DEPENDENCE OF MAGNETOElastic ANISOTROPY ENERGY ON Ni-SUBLAYER THICKNESS IN NiPd NANOMULTILAYERS

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Introduction
Recently, Shin et al. [1-3] have reported observations of room temperature perpendicular magnetic anisotropy (PMA) in Ni/Pd and Ni/Pd multilayers, and they claimed stress-induced magnetoelastic anisotropy played a significant role to induce PMA in these systems. In this study, to clarify the contribution of magnetoelastic anisotropy to the PMA observed in NiPd nanomultilayers, the magnetoelastic anisotropy energy was quantitatively determined by delicate in situ stress and ex situ magnetostriction coefficient measurements.

Experiment
NiPd nanomultilayer films were prepared by sequential dc magnetron sputtering onto glass substrates at Ar sputtering pressure of 2 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 for Ni and 1.2 Å/s for Pd at 2 mTorr, and 1.0 Å/s for Ni and 3 Å/s for Pd at 7 mTorr. The Ni sublayer thickness \( t_{Ni} \) ranged 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.

Results and discussion
To investigate the magnetoelastic anisotropy, delicate in situ stress and ex situ magnetostriction coefficient measurements have been performed using an ultra-sensitive optical displacement sensing apparatus. Fig. 1 demonstrated that a tensile stress of \( 1.0 \times 10^6 \) dyn/cm\(^2\) is existed in the Ni layer for the 7 mTorr samples, with decreasing trend with increasing the Ni sublayer thickness. However, interestingly, stress in 2 mTorr samples varied from tensile\( (4.3 \times 10^6 \) dyn/cm\(^2\)) to compressive\( (-4.2 \times 10^5 \) dyn/cm\(^2\)) with increasing the Ni sublayer thickness as shown in Fig. 1. However, the magnetostriction coefficients are negative in all samples, irrespective of Ar pressure as shown in Fig. 1: the magnetostriction coefficient is negatively increased from \( -0.7 \times 10^{-5} \) to \(-2.8 \times 10^{-5}\) to \(-6.7 \times 10^{-5}\) to \(-2.1 \times 10^{-5}\) with increasing the Ni sublayer thickness for the 2 mTorr samples and 7 mTorr samples, respectively.

The magnetoelastic anisotropy energy \( K_{el} \) is determined using a relation of \( K_{el} = \frac{1}{2} \frac{\lambda^2}{\sigma} \), where \( \lambda \) is the magnetostriction coefficient and \( \sigma \) is stress in the Ni layer. In Fig. 2, we plot the dependence of the magnetoelastic anisotropy energy on the Ni-sublayer thickness in the NiPd nanomultilayers. We found that the dependence of the magnetoelastic anisotropy on the Ni sublayer thickness was very different for the samples of 2 mTorr and 7 mTorr. The magnetoelastic anisotropy for the samples prepared at 7 mTorr is nearly constant with varying the Ni sublayer thickness: \( K_{el} \) of \( -3.5 \times 10^6 \) erg/cm\(^2\) is observed irrespective of the Ni-sublayer thickness as exhibited in Fig. 2. By phenomenological model we have found that the positive large magnetoelastic anisotropy existed in the samples prepared at a higher sputtering pressure plays a significant role to induce PMA in NiPd nanomultilayers.

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References

Fig. 1. Dependence of stress and the magnetostriction coefficient on the Ni-sublayer thickness for the samples of (a) 2 and (b) 7 mTorr.

Fig. 2. Dependence of magnetoelastic anisotropy energy on the Ni sublayer thickness for the samples of 2 and 7 mTorr.