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Direct Measurement of Induced Strain in Permalloy thin Films Deposited under Magnetic Field using Synchrotron GIXRD

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It is widely accepted that magnetic anisotropy can be induced by applying magnetic field during deposition or post-annealing of a magnetic thin film. Many researchers have addressed that the origin is strain, atomic pair ordering, etc.[1] However, hardly found is the experimental evidence on the effect of strain. The reason might be the experimental difficulties incurred from the extremely small strain and magnetostriction coefficient (order of $10^{-5} \sim ^{-6}$) and the tiny volume (tens of nanometer thickness) for the measurement.

This study measures the strains of permalloy thin films of 100 nm thick deposited at various magnetic field (0, 600 or 850 gauss) applied parallel to the substrate. We examine the post-annealed films at zero magnetic field as well. To resolve the above mentioned experimental difficulties we utilize the high power of synchrotron radiation and precise Grazing Incidence X-Ray Diffraction (GIXRD) setup. The precision of the measurement should be 10^{-5} nanometer, which provides 5 effective digits of interplanar spacing (e.g. 0.12345 nm). It is possible to examine the crystallographic planes nearly perpendicular to the substrate by setting the GIXRD measurement plane, which consists of incidence and the detection direction, inclined 1 degree from the substrate. (A normal X-ray diffraction sets the measurement plane to be 90 degree from substrate, and studies the crystallographic planes parallel to the substrate.) The GIXRD measured the lattice parameters of (111) planes in two directions, one for the planes parallel to the applied magnetic field and the other for the normal. The ratio of the two (111) lattice parameters is an indication of anisotropic strain if there exists any.

The results provide the evidence of directional change of strain and lattice parameter, and their annihilation in the post-annealed film. (Fig. 1) Furthermore, a strong relationship is found between the structural parameters and the magnetic properties of the film, especially magnetic anisotropy.

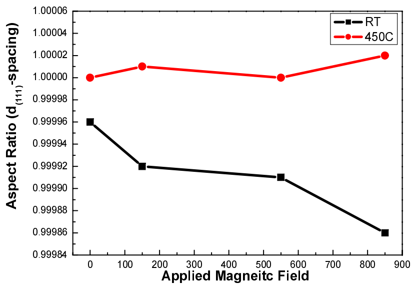

Fig. 1. The Ratio of lattice parameter, d(111) normal to the magnetic field and d(111) parallel, of permalloy films (100 nm thick) signifies the development of anisotropic strain with the applied magnetic field (solid). Post-annealing the films at 450 degree and zero field annihilates the anisotropy (open).st-annealed film.

The synchrotron GIXRD was carried at the PAL (Pohang Accelerator Laboratory) 10C1 beam line.

REFERENCES

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AR03

Magneto-Optical Kerr Effect Enhancement Method for Nanodots

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Magneto-optical Kerr effect (MOKE) is one of the widely used and easy technologies for studying ferromagnetic films due to its simplicity and sub-monolayer sensitivity with sub-nano second time resolving power. However, MOKE has a limitation for the ferromagnetic nanostructure researches due to its poor spatial resolution. Previous study [1], we proposed a method to enhance a MOKE signal for nanostructures, and provide the numerical results for nanowires cases. In this study, we would like to extend the previous work to the nanodot cases. The main idea of the enhancement is follows. The focus laser beam for the MOKE measurement consists of two parts, one is reflected from the nanostructure and the other is from the substrate. Roughly say, the degradation of MOKE signal from the nanostructure is due to the reflected beam from the substrate, where no MOKE signals. So, when we reduce the reflected beam from the substrate, better MOKE signal is expected. Reduction of the reflected beam from the substrate can be easily realized by anti-reflection coating. The results of numerical calculations for the various sizes of nanodots and beam radii with on the substrates with different reflectivities of 0.7, 2.1, 6, and 30 % are plotted in Fig. 1 (a) and (b). It is clearly shown that the reduction of the normalized MOKE signal is much less for lower reflectivity substrate.

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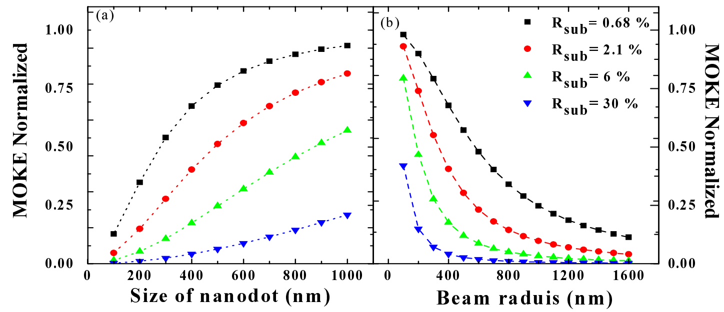

Fig. 1. Normalized MOKE signal are plotted for (a) various sizes of nanodots for a 1500-nm radius Gaussian beam, (b) various beam radii for a 100-nm size of nanodot.