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The effect of intrinsic transport properties of NiFe thin film on the AMR characteristics

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1. Introduction

NiFe thin film, alone or as a layer in multilayers, has been studied to a great amount for the application of magnetoresistive (MR) sensors and reading heads. Recently, more and more thin film has been required for high sensitivity and diverse applications and even more deep study of intrinsic transport properties, which affect the resistivity and the magnetoresistance, become of great importance. For this purpose we examined the thickness dependence of resistivity and anisotropic magnetoresistance (AMR) of $Ni_{18}Fe_{19}$ films with four different process parameters and compared our experiment results with the size effect theory for the free electron model i.e. Fuch-sondheimer model. Then we investigated the effects of intrinsic transport properties such as specularity, mean free path and bulk resistivity on the AMR of $Ni_{18}Fe_{19}$ thin films. Furthermore the influence of microstructure of films on those intrinsic transport properties and thus on the AMR were also studied.

2. Experiment

$Ni_{18}Fe_{19}$ films were deposited on the glass substrate by DC magnetron sputtering with Ar pressures of 1 and 2mTorr, DC powers of 50 and 100W at a base pressure of $5*10^{-7}$ Torr.

Film thickness and surface roughness were measured by long scan profiler and atomic force microscope (AFM) respectively. Four-point probe method was used for the measurement of resistivity. Inplane traverse AMR of films were measured and the samples for AMR measurements were patterned with Cr mask and Ar ion beam dry etching. Microstructures of films were investigated by X-ray diffraction (XRD) and transmission electron microscopy (TEM).

3. Results and Discussion

Figure 1 is the plot of maximum AMR of $Ni_{18}Fe_{19}$ films with four different process parameters. The vertical axis represents the normalized maximum MR of $Ni_{18}Fe_{19}$ films by the maximum MR of film with the process parameter of 50W-2mTorr (we call it reference) which presents the lowest MR for all thickness. The marked values on each symbol represent the real maximum AMR under fully saturated magnetic field.

All films with four different process parameter show the same trend with thickness, i.e. the slight change of MR at the high thicknesses of 500 and 1000 Å, and the large reduction (about half) of MR at the thickness of 100Å. Films with different process parameters at high thicknesses show relatively small discrepancies of MR, but films at the thickness of 100Å show the outstnadingly large discrepancies of MR, espacialy the MR of film with the process parameter of 100W-1mTorr increases 43% compared to that of reference.

To analyze these results we compared our experiment results of the thickness dependence of resistivity with the size effect theory for the free electron model (Fuch-sondheimer model). Transport properties such as ρ_0(the resistivity of infinite thick films), l (mean free path of infinite thick films), and P (specularity : the probabiliy of specularly scattering conduction electron) extracted from comparison are sumarized in table 1.

Although ρ_0 of all films show similar values, l of four films show some different values. When l is high, the AMR of film increases relatively. High mean free path seems to be a result of the reduced defects, such as grain boundary, which is essentially spin independent scattering, and thus contributes to the increase of AMR of thick films.

To investigate further on this issue, we examined the texture of films with the thickness of 1000 Å and the rms surface roughness of films with the thickness of 100 Å. The degree of texture was determined from the full width at half maximum (FWHM) of locking scale XRD patterns of films. Table 1 also sumarizes these resulsts. The degrees of texture which have an effect on the electron transport show no differences for all films. Instead, the variation of the surface roughness of the films is in accordance with the variation of *l* and consequently AMR of films. The better microstructure, such as good intergranular connectivity, of films usually correlates with the low surface roughness. Further investigation including TEM will be discussed.

When the thickness of film is reduced to be comparable with the mean free path of conduction electrons, surface scattering besides the granboundary scattering of bulk material gives a significant contribution to electron transport. This surface scattering increases the resistivity of thin film and thus reduces the AMR of thin films. This is in good agreement with our experiment results in figure 1, that is, the the large reduction of MR at the thickness of 100 Å. Furthermore it can be infered that the higher the specularity, the lower and the better the resistivity and AMR of thin film. The steep increments of MR for Films with process parameter of 100W series are due to their about 2 times higher specularites than films with process parameter of 50W series and this may also have a strong relevance to microstructure.

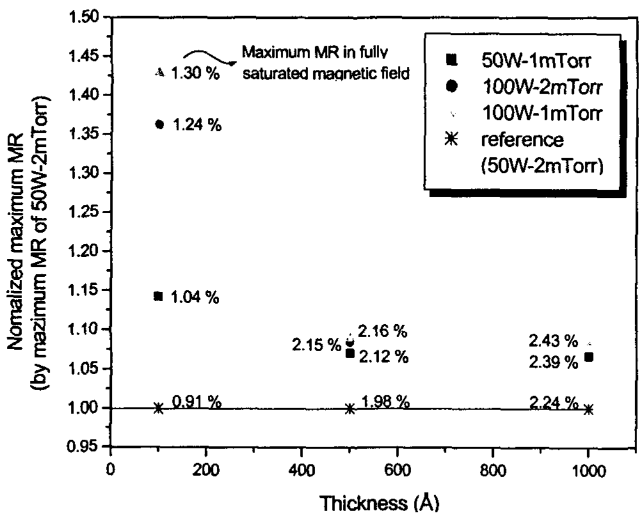

Fig. 1 The plot of AMR as a function of thickness for $Ni_{18}Fe_{19}$ films with four different process parameters

	ρ0 ($\mu\Omega$cm)	specularity (P)	mean free path (Å)	rms roughness (Å)	Degree of texture (FWHM of rocking curve at 2θ<11>=44°)
50w -1mTorr	26	0.10	135	3.47	21
50W -2mTorr	27	0.08	140	3.62	21
100W -1mTorr	26	0.18	155	3.04	21
100W -2mTorr	27	0.15	150	3.06	21

Table 1 Sumarized properties of $Ni_{18}Fe_{19}$ films with four different process parameters

4. Conclusion

From above our experiment results and its comparison with the size effect theory for the free electron model we conclude as follows

(1) Intrinsic transport properties, such as ρ_0, *l*, *P*, of $Ni_{18}Fe_{19}$ films which is related with microstructure are the important factors influencing the resistivity and the AMR of films

(2) The dependence of AMR properties of $Ni_{18}Fe_{19}$ films on the process parameter is greater at thin films than thick films and it was found that specularity is the main intrinsic transport properties affecting AMR of thin films.

5. References

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