Effect of composition and structure on exchange anisotropy of IrxMn(100-x)/NiFe films

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Exchange anisotropy between IrMn antiferromagnetic layer and NiFe ferromagnetic layer has been studied in IrxMn(100-x)/NiFe/Buffer/Si(100) films deposited by D. C. magnetron sputtering method. Among Zr, Ta, and Cu used as buffer layer, Zr and Ta enhanced the fcc (111) texture of NiFe and IrMn layer, but Cu did not affect microstructure of those layers. Strong fcc (111) texture of IrMn layer was confirmed to be the origin of exchange anisotropy of IrMn. Ir composition control in IrMn layer showed that γ-phase IrMn is stabilized between 10 and 30 at. % Ir, and 21 at. % Ir in IrMn layer was optimum composition that showed maximum exchange anisotropy field. above 200 Å thickness of IrMn, antiferromagnetic property is stabilzed to show saturated exchange anisotropy field. Base pressure was confirmed to be critical requisite in IrMn-based spin-valve GMR system.

1. Introduction

Recently, Giant Magnetoresistance(GMR) device has become attractive for future high areal density read head or magnetic sensor.[1] The GMR effect appears in many systems such as antiferromagnetic coupled multilayers, uncoupled multilayers, and exchange-biased spin-valve multilayers.[2] Among those, exchange-biased spin-valve system composed of antiferromagnetic pinning layer, ferromagnetic pinned layer, nonmagnetic spacer layer, and ferromagnetic free layer shows high magnetoresistance and good sensitivity thus has a good application possibility.

Antiferromagnetic layer of spin-valve system prevents ferromagnetic pinned layer from magnetization reversal, that is 'exchange-biased', which gives exchange anisotropy on pinned layer.[3] Antiparallel magnetization arrangement between reversed magnetization of free layer by external field and exchange-biased magnetization of pinned layer by antiferromagnetic layer is origin of magnetoresistance.

We have studied on the exchange anisotropy of the system with IrMn as antiferromagnetic layer and NiFe as ferromagnetic layer through investigation of microsturucture and magnetic properties.

2. Experimental Procedure

Si (100) wafers were used as substrate. The specimens were prepared on the size of 10mm$\times$10mm square. IrMn/NiFe/Buffer multilayer deposited onto the substrate. Deposition was performed by D.C. magnetron sputtering in the presence of 300 Oe magnetic field along the film plane with a base pressure of 1.5×10^{-6} Torr. Ta, Zr, and Cu were used as a buffer layer, respectively. NiFe alloy target for NiFe layer and high purity Mn target and Ir chips for IrMn layer were used. NiFe deposition conditions were fixed of 4 mTorr Ar pressure and 24 W input power for 100 Å thickness. Thickness of IrMn was varied 50$\sim$500 Å but Ar pressure was fixed 4 mTorr. The Ir concentration of IrMn layer was changed by the number of Ir chips on a Mn target.

The composition of IrMn layers were analyzed by EPMA and RBS. Crystal structure of the multilayer was investigated by XRD and HRTEM and vibrating sample magnetometer was used for magnetic property analysis.

3. Results and discussion

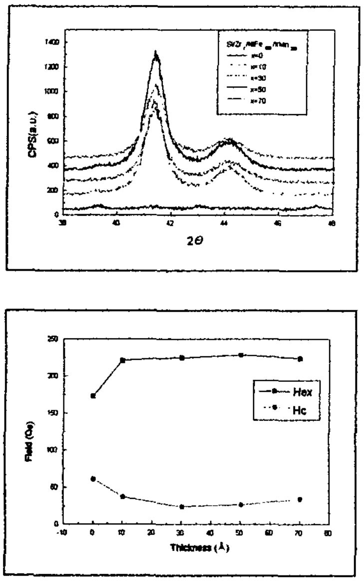

Fig. 1 Zr Buffer

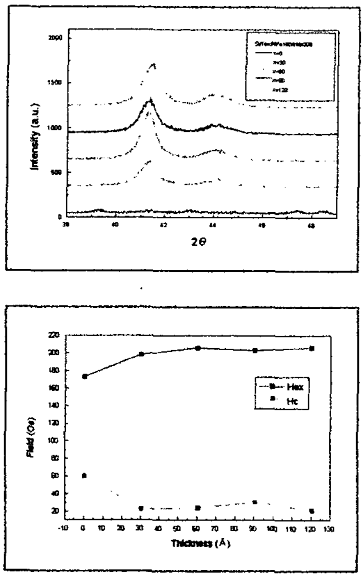

Fig. 2 Ta Buffer

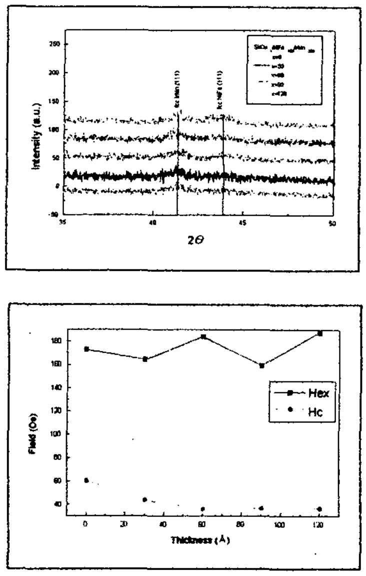

Fig. 3 Cu buffer

3.1 Effecct of buffer layer

Fig. 1 indicates magnetic properties and microstructure changes with respect to the variation of Zr buffer layer thickness. Exchange anisotropy field (Hex) increases then becomes saturated and coercive force (Hc) decreases as Zr layer is getting thicker. The reason of this phenomena can be explained by the growth of (111) texture in NiFe and IrMn layers. Critical condition that IrMn layer can show antiferromagnetic propertiy is (111) texture and this condition can be fulfilled by insertion of proper buffer layer, which is proved by XRD patterns. Above 50 Å of Zr thickness, Zr layer with a contiuous and stable film structure provides the multilayer with fcc (111) texture of NiFe and IrMn. Diminution of Hc can be explained by interface roughness enhancement and grain size refinement. RMS roughness decreases as film thickness increases. Fig. 2 indicates magnetic properties and microstructure changes with respect to the variation of Ta buffer layer thickness. Ta buffer layer shows similar effects on

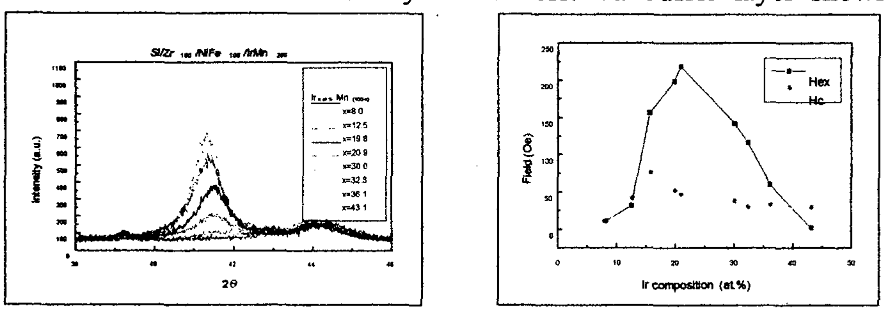

Fig. 4 Hex, Hc and microstructure with Ir composition

NiFe/IrMn layers with Zr buffer layer. Effect of Cu buffer layer is shown on Fig. 3 Cu buffer does not affect microstructure of NiFe/IrMn layers thus no texture appears.

3.2 Effect of composition

Fig. 4 indicates relationship between Ir concentration of IrMn layer and magnetic properties and microstructures. In Ir-Mn alloys between 10~30 at.% Ir, the fcc structure can be preserved down to room temperature. In the region of stabilized γ -Mn phase, there exists optimum composition of 21 at.% Ir that makes Hex maximum, 230 Oe.

3.3 Effect of thickness of IrMn layer

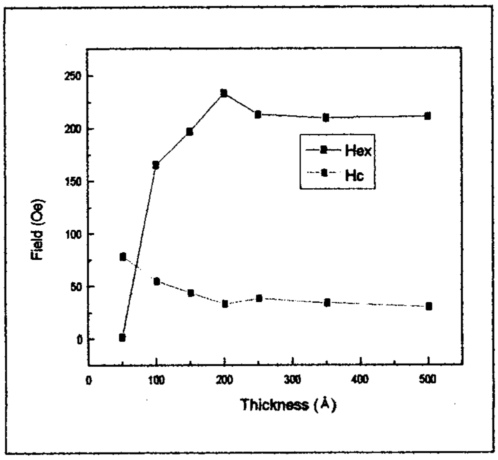

Fig. 5 Hex and Hc variation with IrMn thickness

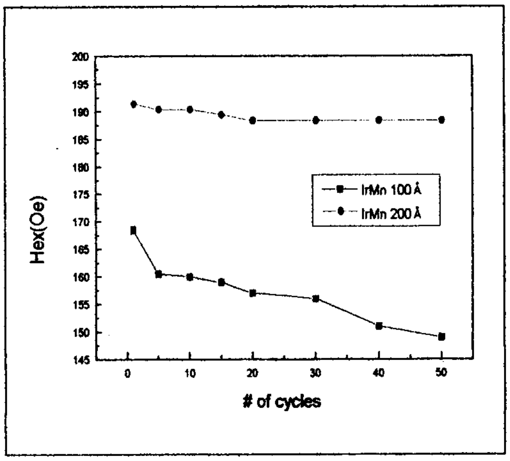

Fig. 6 Training effect comparision of 200Å with 100 Å IrMn

According to fig. 5, IrMn layer needs enough thickness for magneto- crystalline anisotropy that enables the antiferromagnetic property. Above 200Å thickness, stable antiferromagnetic layer can prevent magnetization reversal of pinned ferromagnetic layer. Fig. 6 shows magnetic stability of 200 Å IrMn layer compared to that of 100 Å IrMn layer by training effect comparision.

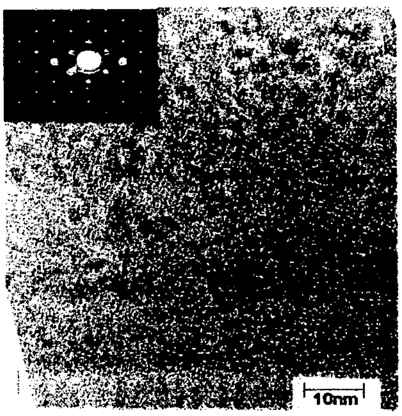

Fig. 7 IrMn/NiFe/Zr multilayer deposited after 8×10^{-6} Torr base pressure

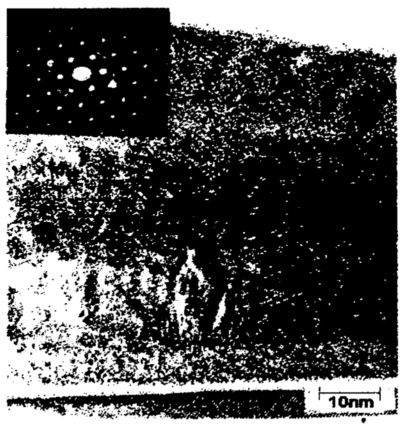

Fig. 8 IrMn/NiFe/Zr multilayer deposited after 2×10^{-6} Torr base pressure

NiFe/IrMn layers with Zr buffer layer. Effect of Cu buffer layer is shown on Fig. 3 Cu buffer does not affect microstructure of NiFe/IrMn layers thus no texture appears.

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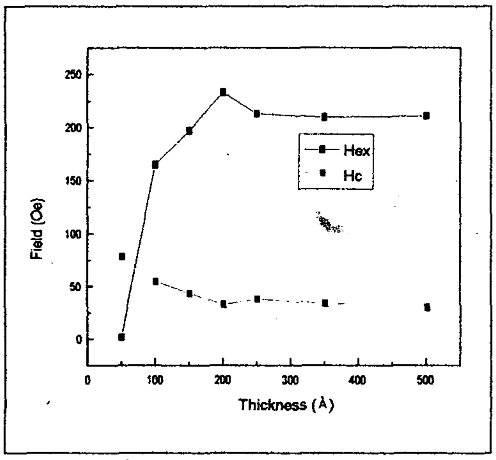
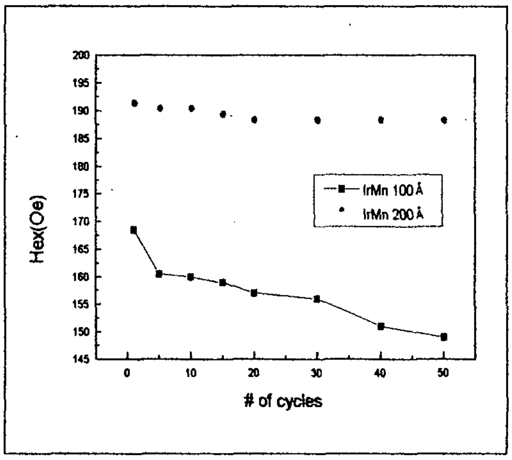


Fig. 5 Hex and Hc variation with IrMn thickness



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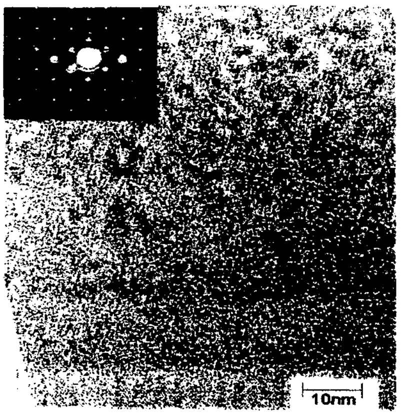

Fig. 7 IrMn/NiFe/Zr multilayer deposited after 8×10^{-6} Torr base pressure

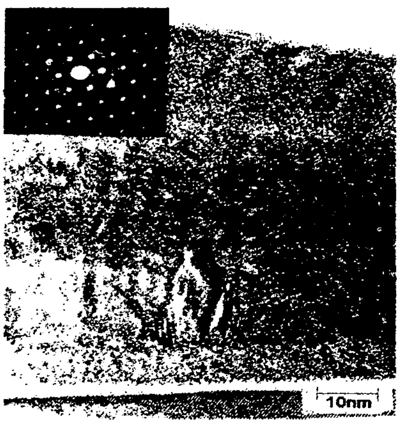

Fig. 8 IrMn/NiFe/Zr multilayer deposited after 2×10^{-6} Torr base pressure

3.4 Effect of base pressure

IrMn/NiFe/Zr multilayers deposited after low vacuum shows amorphous and no texture because of impurity gas molecules as multinucleation sites. But that of high vacuum shows epitaxi at interface between IrMn and NiFe and texture in spot pattern. Hex of the former multilayer is zero, that is no sfift of hysteresis. Otherwise, that of the latter is 60 Oe. Thus high vacuum is critical requisite in this process.

4. Conclusion

The exchange anisotropy and microstructure of IrMn/NiFe layers with various buffer layer were investigated. IrMn/NiFe layers with Ta or Zr buffer showed strong fcc (111) texture thus high Hex, but Cu buffer did not affect microstructure of the layers. The fcc IrMn structure (γ-Mn phase) was obtained at 21 at.% Ir, which corresponds Ir-Mn phase diagram. Above 200 Å thickness, IrMn layer showed stable anisotropy on 100 Å NiFe layer. It was confirmed that base pressure was critical factor in IrMn based spin-valve system.

The IrMn/NiFe with proper buffer layer can be promising candidate for spin-valve GMR head application.

5. References

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[3] A. P. Malozemoff, J. Appl. Phys., vol. 63, No.8., 15 April (1988)