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BOTTOM IrMn-BASED SPIN VALVES BY USING OXYGEN SURFACTANT†

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1. INTRODUCTION

To reach 100 Gbit/in^2 magnetic recording densities in hard disk drives specular enhancement of giant magnetoresistance (GMR) effect in spin valve (SV) films has become one of the indispensable means for application as read elements in recording heads [1]. More recently specular spin valve (SSV) structure containing nano-oxides layers (NOL) were reported [2], where MR enhancement is caused to extended mean free path of majority spin polarized electrons through specular reflection at metal/insulator interfaces [3] in the SV films. In this work, we report the fabrication of specular bottom MnIr-based SSVs with NOL prepared by O_2 exposure. The effect of the thickness of CoFe pinned layer deposited prior to exposure to O_2 flows on magnetoresistive properties of the SSV has been investigated.

2. EXPERIMENTAL

The SSV films with the structure (A) of Ta30/NiFe20/IrMn70/CoFe*t*/oxidation/CoFe(30-*t*)/Cu20/CoFe30/Ta35 (all thickness in angstroms) and the dual SSV films with the structure (B) Ta30/NiFe20/IrMn70/CoFe10/oxidation/CoFe20/Cu20/CoFe30/Cu23/CoFe30/IrMn70/Ta30 were deposited by the dc magnetron sputtering on thermally oxidized Si (111) substrates at room temperature under a magnetic field of about 100 Oe. Oxidation indicates exposure to different O_2 (99.9999%) flows. The background pressure was below 5×10^{-8} Torr and the working pressure was 2 mTorr. The oxygen exposure was done for 3 min with 0.4~2.4 sccm O_2 mixed with 8 sccm Ar resulting in a total pressure of 2 mTorr in load lock chamber system. A series of annealing were applied during 1 h under a magnetic field of 1050 Oe in vacuum furnace with a base pressure 5×10^{-7} Torr. The MR ratio and magnetization curves were measured by a four-point method and a vibrating sample magnetometer (VSM), respectively. The film surface roughness and the film interfacial morphology were determined by scanning probe microscopy (SPM) and x-ray reflectivity (XRR) using Cu $K\alpha$, line, respectively.

3. RESULTS AND DISCUSSION

Fig. 1 shows the annealing temperature dependence of the MR ratio and H_{ex} for the SSV (solid symbols) with t= 10 Å, which was exposed for 3 min with 2 sccm O_2 flow, and conventional spin valves (CSV) (open symbols) Ta30/NiFe20/IrMn70/CoFe30/Cu20/CoFe30/Ta35 annealed for a 1 h. The MR ratio and exchange coupling field (H_{ex}) of the SSV and CSV increase up to 220 ℃ of annealing temperature, and then fall to zero at 280 ℃, and 260 ℃, respectively. It is suggest that the formation of a NOL improved thermal stability toward diffusion of the SSV. The major MR curves of a SSV and CSV previously subjected to annealing for a 1 h at 220 ℃ are shown in Fig. 2(a), and also the minor curves are shown in inset graph of Fig. 2(b). The MR ratio and H_{ex} increase from 5.6% to 8.6% and from 250 Oe to 275 Oe with O_2 exposure, respectively. In addition, the interlayer coupling field (H_{int}) between free layer and pinned layer and the coercivity of the free layer (H_{cf}) are smaller in the SSV. Effectively, only a small decrease (~8%) of the SSV magnetic moment is observed after inserting the NOL layers as shown in Fig. 2(b). As shown in inset graph of Fig. 2(a), the MR ratio of dual SSV increases from 10% to 12.2%. In Fig. 3, the MR ratio and H_{ex} are given for the SSV. When the O_2 exposed surface is closer to the IrMn surface with decreasing t, MR ratio increases and reaches peak at a critical thickness before decreasing rapidly. The critical thickness tends to be larger for SV films exposed to higher O_2 flows. The rapid decrease of MR ratio in t for values slightly under critical thickness coincides with the significant degradation in the H_{ex} as can be seen inset graph of Fig. 3. This degradation of H_{ex} probably results from the damaged pinning properties of IrMn due to the proximity of the O_2 exposed CoFe surface to IrMn. Fig. 4 shows the incidence angle dependence of the specular XRR measurements for SV films prepared (a) with (t=10) and (b) without (t=0) the O_2 exposure, respectively. The XRR data show the interfaces of the SSV film with O_2 exposure are smoother than the CSV film, in agreement with the observed decrease of the value of rms surface roughness from 2.33 Å to 1.19 Å by SPM measurements.

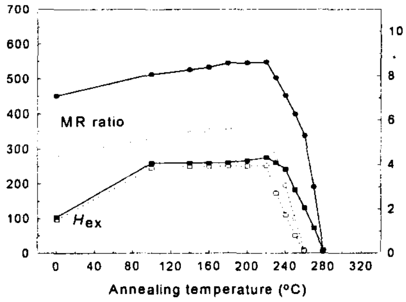

Fig. 1. The annealing temperature dependence of the MR ratio and H_{ex} for the SSV (solid symbols) and CSV (open symbols).

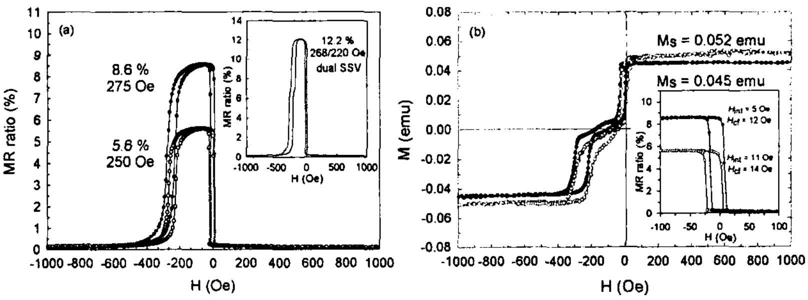

Fig. 2. The major MR curves (a), minor MR curves (inset graph of (b)), and magnetization curves (b) of SSV and CSV annealing for a 1 h at 220 °C. Inset graph of (a) shows MR curves of dual SSV.

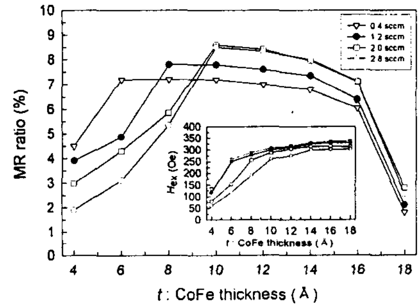

Fig. 3. MR ratio and H_{ex} (inset graph) of the SSV as a function of the CoFe thickness, t, deposited prior to exposure to various O_2 flows (0.4~2.8 sccm).

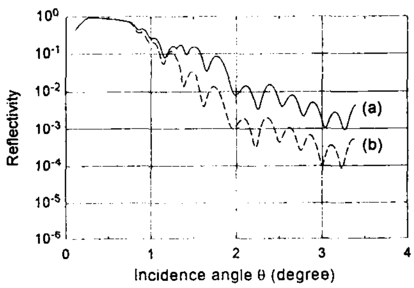

Fig. 4. Incidence angle dependence of specular x-ray reflectivity of the SSV (solid curve (a)) and CSV (dashed curve (b)).

4. CONCLUSIONS

In conclusion, the specularity of bottom IrMn-based SV with structure Ta30/NiFe20/IrMn70/CoFet/oxidation/CoFe(30-t)/Cu20/CoFe30/Ta35 was investigated through exposure of part of the CoFe pinned layer to different O_2 flows. The optimal enhancement in MR ratio depends significantly on the location of the O_2 exposed surface within CoFe pinned layer and on the O_2 partial pressure used. The H_{ex} decreases when the O_2 exposed CoFe surface is too close IrMn. Under optimal conditions, a MR ratio of 8.6% with H_{ex}~275 Oe for the bottom single SSV and MR ratio 12.2% with H_{ex}~268/220 Oe for the dual SSV were obtained. XRR data show smoother interfaces for the SV subjected to O_2 exposure. Thus the MR ratio enhancement coupled with the lower H_{int}, R_s, and magnetic moment of the SSV can be attributed to an enhanced specular scattering as a result of smoother interfaces after O_2 exposure.

5. REFERENCES

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