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Characteristics of the AlOx barrier with CoFeB Pinned Layer in Magnetic Tunnel Junctions

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1. Introduction

The magnetoresistance(MR) ratio and junction resistance(RA) of magnetic tunnel junctions (MTJs) depends on the charateristics of the insulating layer interface. The CoFeB amorphous magnetic thin films have been givenincreasing attention for application to spin valve structure due to their low coercivity and high electrical resistivity. This amorphous electrode is expected to improve the properites of the insulating barrier interface in MTJs. There have been reported high MR ratios with the amorphous electrode.[1,2] In this work, amorphous FM electrode, CoFeB, was used in MTJs to improve the property of the insulating layer interface. In order to understand the effects of the electrode on magnetic properties, the amorphous CoFeB and the crystalline CoFe were used for MTJs pinned layers. We have studied characteristics of the interface between the insulating layer and the pinned layer and their effects on MR ratio and resistance.

2. Experiment

CoFeB tunnel junctions were prepared in a DC magnetron sputtering system with a base pressure of 3×10^{-8} Torr and deposition pressure of 1 mTorr. The structure of MTJs was Ta(50nm)/NiFe(8nm)/IrMn(10nm)/PL(4nm)/AlOx(Al 1.1nm)/CoFeB(3nm)/NiFe(15nm). The CoFeB and the CoFe were used for pinned layers. n these junctions the following three different PLs were used CoFeB 4nm (PL1), CoFe 1nm/CoFeB 2nm/CoFe 1nm (PL2) and CoFe 4nm (PL3). The junctions were made by a photolithographic method to measure the MR ratio. The samples were annealed from 200°C to 380°C for 50min with a magnetic field in a vacuum atmosphere with a pressure of 3×10^{-6} Torr. To study the characteristics of interface between insulating layer and pinned layer the depth profiles of the insulating barrier before and after annealing were analyzed by XPS and SIMS.

3. Results and discussion

Fig. 1 shows change of MR ratio and RA products with annealing temperature. When the CoFeB was used for the pinned layer, the MR ratio was higher than that of CoFe pinned layer after annealing process. The maximum MR ratios were shown on 260°C annealing. In CoFeB pinned junctions, the RA products increased with increasing annealing temperature up to 380°C annealing. The RA products increased up to a 280°C annealing and decreased over this temperature in the tunnel junctions with CoFe pinend layer.

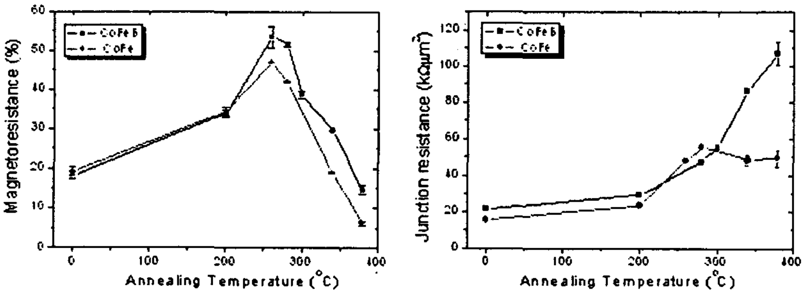

Fig. 1 Magnetoresistance and junction resistance change with annealing temperature

To study the different behavior of the junction resistance in two different MTJs, the depth profile of Al_2O_3 insulating layer was analyzed by XPS in the as-deposited states and after annealed states.Fig. 2 and 3 show the XPS depth profiles of B and O in AlOx barrier in the CoFeB pinned MTJs at the as-deposited and annealed states respectively. Both of the B 1s and B-oxide 1s peaks existed in AlOx layer. The O peaks were separated by AlOx and B_2O_3peaks near the interface of CoFeB/AlOx after anneling in Fig. 3. However B-oxide peak and O peaks separation were not observed in AlOx layer of the CoFe pinned MTJs. The B diffusion into AlOx layer was also confirmed by depth profile of SIMS. This results indicate B in CoFeB layer diffuse into AlOx barrier even before the crystallization of CoFeB pinned layer.[3] High resolution TEM image analysis showd the CoFeB pinned layer begins crystallization after 340°C annealing. This formation of B-oxide is the main reason for the increase of RA values with annealing temperature in CoFeB pinned MTJs.The higher MR in the MTJ with the CoFeB layer must be associated with clean interface formation at AlOx and CoFeB pinned alyer. The XPS data show B exist as B_2O_3, which has a comparable heat of formation to AlOx..As shown Fig.3 b) the existence of B_2O_3 at the Al and CoFeB pinned layer indicates excessive O forms B-oxide and this makes crystal and clean interface.

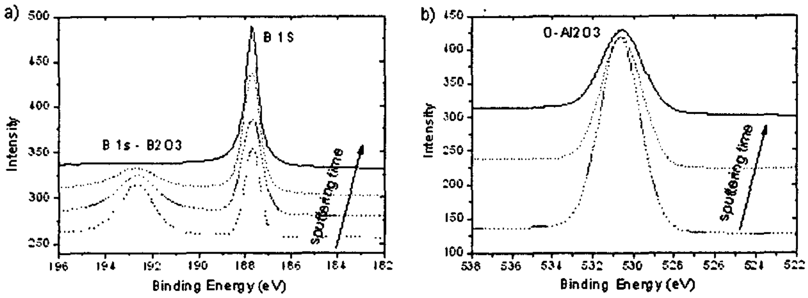

Fig. 2 The depth profile of a) B 1s peaks and b) O 1s peaks at as-deposited state in Al_2O_3 barrier of CoFeB pinned magnetic tunnel junctions.

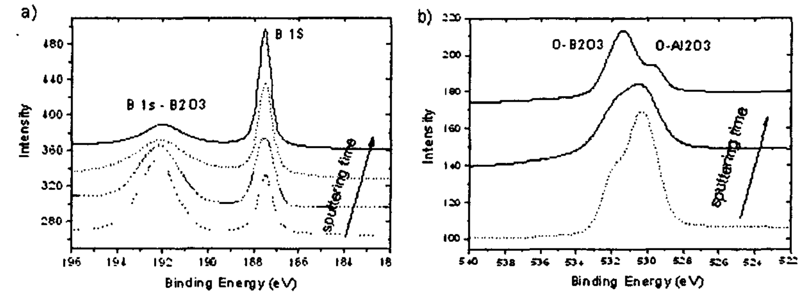

Fig. 3 The depth profile of a) B 1s peaks and b) O 1s peaks at annealed state in Al_2O_3 barrier of CoFeB pinned magnetic tunnel junctions.

4.Conclusion

The characteristics of the insulating barrier interface were investigated in annealed MTJs with the amorphous CoFeB and crystalline CoFe pinned layer structures. The B diffused into adjacent AlOx layer during the annealing and the B-oxide was formed at the interface of CoFeB and AlOx. The higher MR in the MTJ with the CoFeB layer was associated with clean interface formation at AlOx and CoFeB pinned layer. As shown XPS profiles, the existence of B_2O_3 at the Al and CoFeB pinned layer indicates excessive O forms B-oxide and this makes crystal and clean interface.

5.Reference

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[2]K. Tsunekawa, Y. Nagamine, H. Maehara , 9th Joint MMM/Intermag conference BD

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