barrier because it induces large reduction of the MR ratio due to the imperfectness of very thin tunnel barriers (~1 nm).

The use of current perpendicular to plane giant magnetoresistance (CPP-GMR) devices is another choice to solve the problems. However, in the case of CPP-GMR devices, it is not easy to obtain high MR ratio because the resistance of the devices are too low because of the very low resistivity of metallic layers between two magnetic electrodes.

In this study, we propose novel MR devices, which use degenerate oxide semiconductors (Nb-doped $SrTiO_3$ [2]) as intermediate layers between two magnetic electrodes. The devices allow us to control resistance-area products and MR ratio precisely by changing resistivity of Nb-STO layers, that is, Nb concentration in $SrTiO_3$.

2. Experimental methods

$La_{0.7}Sr_{0.3}MnO_3$ (100 nm)/Nb (5 mol%) doped $SrTiO_3$ (5~50 nm)/Co (30 nm) trilayer films were fabricated on MgO (100) substrates by magnetron sputtering. First, the $La_{0.7}Sr_{0.3}MnO_3$/Nb-$SrTiO_3$ multilayers were in-situ formed at 780°C in a 10 Pa of Ar+0.1%O_2, and then Co metals were deposited ex-situ on the multilayers at room temperature. By using the $La_{0.7}Sr_{0.3}MnO_3$ (LSMO)/ Nb-$SrTiO_3$ (Nb-STO)/Co trilayers, magnetic junctions with 25~100 μm square in area were then fabricated by a photolithographic process and Ar ion milling.

Structural characterization was performed by X-ray diffraction (XRD) measurements. The magnetization measurements were performed using a vibrating sample magnetometer for temperatures in the range 77-300 K in magnetic fields up to 1 T. The electrical resistivity was measured in the temperature range from 4.2 to 300 K by the standard four-probe method. Magnetoresistance (MR) measurements were performed using the standard DC four-probe method at a bias voltage of 1 mV.

3. Results and Discussions

Figure 1 shows XRD patterns of Co/Nb-STO (50 nm)/LSMO trilayers formed on MgO substrates. Only

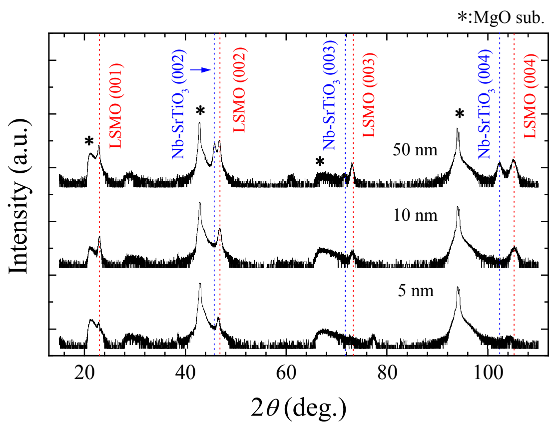


Fig. 1. X-ray diffraction patterns of Co/Nb-$SrTiO_3$ (50nm)/LSMO multilayers formed on MgO.

(00*l*) peaks of Nb-STO and LSMO films except substrate peaks were observed, indicating Nb-STO and LSMO films were single phase and had a c-axis orientation normal to the surface of the substrates. We cannot observe Co related peaks, indicating that Co metal has amorphous or

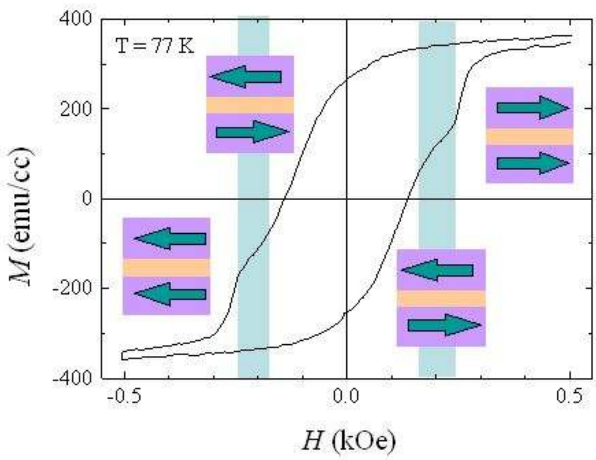


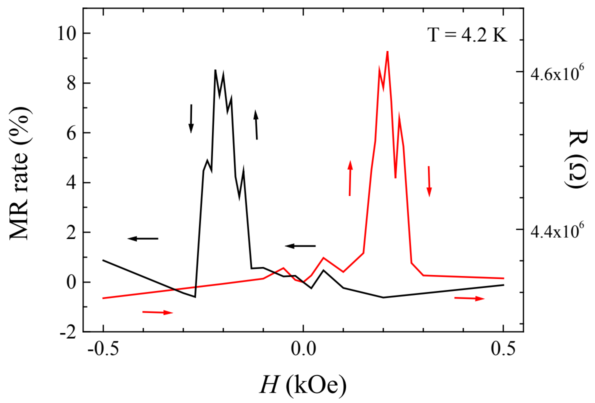
Fig. 2. Hysteresis curves of Co/Nb-$SrTiO_3$ (10nm)/LSMO trilayer films measured at T=77 K.

polycrystal like structures.

Typical electron concentration and mobility of the Nb-STO films formed in the same growth conditions was estimated to be 4.4×10^{18} cm^{-3} and 3.0 cm^2/Vs at room temperature, respectively from Hall measurements.

In the hysteresis curves of Co/Nb-STO (10 nm)/LSMO trilayer films at 4.2 K, two step magnetization reversal transitions were observed (Fig. 2); one around 150 Oe, which corresponds to the coercive field (H_c) of LSMO, and another around 250 Oe, which corresponds to H_c of Co. This indicates that antiparallel alignment of magnetization between LSMO and Co layers occurs in the magnetic field range of ±~150-250 Oe.

The Magnetic junctions using the trilayer films showed positive magnetoresistance (MR) of 9.2 % at 4.2 K (Fig. 3). The resistance increases drastically in the field range of ±~130-270 Oe, which correspond to the magnetization switching of the LSMO layers. The positive MR was



observed in the junctions with intermediate layer thickness of 10 nm. This means that the mechanism for the positive MR is different from simple TMR devices, which use insulative barrier layers such as $SrTiO_3$, MgO, etc. Typical thickness of barrier layers of TMR devices was limited below ~ 3 nm because of limitation of tunneling length.

The origin of the MR effects in the trilayer films is under investigation, however we consider injection of spin-polarized carriers from half-metallic LSMO to semiconducting Nb-STO thorough Schottky and/or tunnel barriers at the interfaces plays an important role.

4. Conclusions

In this study, we fabricated MR devices using semiconducting Nb doped $SrTiO_3$ as intermediate layers between two magnetic electrodes. XRD measurements showed Nb-STO and LSMO layers were epitaxially grown on MgO substrates, however Co has amorphous or polycrystal like structures. The Magnetic junctions using the trilayer films showed positive MR of ~10 % at 4.2 K. The resistance increases drastically in the field range of ±~130-270 Oe, which correspond to the magnetization switching of the LSMO layers. These results showed magnetic junctions using degenerated semiconductors such as Nb-STO as intermediate layers is one of the candidates for fabrication of future MR devices.

Acknowledgements

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