Magnetization reversal processes in perpendicularly magnetized FePt dots and antidot arrays

We have fabricated FePt dot and antidot lattices with various diameters *d* ~ 40 nm, 100 nm, and 200 nm by electron beam lithography. The antidots were fabricated with square, circular and triangular shapes. Magnetization reversal in these FePt nanosized-arrays was studied by magneto-optical Kerr effect using the micro-sized laser spot. Magnetic force microscopy imaging revealed the reversal processes showing the domain wall trap in the antidote lattices.

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 first 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 exists a critical thickness where the coercive and saturation fields show 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.

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 magnetization reversal study of $L1_0$ ordered FePt antidot systems during my stay in IMR. We have fabricated MALs with the dimension 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. Fig. 1 shows the SEM images of two representative FePt MALs on MgO (100) substrates.

Magnetic hysteresis loops were measured by a magneto-optical Kerr effect set-up using the micro-sized laser spot in the polar configuration, which revealed that coercivity in the antidot lattices strongly dependent on the size of the antidots (data not shown). In order to understand the domain structure we performed magnetic force microscope (MFM) observation under external fields. Fig. 2 shows the MFM images of an antidot lattice where the length of the antidots is 200 nm. It is noticed that domain walls are trapped between the antidot structures. Under external magnetic field the domains grow but their expansion is limited within the antidot structures. The observed MFM results are well reproduced by micromagnetic based OOMMF (Object oriented micromagnetic framework) simulations (data not shown). Kerr microscopy measurements are being investigated on the antidot samples in NISER, India.

In addition to the FePt antidots, we have performed the research work on magnetization reversal process in the perpendicularly magnetized FePt dots, and observed the “superferromagnetic behavior” in the artificially fabricated structures [2].

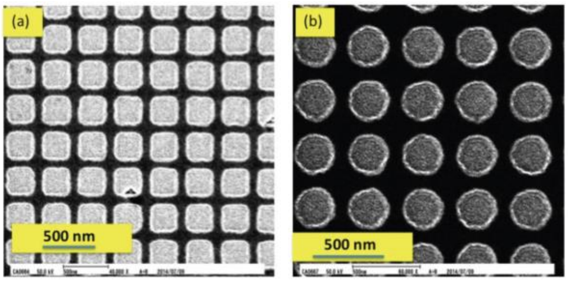

Fig. 1 Scanning electron microscopy images of FePt antidot lattices with (a) rectangular and (b) circular shapes of the holes.

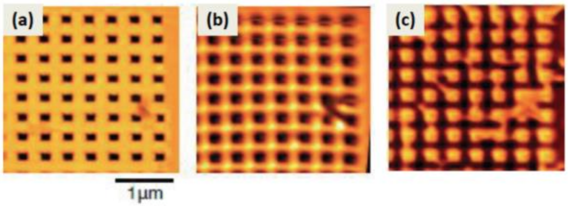

Fig. 2 (a) Morphology of a FePt antidote lattice with *d* = 200 nm. The image shown in (b) is the magnetic domain structure taken after remanence after positive saturation. (c) Magnetic domain image taken near coercive field of $\mu_0 H$ = -0.15 T.

References

[1] S. Mallick, S. Bedanta, T. Seki and K. Takanashi, J. Appl. Phys. **116**, 133904 (2014).

[2] S. Bedanta, T. Seki, H. Iwama, T. Shima, and K. Takanashi (to be published).

Keywords: magnetic, nanostructures, scanning electron microscoscopy
Full Name: Dr. Subhankar Bedanta, Reader in Physics, National Institute of Science Education and Research (NISER), Bhubaneswar, Odisha, India-751005
E-mail: sbedanta@niser.ac.in