

Effects of annealing on structural and TMR properties in rf-sputtered CoFeB/MgO/CoFeB magnetic tunnel junctions

J. Y. Bae^{1*}, D. J. Kim¹, W. C. Lim¹, T. D. Lee¹, K. W. Kim² and T. W. Kim²

¹ Department of material science & engineering , KAIST, Daejeon

² Device Lab., SAIT, Suwon

1. Introduction

Theoretical calculation for Fe/MgO/Fe predicted several 1000% TMR ratio [1, 2]. Immediately after their predictions, the experiments have demonstrated over 100% TMR ratio in the MTJs with Fe/MgO/Fe and CoFe/MgO/CoFe [3, 4]. Later the CoFeB/MgO/CoFeB junctions showed better properties than the CoFe/MgO/CoFe junctions because the MgO layer had a good crystalline structure with (001) texture and smooth and sharp interface between CoFeB/MgO [5]. The (001) growth of the MgO barrier without extra oxidation of electrode materials is crucial factor of high TMR ratio. We will investigate the deposition method of the MgO barrier and annealing effect on structural and magnetic properties of magnetic tunnel junctions in RF sputtering system.

2. Experiment

Magnetic tunnel junctions of Ta (30 nm)/NiFe (8 nm)/ IrMn (10 nm)/CoFeB (4nm)/MgO (2 nm)/CoFeB (5 nm)/Ta (5m) were deposited on the thermally oxidized Si wafers by a 7-target magnetron UHV sputtering system. The junctions of $10\mu\text{m}\times 10\mu\text{m}$ were fabricated by a photolithographic method to measure the MR ratio. The junctions were deposited with an applied magnetic field of 500Oe to align an easy axis of magnetization. The MgO tunnel barrier was formed by rf-sputtering from MgO composite-target. The junctions were annealed at temperatures ranging from 200-380 °C under vacuum (-3×10^{-6} Torr) for 1 hr in 1000 Oe magnetic field. The phase identity of the films was investigated by XRD. The interface of the films was investigated by high resolution TEM, and the MR transfer curve was measured at room temperature using a two-point probe measurement system with fields up to 120 Oe.

3. Results and Discussion

Typical MR curves are shown in Fig. 1 (a) annealed at 280°C, (b) annealed at 340°C and (c) annealed at 380°C for 1hr. The TMR curve of the 280°C annealed junction shows a relatively small MR of ~35%. The TMR ratio increased drastically by higher than 340°C annealing and a TMR ratio of 110% obtained after 380°C annealing. The exchange bias decreased after 380°C annealing, shown in Fig. 1 (c). The RA product of magnetic tunnel junction annealed at 280°C ($\sim 450\text{k}\Omega\mu\text{m}^2$) was little higher than those of the other junctions annealed at 340°C ($\sim 180\text{k}\Omega\mu\text{m}^2$) and 380°C ($\sim 100\text{k}\Omega\mu\text{m}^2$). In order to see the annealing effect on magnetic tunnel junctions, we analyzed them with high resolution TEM. The HRTEM images in Fig. 2 shows the CoFeB/MgO/CoFeB interfaces for the annealed junctions (a) as-deposited, (b) annealed at 280°C, (c) annealed at 340°C and (d) annealed at 380°C. The MgO barrier showed (001) texture at as-deposited and annealed junctions. At as-deposited state, the top and bottom CoFeB electrodes

were amorphous structure and the CoFeB electrodes showed amorphous structure up to 280°C annealing. The crystallization partially appeared after 340°C annealing at the interface between the MgO barrier and CoFeB layers and CoFeB layers had complete crystal structure after 380°C annealing. Crystallization of amorphous CoFeB with lattice matching to MgO (100) occurred at the interface between MgO and CoFeB after annealing at 340°C, shown in Fig. 2 (c). The (100) plane of MgO makes an angle of 45° with (110) plane of CoFeB, suggesting that the following orientation relation exists on MgO/CoFeB interface; MgO (100) [001] || CoFeB (100) [110]. Therefore, the annealing changes the interface structure from amorphous CoFeB/crystalline (100) MgO to crystalline (100) CoFeB/crystalline (100) MgO, producing high TMR ratio.

4. Acknowledgments

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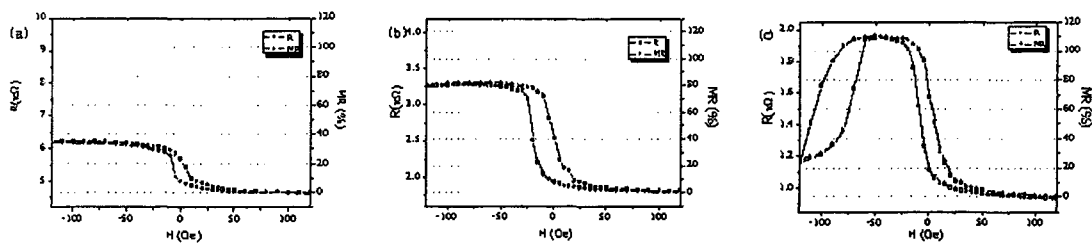


Figure 1 a) The measured MR curves of CoFeB/MgO/CoFeB junctions, a) annealed at 280°C, b) annealed at 340 °C and c) annealed at 380 °C for 1hr

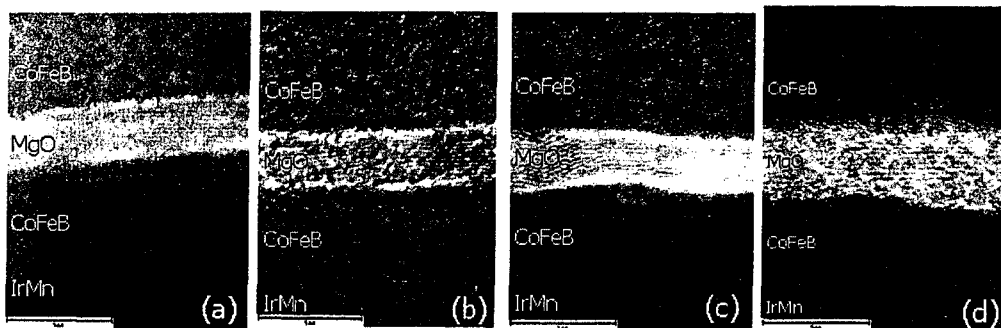


Figure 2 The HRTEM images in CoFeB/MgO/CoFeB interfaces for the annealed junctions a) as-deposited, b) annealed at 280°C, c) annealed at 340°C and d) annealed at 380°C.

5. References

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