Effects of Short-Range Roughness on Exchange Coupling in NiO Spin-Valves

C. M. Park*, K. A. Lee
Physics Department, Dankook University
D. G. Hwang, S. S. Lee,
Physics Department, SangJi University

I. INTRODUCTIONS

Although extensive works have been carried out to study various kinds of exchange coupled systems, the exchange coupling mechanism is not yet fully understood[1]. In our previous study, the $\mathbf{H}_{ex}$ of the NiO/NiFe bilayers epitaxially deposited on MgO(111), (110) and (100) substrates were independent on the crystallographic orientation of NiO films[2]. Also Lai, et. al., reported that the $\mathbf{H}_{ex}$ of the exchange-coupled bilayers does not depend on the degree of interfacial roughness and the existence of (111) texture at all, but rather is enhanced in the small-grained NiO due to the formation of small domains in NiO [3]. In this article we describe more detailed investigation of exchange coupling properties, crystal orientations and surface morphologies of NiO films.

II. EXPERIMENTALS

NiO films were deposited on Corning glass 7059 by rf-magnetron sputtering of a sintered powder target of 3-inch diameter at the Ar partial pressure of 1.5 mTorr. The deposition rates of the NiO film were varied from 6 Å/min to 36 Å/min. The uniaxial magnetic field during deposition was applied to 320 Oe. Other metals were deposited by dc-magnetron sputtering. The exchange coupling field $\mathbf{H}_{ex}$ and coercive field $\mathbf{H}_{c}$ for the NiO/NiFe bilayers were obtained from Magnetoresistance(MR) curves. The crystal orientations and surface morphologies of NiO films were characterized using x-ray diffraction and atomic force microscope(AFM).

III. RESULTS AND DISCUSSIONS

The MR curves of the $NiFe_{50A}\backslash Cu_{20A}\backslash NiFe_{50A}$ spin-valves on the NiO films deposited at 6 Å/min and 30 Å/min, as shown in figure 1, have a almost same MR ratio of 4%, but these shapes are very different due to the change of the $\mathbf{H}_{ex}$ and $\mathbf{H}_{c}$. The rms roughnesses for 6 Å/min and 30 Å/min are similar to 4.2 Å and 5.5 Å, however, as shown in the AFM images of fig.2, the morphology for the high rate of 30 Å/min has a very finer cluster than that of 6 Å/min. Figure 3 shows the MR major and minor curves of $NiFe_{50A}\backslash Cu_{50A}\backslash NiFe_{50A}$ spin-valves on the modulated NiO films such as (C) glass\$NiO_H$(300 Å)\$NiO_L$(300 Å) and (D) glass\$NiO_L$(300 Å)\$NiO_H$(300 Å)\$NiO_L$(300 Å). The MR curve of the spin-valves with glass\$NiO_H$(300 Å)\ NiO_L(300 Å) is similar to that of the NiO spin-valves deposited at 6 Å/min, as shown in figure 1(a). And, In figure 4(C), the AFM image of this NiO is analogous to the surface of 6 Å/min, even if the rms roughness of the modulated NiO film increased to 8.5 Å. Also, the MR curve of the sample D is similar with that of 30 Å/min. In AFM image of figure 4(D), the rms roughness is 6.4 Å, however, the short-range order roughness shows a finer than that of the sample C.

VI. CONCLUSIONS

The $\mathbf{H_{ex}}$ and $\mathbf{H_c}$ increased with deposition rates of NiO film. It is discussed by short-range order roughness rather than rms roughness. The exchange coupling in the modulated NiO films depends on inserted NiO$_H$ and top NiO$_H$ rather than bottom NiO$_H$.

REFERENCES

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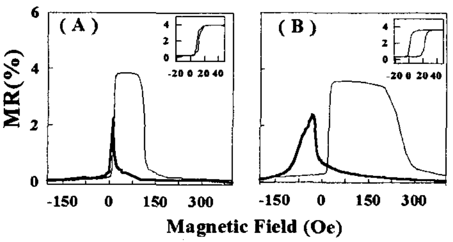


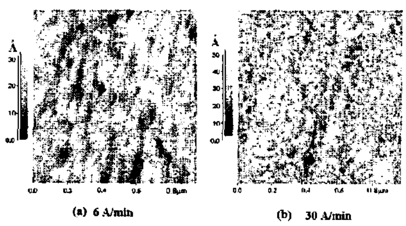
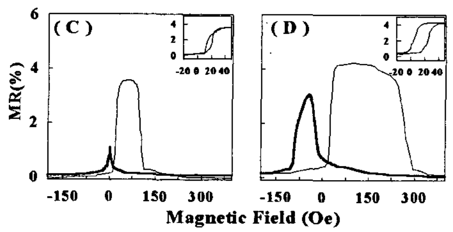


Figure 1. The MR curves of the NiFe$_{50Å}$\Cu$_{50Å}$\NiFe$_{50Å}$ spin-valves on (A) glass\NiO(300 Å at 6A/sec) and (B) glass\NiO(300 Å at 30A/sec).

Figure 2. The AFM images of the NiO$_{600Å}$ films deposited at (a) 6 Å/min and (b) 30 Å/min.



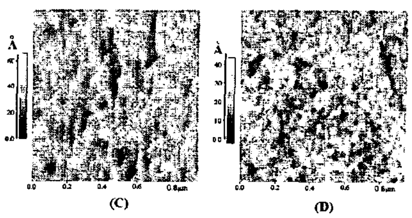


Figure 3. The MR curves of the NiFe$_{50Å}$\Cu$_{50Å}$\NiFe$_{50Å}$ spin-valves on the modulated NiO films such as (C) glass\NiO$_H$300 Å)\NiO$_L$(300 Å) and (D) glass\NiO$_L$(300 Å)\NiO$_H$(300 Å)\NiO$_L$(300 Å), where NiO$_L$ and NiO$_H$ were deposited at 6 Å/min and 30 Å/min, respectively.

Figure 4. The AFM images of the modulated NiO films such as (C) glass\NiO$_H$(300 Å)\NiO$_L$(300 Å) and (D) glass\NiO$_L$(300 Å)\NiO$_H$(300 Å)\NiO$_L$(300 Å).