Geometrical Dependence of Magnetic Properties for Magnetic Antidot Lattices of Heusler Alloy

$Co_2Fe_{0.4}Mn_{0.6}Si$ Heusler alloy thin films with $L2_1$ ordered structure have been prepared using ultrahigh vacuum magnetron sputtering. Magnetic antidot lattice (MAL) arrays with square, circular, triangular, and diamond shaped holes with the feature size of 100 nm, 200 nm, and 500 nm have been microfabricated using e-beam lithography. Magneto-optical Kerr effect measurements using the micro-size laser spot, which is called μ-MOKE, revealed the appearance of strong cubic and weak uniaxial magnetic anisotropy in the Heusler alloy thin films.

Half-metallic Heusler compounds with full spin polarization have recently attracted huge research interest because of their potential applications in spintronic devices [1]. On the other hand, the magnetization reversal in magnetic antidot lattice (MAL) arrays is better controlled in comparison to continuous thin films because the well-defined periodic holes act as the nucleation and pinning centers for the reversed domains. The exchange coupled MAL arrays are ideal for ultrahigh density magnetic storage applications because of their physical dimension not being restricted by the superparamagnetic blocking [2]. The aim of this collaborative work is to understand the effect of shape and lattice geometry of the MAL arrays of Heusler alloy on the magnetization reversal and domain wall motion. Thin films with different thickness (15, 20, and 25 nm) were grown in an ultrahigh vacuum chamber with a base pressure < 1.5×10^{-7} Pascal. The epitaxial growth of the films was studied by x-ray diffraction (XRD). The MAL arrays with different shapes and lattice symmetries were microfabricated using e-beam lithography and subsequently Ar^+ ion milling. The magnetic hysteresis loops have been investigated by vibrating sample magnetometry (VSM) and magneto-optical Kerr effect system having the micro-size laser spot (μ-MOKE).

VSM measurements revealed highest saturation magnetization (M_s) and coercive field (H_c) for the Heusler alloy thin film with thickness of 20 nm. Fig. 1 shows the H_c vs ϕ (angle between applied magnetic field and easy magnetization axis) plot for the thin films measured using μ-MOKE. The plot reveals the formation of epitaxial growth induced the strong cubic anisotropy and the weak uniaxial anisotropy. The possible origin for the uniaxial anisotropy can be many viz. oblique angular deposition, strain relaxation, anisotropic formation of chemical bonds, interfacial roughness due to lattice mismatch, surface morphology, etc. Fig. 2 shows the scanning electron microscopy (SEM) images of the microfabricated MAL arrays of square, circular, triangular, and diamond shaped holes with the feature size of 500 nm. μ-MOKE measurements revealed magnetic hardening in the MAL arrays with incorporation of the holes in the continuous thin films. This is expected because the domain wall propagation in such MAL arrays is laterally restricted by the presence of the periodic holes.

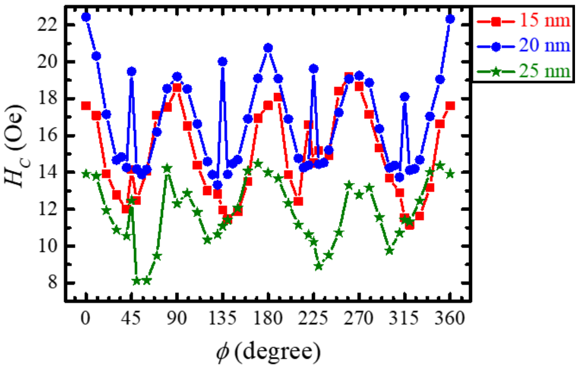

Fig. 1: H_C vs ϕ plot for Heusler alloy thin films with thickness of 15 nm (red curve), 20 nm (blue curve), and 25 nm (green curve).

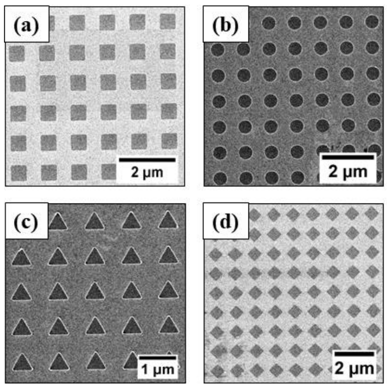

Fig. 2: SEM images of square (a), Circular (b), triangular (c), and diamond (d) shaped antidots with feature size of 500 nm.

The static and dynamic response of the magnetization and domain walls will be performed using Kerr microscope, time-resolved MOKE, magnetic force microscopy (MFM), and x-ray photoemission electron microscopy (XPEEM).

References

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