P-23

ORIGIN OF EASY-AXIS REORIENTATION WITH SPUTTERING PRESSURE IN Ni/Pd MULTILAYERS

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Ni/Pd 다층박막에서 스퍼터링 압력에 따른 자화용이축의 되방향잡기

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I. INTRODUCTION

Recently, Shin *et al.*[1-2] have observed room-temperature PMA in Ni/Pt, Ni/Pd multilayers and revealed that stress-induced magnetoelastic anisotropy plays a significant role to induce PMA in these systems. In this paper, in addition to the magnetoelastic anisotropy, other contributions of the surface, magnetocrystalline, and magnetostatic anisotropies were studied to clarify the origin of easy-axis reorientation in Ni/Pd multilayers with varying the sputtering pressure. Especially, magnetoelastic anisotropy was quantitatively determined by careful *in situ* stress and *ex situ* magnetostriction coefficient measurements.

II. EXPERIMENT

Ni/Pd multilayer films were prepared on corning glass substrates of 130-㎛ in thickness by sequential dc magnetron sputtering of Ni and Pd at an Ar sputtering pressure of 2 mTorr and 7 mTorr. Typical deposition rates, obtained under an applied power of 30 W to each target and a target-to-substrate distance of 75 mm, were 0.5 Å /s and 1.2 Å /s for Ni and Pd at 2 mTorr, and 1.0 Å/s and 3 Å/s for Ni and Pd at 7 mTorr, respectively. The Ni sublayer thickness t_{Ni} ranges from 5 to 20 Å, but Pd sublayer thickness t_{Pd} of 6 Å and the number of repeats of 30 were maintained to be constant for all samples.

III. RESULTS AND DISCUSSION

The surface anisotropy estimated from a linear fitting of $K_u^{eff}t$ · t plot was 0.016 erg/cm^2 for the 2 mTorr samples and 0.03 erg/cm^2 for the 7 mTorr samples. The surface anisotropy was increased about 88% with increasing an Ar sputtering pressure. However, the enhancement of the surface anisotropy alone could not explain the observed PMA in Ni/Pd multilayers since the surface anisotropy is not large enough to overcome the negative contribution of the shape anisotropy. To examine the contribution of the magnetoelastic anisotropy, delicate *in situ* stress and *ex situ* magnetostriction coefficient measurements have been performed using an ultra-sensitive optical displacement sensing apparatus. We have observed a tensile stress of $1.0\text{-}2.5\times 10^{10}$ dyne/cm^2 in the Ni layer for the 7 mTorr samples. However, interestingly, stress in 2 mTorr samples varied from tensile(4.3×10^{10} dyne/cm^2) to compressive(-0.2×10^{10} dyne/cm^2) as the Ni sublayer thickness was increased. However magnetostriction coefficients were negative in all samples, irrespective of Ar pressure. Magnetostriction coefficient was negatively increased from -0.7×10^{-5} to -2.8×10^{-5} with the Ni layer thickness for the 2 mTorr samples and from -0.7×10^{-5} to -2.4×10^{-5} for the 7 mTorr samples. The magnetoelastic anisotropy K_e was determined using a relation of $K_e=-3/2\lambda\sigma$, where λ is the magnetostriction coefficient and σ is the stress in the Ni layer. The estimated magnetoelastic anisotropy varied from 4.6×10^5 to -0.8×10^5 erg/cm^3 for the samples made at 2 mTorr and 2.8×10^5 to 4.2×10^5 erg/cm^3 for the 7 mTorr samples. The magnetoelastic anisotropy for the samples of 2 mTorr was largely dependent on the Ni sublayer thickness. However the magnetoelastic anisotropy for the samples of 7 mTorr was almost constant with varying the Ni sublayer thickness. We found that the magnetoelastic anisotropy K_e increased about 250% for the samples of (11-Å Ni/ 6-Å Pd)$_{30}$ with increasing Ar sputtering pressure.

Using the phenomenological model, we have quantitatively determined K_d, K_λ, and K_s, as shown in Fig.1. In Fig. 1 we plot all anisotropy constituents of K_u^{eff}, K_d, K_λ, and $2K_s/t_{Ni}$ as a function of t_{Ni} for the 2-mTorr(a) and 7-mTorr(b) samples, together with K_c. From this figure, we can see that the samples prepared at a higher Ar sputtering pressure of 7 mTorr have larger surface anisotropies by about a factor of two than the samples prepared at a lower sputtering pressure of 2 mTorr. However, it should be noticed that the enhancement of the surface anisotropy alone for the 7-mTorr samples could not sufficiently overcome a negative contribution of the shape anisotropy to yield PMA in these samples. Fig. 1 clearly demonstrates that a positive contribution of the magnetoelastic anisotropy, comparable to the surface anisotropy for the 7-mTorr samples, is crucial for the observed PMA in these samples.

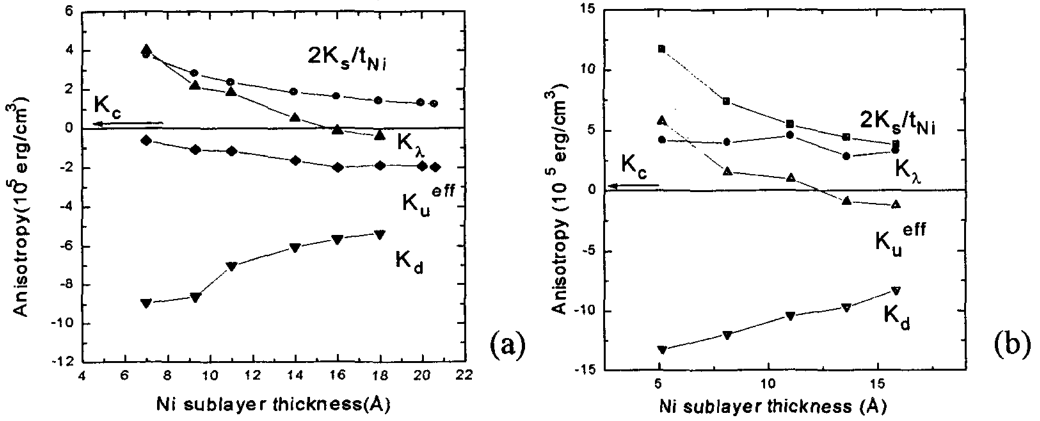

Fig. 1 K_u^{eff}, K_d, K_λ , and $2K_s/t_{Ni}$ as a function of the Ni sublayer thickness, together with K_c, for the samples prepared at 2-mTorr(a) and 7-mTorr(b) Ar pressure

IV. REFERENCES

[1] S.-C. Shin, G. Srinivas, Y.-S. Kim, and M.-G. Kim, Appl. Phy. Lett. **73**, 393 (1998).

[2] J.-R. Jeong and S.-C. Shin, J. Appl. Phys. **85**, 5762 (1999).