ION IMPLANTATION INDUCED DISORDER IN FePt-C FILMS

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Ion implantation induced local modification of magnetic properties of magnetic thin films has attracted the attention of the researchers due to its potential applications in magnetic data storage and magnetic logic devices [1]. As magnetic properties of any system heavily depend on the composition, ion implantation through a hard mask can be used to modify the composition locally, in order to make magnetic nanostructures (e.g., patterned media or heated-dot-magnetic recording media). In addition to compositional modification, ion implantation can also modify the magnetic properties by changing the atomic arrangement of the system. Even though the magnetic properties in some systems, such as FePt, heavily depend on the atomic arrangement, this aspect has not been well investigated. In this study, therefore, we investigate the effects of ion implantation of FePt, using low (4.5 keV for $^{40}Ar^{+}$ and 7.5 keV for $^{14}N^{+}$ ions) and high (100 keV for $^{40}Ar^{+}$ and 40 keV for $^{14}N^{+}$ ions) energy ions through a hard mask patterned using di-block copolymer (DBCP) based self-assembly process.

Film stack "FePt-C (at% of C: 18.75) [8 nm]/ MgO [8 nm]/ NiTa [35 nm]/ Glass substrate", as shown in figure 1(a), was deposited using dc magnetron sputtering. After depositing the film stack, a mask pattern was fabricated using self-assembly of PS-PDMS DBCP. Figure 1(b) shows the AFM image of the mask pattern on FePt-C films. The centre to centre distance, as calculated from the Fast Fourier Transform (FFT) of the AFM image, is 48 nm. After successfully creating the mask pattern on FePt, ion implantations of $^{14}N^{+}$ and $^{40}Ar^{+}$ ions were performed. Figure 1(d) shows the XRD patterns of the pristine and implanted samples, which show the presence of superlattice (001) peak. This peak confirms the presence of $L1_0$ face centered tetragonal ordered phase in these films [2]. XRD patterns reflect a shift in the FePt (111) peak towards lower 2θ angles with implantation (except for low energy $^{40}Ar^{+}$ ions), which implies an increase in the interplanar spacing (corresponding to FePt (111) peak). Interestingly, FePt (001) peak disappears even for the low energy $^{40}Ar^{+}$ ion implantation case, which indicates a transformation from ordered face centred tetragonal phase to disordered face centred cubic phase. These results are well understood from the TRIM simulations [3] as shown in figure 1(e). For low energy Ar^{+} implantation, the ions stop in the middle of the magnetic FePt layer whereas in other cases the ions stop at the layers below the magnetic FePt layer. When the ions are implanted in the film, the maximum kinetic energy transferred from implanted ion to the atom in the film is given by [4]

$$E_p = \frac{4Mm}{(M+m)^2}E \quad (1)$$

Where M, m and E stand for the atomic weight of the displaced atom in the film, atomic weight of implanted ion and energy of implanted ion. Here, the factor $4Mm/(M+m)^2$ is larger for $^{40}Ar^{+}$ ions compared to $^{14}N^{+}$ ions. However, at the same time, we should also consider where these ions are stopping in the stack as we stated before. These results can further be understood from the magnetic measurements. The hysteresis loops of pristine sample measured using vibrating sample magnetometer show large coercivity in both in plane and out of plane direction. However, it is important to note that the remanence was smaller in the in-plane direction. These observations clearly suggest the uniaxial anisotropy in the out of plane direction. But at the same time there are some spins, which are slightly away from out of plane direction. The decreased coercivity and larger remanence in the in-plane direction in the implanted samples clearly suggest the change in the anisotropy direction from the out of plane to in plane direction. Most importantly, this effect is partial

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for the low energy $^{40}Ar^{+}$ ion implanted samples. In order to confirm our attributions, we performed torque measurements of these samples. The torque curves of the FePt pristine samples exhibits the 180° periodicity of the peaks, which confirms uniaxial anisotropy of the samples. At the same time presence of other less intense peaks, suggest that some of the spins are away from the easy axis direction. Also, it important to note that first peak in the torque curve has positive torque value that means the out of plane direction is the easy axis direction. Upon implantation (except for low energy $^{40}Ar^{+}$ ions), the first peak in the torque curve appeared in the fourth quadrant, which confirmed the change in easy axis direction from out of plane to in plane direction. These results are well supported by magnetic force microscopy domain maps, where we observed typical stripe domains for granular pristine film. Except for the low energy 40Ar+ ion implantation case, the diminished or less intense stripe domains suggest the decrease in perpendicular anisotropy of the samples.

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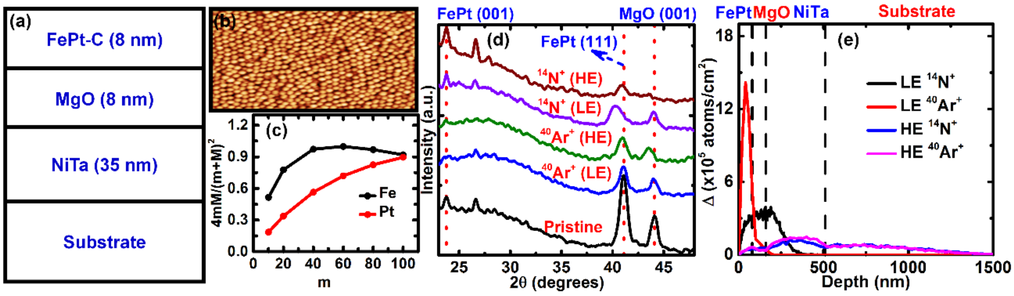

Fig. 1 (a) Schematic of the film stack used for study, (b) AFM image of the mask pattern on FePt-C films, (c) Illustration of the dependence of $4Mm/(m+M)^2$ on atomic weight of implanted ions, (d) XRD patterns and (d) TRIM (Transport of Ions in Matter) simulations of pristine and implanted FePt-C samples (Δ: distribution of implanted ions after cascaded scattering, note here HE: high energy and LE: low energy).

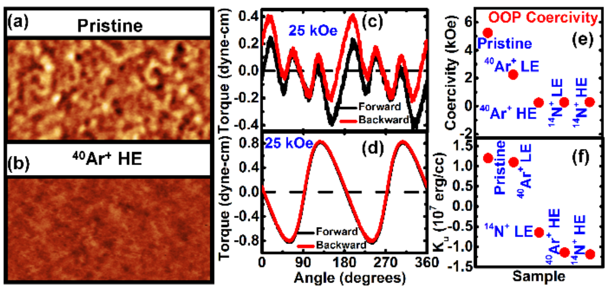

Fig. 2 (a) MFM domain maps of pristine, (b) HE $^{40}Ar^{+}$ ion implanted FePt-C samples, (c) Torque curves of pristine, (d) HE $^{40}Ar^{+}$ ion implanted FePt-C samples, (e) Out of plane coercivity and (f) anisotropy constant of pristine and implanted FePt-C samples.