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IrMn-based specular spin valves with spin filter layer †

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스핀필터층을 이용한 IrMn Specular 스핀밸브 †

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I . INTRODUCTION

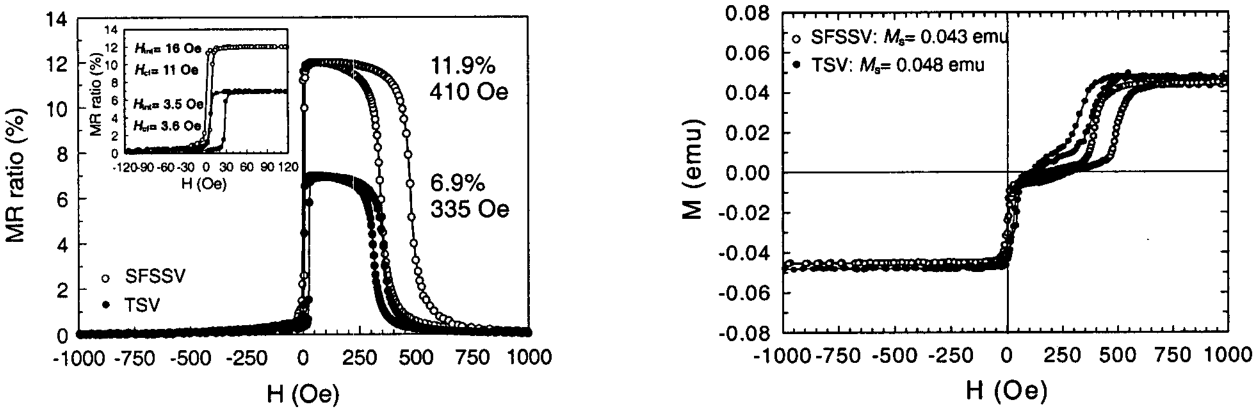
Giant magnetoresistance (GMR) heads are expected to support areal densities beyond 100 Gbit/in², however, as areal densities continue to grow, more advanced spin valve structures are required. The reduction of free layer thickness is very effective in increasing the output of the spin valve heads. However, it causes deterioration of the soft magnetic property of the free layer and a decrease of the magnetoresistance (MR) ratio in traditional spin valves (TSV). These problems are solved by using spin filter spin valve (SFSV) structure [1, 2]. In this paper, we prepared the SSV having the SFL with the structure Ta/NiFe/IrMn/CoFe/(NOL1)/CoFe/Cu/CoFe/Cu/(NOL2)/Ta using 22 at. % Ir IrMn, 25 at. % Co CoFe, and 20 at. % Fe NiFe alloy films, and the dependence of the MR ratio, the interlayer coupling field (H_{int}) and the coercivity of the free layer (H_{cf}) on the free layer thickness (t_F) and the spin filter layer thickness (t_{SF}) have been investigated.

II . EXPERIMENT

The SFSSV films with the structure of substrate/Ta3/NiFe2/IrMn7/CoFe1/(NOL1)/CoFe2/Cu1.8/CoFe(t_F)/Cu(t_{SF})/(NOL2)/Ta3.5 and the TSV films with the structure of substrate/Ta3/NiFe2/IrMn7/CoFe3/Cu1.8/CoFe4/Ta3.5 (in nm) were deposited by dc magnetron sputtering on thermally oxidized Si (100) substrates at room temperature. Two fold layers consisting of Ta and a very thin layer of NiFe were used as under layers to obtain the exchange biasing of the overlaying CoFe by IrMn. A magnetic field of 100 Oe was applied during deposition to induce the uniaxial magnetic anisotropy in ferromagnetic layer. The background pressure of the vacuum chamber was below 2×10^{-8} Torr and the argon (99.9995%) gas pressure was 2 mTorr. The oxidation was done for 3 min with 2 sccm O_2 mixed with 8 sccm Ar resulting in a total pressure of 2 mTorr in a load lock chamber system. In order to induce a exchange coupling field (H_{ex}) between the IrMn layer and the CoFe pinned layer, a series of annealing was applied under a static magnetic field of 1050 Oe in vacuum furnace with a base pressure 8×10^{-7} Torr at various temperature (100 ~ 280 °C). Each annealing at a designated temperature consisted of a 1 h ramp to the temperature, a 1 h soak at the temperature and a 1 h cool down to room temperature. The MR ratio and the magnetic properties of annealed films were measured by a four-point probe method and a vibrating sample magnetometer at room temperature, respectively. In accordance with the study for annealing temperature dependence of the MR ratio and H_{ex}, all the SFSSV and TSV films presented below were obtained after a thermal treatment at 210 °C.

III. RESILTS AND DISCUSSION

Figure 1 shows the typical major MR curves (a) and the magnetization curves (b) for the annealed SFSSV (open symbols) Ta3/NiFe2/IrMn7/CoFe1/(NOL1)/CoFe2/Cu1.8/CoFe1.5/Cu1.5/(NOL2)/Ta3.5 film and the annealed TSV



(a) (b)

Fig. 1. Major MR curves (a) and the magnetization curves (b) for the annealed SFSSV (open symbols) Ta3/NiFe2/IrMn7/CoFe1/(NOL1)/CoFe2/Cu1.8/CoFe1.5/Cu1.5/(NOL2)/Ta3.5 film and the annealed TSV (solid symbols) Ta3/NiFe2/IrMn7/CoFe3/Cu1.8/CoFe4/Ta3.5 film. Minor MR curves are shown in the inset graph of (a).

(solid symbols) Ta3/NiFe2/IrMn7/CoFe3/Cu1.8/CoFe4/Ta3.5 film, and also the minor MR curves are shown in the inset graph of Fig. 1(a). In the magnetization curves of Fig. 1(b), there are obvious shifts in the upper half of the hysterisis loops corresponding to the major MR curves of Fig. 1(a). Enhancement of the MR ratio over 72% compared to the TSV has been achieved for SFSSV even when the CoFe t_F goes down to 1.5 nm. Moreover, the H_{ex} is about 410 Oe, the H_{int} is about 3.5 Oe, and the H_{cf} is about 3.6 Oe compared to TSV (MR ratio = 6.9%, H_{ex} = 335 Oe, H_{int} = 16 Oe and H_{cf} = 11 Oe). In SFSSV, a considerable value of H_{ex} is still maintained and a decrease in H_{int} and H_{cf} is also observed. These results show the SFSSV has the enhanced MR ratio by specular scattering effect and improved soft magnetic properties of a thin free layer even when the t_F is 1.5 nm because the addition of the SFL increases the effective mean free path (λ_{eff}) of the majority spin electrons.

IV. CONCLUSION

Antiferromagnetic $Ir_{22}Mn_{78}$-pinned SFSSV with structure Ta3/NiFe2/IrMn7/CoFe1/(NOL1)/CoFe2/Cu1.8/CoFe(t_F)/Cu(t_{SF})/(NOL2)/Ta3.5 were investigated. It was shown that the MR ratio had been significantly improved for spin valves with ultrathin free layer. An optimal MR ratio of 11.9% was obtained when t_F was 1.5 nm and t_{SF} = 1.5 nm. The MR ratio remained larger than 11% even when the t_F went down 1.0 nm. The H_{cf} of the free layer was smaller than 4 Oe when the t_F was 1 ~ 4 nm. Furthermore, the property of H_{int} could be explained by considering the RKKY and magnetostatic coupling. Thus, it was found that the SFL made it possible to reduce the free layer thickness and enhance the MR ratio without degrading the soft magnetic property of the ultrathin free layer.

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V. REFERENCES

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