Magnetization reversal processes in FePt antidot arrays

We fabricated FePt antidot lattices with various diameters *d* ~ 40 nm, 100 nm, and 200 nm by electron beam lithography, in which the shapes were designed to be squares, circulars and triangulars. In order to understand the magnetization reversal process in these FePt antidot-arrays, the magneto-optical Kerr effect were measured using the micro-sized laser spot system, and the unique behavior of magnetization reversal was observed.

The $L1_0$-FePt alloy is one of the most promising materials for future ultrahigh density magnetic storage devices because it possesses a huge uniaxial magnetocrystalline anisotropy (K_u = 7 x 10^7 erg/cc) which leads to the high thermal stability of magnetization in a nanometer scale. The aim of this international collaboration work is to understand the magnetization reversal processes in thin films, dots and antidots of FePt. In this collaboration, we previously studied the magnetization reversal process in FePt thin films deposited on MgO (110) substrates exhibiting in-plane uniaxial magnetic anisotropy. The thin films were prepared by sputtering in the group of Prof. K. Takanashi, IMR, Tohoku University. It was found that the uniaixal magnetocrystalline anisotropy energy increased with the increase in film thickness and deposition temperature. Domain imaging performed by magneto-optic Kerr microscopy with a longitudinal geometry at NISER, India suggested that the domain structure and magnetization reversal process strongly depended on the film thickness and the deposition temperature. For the films deposited at a certain temperature, there existed a critical thickness where the coercive and saturation fields showed maxima. [1]

Based on the experimental results for the FePt thin films, we investigated the details of magnetization reversal process for nano-structured FePt. Magnetic micro-/nano-structures are not only interesting for fundamental research but they have a high potential for applications. We studied on “negative” magnetic structure that was made using lithography to create a mesh of “holes” in a continuous FePt magnetic thin film. These negative structures are called as “antidots”. The array of such antidots is called as “magnetic antidot lattice (MAL)”. MALs are receiving intense research interest because of their potential advantages, such as lack of superparamagnetic limit to the bit size (as compared to dot arrays). The domain wall (DW) motion and their dynamics in such MAL system have not been studied so far. The major question is how a magnetic DW will behave in a MAL system where there are periodic defects. Also so far a systematic study on MAL systems for various shape, size and interdot spacing has not been performed. The domain nucleation, domain size and shape will certainly be affected by the shape and size of antidots. In this context, one goal of this collaboration work is to reveal the domain formation and measure the DW velocity as a function of applied magnetic fields with the Kerr microscopy.

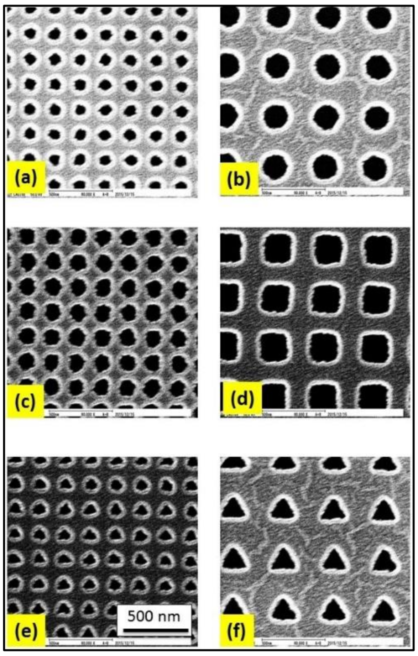

Fig. 1: Scanning electron microscopy images of FePt antidot lattices with (a) circular and (a and b), square (c and d), and triangular (e and f) shapes. For each shape we fabricated both 100 and 200 nm size antidots. All images are in same scale and the scale bar is shown in (e).

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It should be noted that magnetization reversal of the perpendicularly magnetized FePt antidots have never been studied. As the first step to reveal the DW dynamics in MALs, we focused on the study of magnetization reversal behavior for $L1_0$ ordered FePt antidot systems. We fabricated the MALs with various dimensions of the antidots ranging from 200 nm to 40 nm. MAL arrays for various types of lattices such as square and honeycomb were fabricated in order to study the effect of the lattice pattern on the magnetization reversal. Scanning electron microscope (SEM) revealed that the size and shape of the antidot lattices were well controlled. In addition to the perpendicularly magnetized FePt antidots, magnetic antidots of FePt thin films with in-plane anisotropy were prepared.

Fig. 1 shows the SEM images of FePt MALs on MgO (100) substrates with circular, square and triangular shapes.

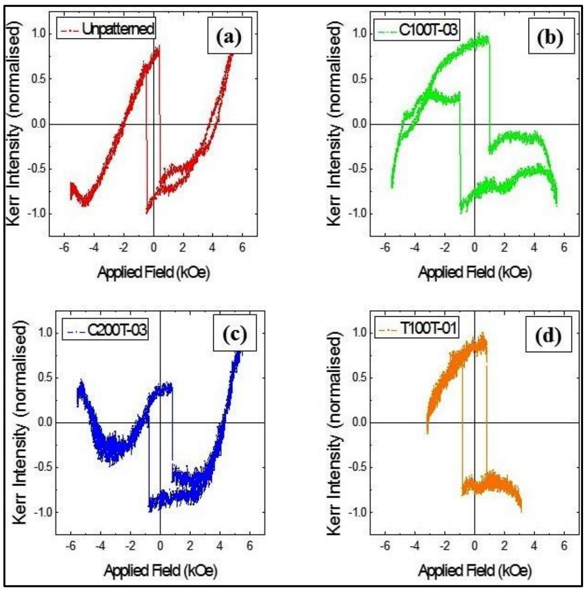

Fig. 2 Magnetic hysteresis loops were measured by a magneto-optical Kerr effect set-up using the micro-sized laser spot in the longitudinal configuration. Hysteresis loops are shown for (a) the unpatterned film, (b) circular antidots with 100 nm and (c) 200 nm diameter, and (d) triangular antidots with dimension of 100 nm.

Magnetic hysteresis loops were measured using a magneto-optical Kerr effect set-up with the micro-sized laser spot in the longitudinal configuration, which revealed that coercivity in the antidot lattices strongly depended on the size of the antidots (see Fig. 2). In order to understand the domain structure we will perform magnetic force microscope (MFM) under external fields. We are now performing micromagnetic based OOMMF (Object oriented micromagnetic framework) simulations to understand the domain nucleation and domain wall motion in antidote arrays. Kerr microscopy measurements are being investigated on the antidot samples in NISER, India. [2] Also in the framework of this collaboration we have published our work on the interaction induced superferromagnetic domain state in the perpendicularly magnetized FePt dot arrays. [3]

References

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