EXCHANGE COUPLED FeCo/L1$_0$-FePt BI-LAYER THIN FILMS FOR ULTRA HIGH DENSITY DATA STORAGE

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I. INTRODUCTION

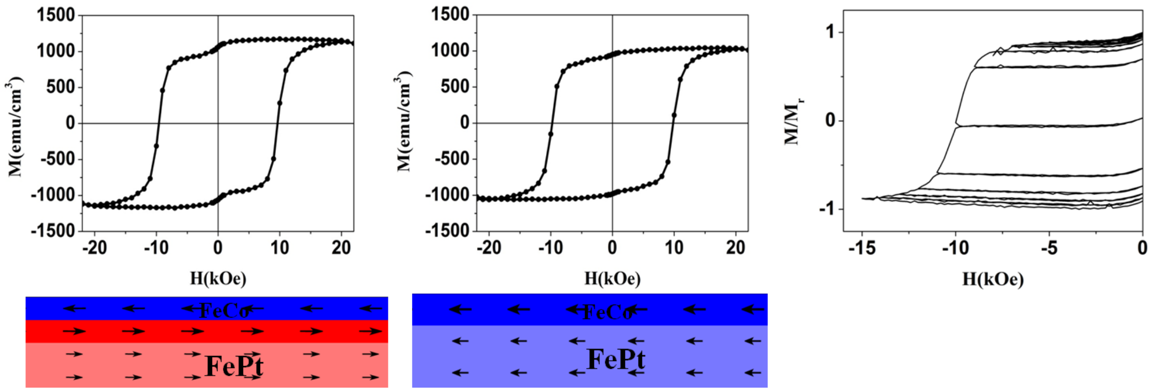
Exchange spring magnets have attracted the interests of researchers for magnetic recording applications and to develop rare earth free magnets [1]. FePt and FeCo individually are well established systems, with the former classified as hard magnetic material and latter as the soft one. FeCo has very high saturation magnetization (~ 2.4 Tesla) [2] and low anisotropy (4×10^4 J/m^3) [3] and hence this material is a good candidate to couple with L1$_0$ FePt hard phase known to possess a relatively low magnetisation (1140 emu/cm^3) [4] and high anisotropy (5×10^6 erg/cm^3) [5], for applications in read heads. In this communication, we report the results obtained in FeCo/FePt bi-layer system deposited on Si < 100 > substrates.

II. EXPERIMENTAL DETAILS

FeCo and FePt thin films were deposited by RF and DC magnetron sputtering respectively in the base Argon pressure of 0.02 mbar. The bi-layer FeCo/FePt films were annealed in a microprocessor controlled tubular furnace at 500 ˚C in the presence of Argon (95%) and Hydrogen (5%) to reduce the possible presence of oxides and enhance crystallinity. The annealing temperatures were chosen so as to obtain the desired L1$_0$ phase of FePt and to have minimum diffusion into the substrate. High energy X-Ray Diffraction (XRD) was performed in the glancing angle mode to find the structural variation of films on annealing. The thickness and composition of two layers was obtained by Rutherford Backscattering (RBS) spectrum. Field Effect Scanning Electron Microscopy (FESEM) was done to look at the morphology of the films. The bulk magnetic properties of these bi-layered films were investigated by Vibrating Sample Magnetometer (VSM). Micromagnetic Simulations were performed to have an estimate of the direction of easy axis of the individual layers.

III. RESULTS AND DISCUSSIONS

Fitting the spectra obtained by Rutherford Backscattering (RBS) using RUMP software gives the thickness of $Fe_{0.55}Pt_{0.45}$ as 27 nm and $Fe_{0.5}Co_{0.5}$ as 6 nm. The XRD pattern of the film annealed at 500 ˚C shows the appearance of super lattice peak (001), (110) and splitting of (002) peak into (002) and (020) indicating the L1$_0$ phase of FePt. Microstructure of the films, seen by FESEM showed uniform grains for the as prepared and the annealed samples.



(a) (b) (c)

Fig. 1 Experimental hysteresis loop and simulated domain configuration at 8 kOe of (a) FeCo(12 nm)/FePt(27 nm) (b) FeCo(6 nm)/FePt(27 nm) (c) Experimental recoil curves for FeCo(6 nm)/FePt(27 nm)

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Fig. 1 shows the experimental hysteresis loop and its corresponding domain configuration simulated in the in-plane configuration for FeCo (12 nm)/FePt (27 nm) (figure 1(a)) and FeCo (6 nm)/FePt (27 nm) (figure 1(b)). A wider hysteresis loop with coercivity ~ 10 kOe both in the in-plane and out of plane configuration and high saturation magnetization (M_s) ~ 1064 emu/cm^3 was observed on annealing at 500 ˚C. The high coercivity is attributed to the large magnetocrystalline anisotropy of $L1_0$ FePt, while the large magnetization is due to presence of FeCo layer. The maximum energy product BH_{max} was calculated to be 47 MGOe. This is slightly less than the energy product of NdFeB permanent magnets which is 48 MGOe [6], but still plays competitive role in the development of rare earth free magnets.
The exchange coupling strength between the FeCo and the $L1_0$-FePt was analyzed by recording the recoil curves in the out of plane configuration as shown in Fig. 1(c). The almost closed recoil curves up to a reverse field H_r ~ 4 kOe depict the strong exchange coupling between the two layers. Further, increase in H_r beyond 4 kOe results in open recoil curves. The openness of recoil curves gradually increases with increase in H_r and is directly related to the amount of uncoupled soft FeCo [7-8]. The amount of the uncoupled soft phase was determined to be 1.02 % by the first derivative of the hysteresis loop. As the FeCo thickness was ~ 6 nm which is of the order of twice that of exchange length of FePt, therefore, 98.98 % of FeCo is highly exchange coupled with FePt. These properties make the present system suitable for granular magnetic recording with high storage capacity, which can be further extended to bit patterned media. The detailed investigation of magnetization reversal mechanism and hence the interlayer exchange coupling in FeCo/FePt bilayer system was carried out using micromagnetic simulations with OOMMF [10] software. This software numerically solves Landau Lifshitz Gilbert equation [11] using finite difference method to find the solution of magnetization at different positions of the sample used. Figure 1(a) and (b) shows the domain configurations of the multilayers with different thickness of soft material at 8 kOe applied field simulated by this software.

IV. CONCLUSIONS

Exchange spring magnets with FeCo/$L1_0$ FePt bi-layer was fabricated with high saturation magnetization, high coercivity, high energy product and high exchange coupling between the two layers. The interlayer exchange coupling was experimentally investigated by recoil curves. The experimental observations along with the micromagnetic simulations predict that the strength of exchange coupling strongly depends on the thickness of the soft layer. Therefore, the fabricated exchange spring magnets can be a promising material for magnetic recording applications with high storage capacity.

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