P-11

Annealing temperature and crystalline texture dependence of magnetoresistance in IrMn-based top and bottom spin valves †

Sookmyung Women's Univ. J. Y. Hwang*, S. S. Kim, M. Y. Kim and J. R. Rhee
Sangji Univ. S. S. Lee and D. G. Hwang, Chungbuk National Univ. S. C. Yu, Kongju National Univ. H. B. Lee

Top and bottom 형 IrMn 스핀밸브 박막의 열처리 온도와 결정구조 의존성 †

숙명여대 황재연*, 김순섭, 김미양, 이장로
상지대 이상석, 황도근, 충북대 유성초, 공주대 이희복

Ⅰ. INTRODUCTION

IrMn has been identified as a promising antiferromagnetic (AFM) material for giant magnetoresistance/spin valve (GMR/SV) heads in high density magnetic recording [1] due to its high exchange coupling field (H_{ex}), high blocking temperature (T_B), and low critical thickness (~80Å) [2]. Therefore, exchange coupled IrMn/CoFe bilayer is suitable for narrow gap head structure [3], since IrMn shows a high H_{ex} at smaller layer thickness than other ordered AFM films, such as NiMn and PtMn [1]. In this paper, we present a fabrication method of $Co_{75}Fe_{25}/Ir_{22}Mn_{78}$ exchange coupled top spin valve (TSV), bottom spin valve (BSV) and dual spin valve (DSV) by dc magnetron sputtering, focusing on SV performance around the optimal IrMn thickness (~100Å). The effect of annealing treatments on the magnetic, magnetoresistive, and structural properties of the devices have been also investigated.

Ⅱ. EXPERIMENT

The GMR/SV films with the structures of top Ta45/NiFe30/CoFe20/Cu30/CoFe12/IrMn100/Ta45, bottom Ta45/NiFe20/IrMn100/CoFe12/Cu30/CoFe20/NiFe30/Ta45, and dual Ta45/NiFe20/IrMn100/CoFe12/Cu30/CoFe20/NiFe30/CoFe20/Cu30/CoFe12/IrMn100/Ta45 (in Å) were deposited at room temperature by the dc magnetron sputtering on thermally oxidized Si (111) substrates in a field of about 100 Oe. The base pressure of the process was below 2×10^{-8} Torr and the argon (99.9995%) gas pressure was 2 mTorr. To induce large H_{ex}, a series of annealing cycles (a 1 h ramp to 250 °C , a 1 h soak at 250 °C and a 1 h cool down to room temperature) were applied under a static magnetic field of 1050 Oe in vacuum of 5×10^{-7} Torr. The magnetotransport properties were measured using a dc four-point probe method and a vibrating sample magnetometer. The crystal structures were investigated by x-ray diffraction (XRD).

Ⅲ. RESULTS AND DISCUSSION

The dependence of H_{ex} and MR ratio on the number of annealing cycles was investigated. The as-deposited sample shows H_{ex} of 680 Oe and 380 Oe, MR ratios of 2.7% and 5.8% for BSV and TSV, respectively. After the second annealing cycle, the MR ratios for the BSV and TSV show 3.6% and 5.6%, and the curves of H_{ex} become relatively stable with 1180 Oe and 430 Oe, respectively. MR and magnetization curves measured parallel to an easy axis of the BSV, TSV and DSV structures after second annealing treatment are shown in (a), (b) and (c) of Fig. 1, respectively. The coercivity (H_c) of the pinned layer of BSV is found to be 150 Oe. From the minor MR curve (inset), it is found that the interlayer coupling field (H_{int}) is about 12 Oe, and the H_c of the free layer is 5 Oe. The TSV shows a higher MR ratio and lower H_{ex} value. The DSV, with MR ratio of 7.8% and H_{ex} of 850/510 Oe, shows two exchange loops due to the difference in the H_{ex} between the top and bottom pinned layers, as shown in Fig. 1(c). The XRD pattern of IrMn (111) peak of the annealed BSV (Fig. 2(a)) shows a higher peak intensity and 2 θ position (a= 3.79 Å) (a higher perfection of crystalline texture of IrMn layer) than the TSV while the CoFe/Cu/CoFe/NiFe (111) peak position is unchanged. The

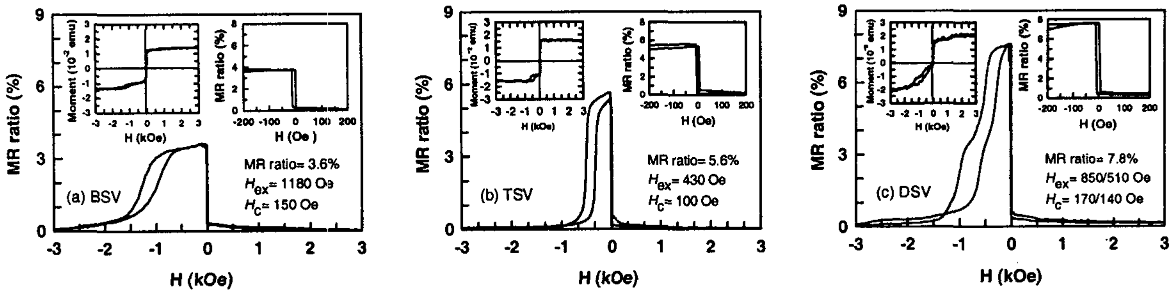

Fig. 1. MR curves for (a) BSV, (b) TSV and (c) DSV after second annealing treatment. The inset graphs show magnetization and minor MR curves.

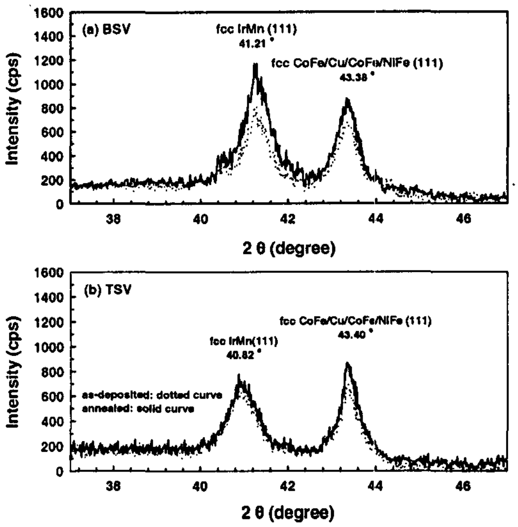

Fig. 2. XRD scan patterns for the (a) BSV and (b) TSV in the as-deposited state (dotted curve) and after the second annealing (solid curve).

IrMn layer of BSV has a superior, more compact fcc (111) texture due to its growth on a thin and smooth underlayer of Ta45/NiFe20 than the TSV. The texture of IrMn layer can be further improved by annealing, leading to a more bulk-like microstructure and to higher H_{ex} values. However, since the CoFe/Cu/CoFe/NiFe layers grow on the rougher IrMn surface with reduced grain size [4] as seen in the (111) peak widths, which leads to a higher sheet resistance, lower MR ratio due to more efficient grain boundary scattering, and a larger H_{int} compared to the TSV structure. The H_{ex} of TSV decreases gradually with the temperature increase, reaching zero at 250 °C. The H_{ex} of BSV remains almost constant at 1180 Oe up to 140 °C, and then falls to zero at 270 °C. In particular, the BSV exhibits a higher T_B of 270 °C, and a MR ratio of 3.6%, and an H_{ex} of 1180 Oe, which is the highest ever reported for other post-annealing AFM films, such as NiMn and PtMn [1].

IV. CONCLUSION

In conclusion, the BSV shows lower MR ratio and higher H_{ex} than the TSV. The high H_{ex} has been attributed to the better IrMn (111) texture with smaller lattice constant. The reduced MR ratio is attributed to rougher interfaces in the CoFe/Cu/CoFe/NiFe layers with reduced grain size due to the rougher IrMn surface. The results concerning magnetic properties together with structural investigations suggest that H_{ex} is mainly dependent on the quality of fcc (111) crystalline texture while MR ratio is sensitive to both crystalline texture and interface roughness.

† This work was supported by Grant No. R06-2003-007-01001-0 from the Basic Research Program of the Korea Science and Engineering Foundation.

V. REFERENCES

[1] S. Mao et al., Appl. Phys. Lett. **69**, 3593 (1996).

[2] A. J. Devasahayam et al., J. Appl. Phys. **83**, 7216 (1998).

[3] H. N. Fuke et al., Appl. Phys. Lett. **75**, 3680 (1999).

[4] G. Anderson et al., J. Appl. Phys. **87**, 6989 (2000).