ROBL-CRG	**Experiment title:** **$L1_0$ ordering in FePt films designed for future magnetic memory materials**	**Experiment number**: **20_02_635**
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REPORT

Due to its high magneto-crystalline anisotropy ($0.7\text{-}1\times10^8$ erg/cm^3) the $L1_0$ phase of FePt alloys belongs to the preferred materials for future magnetic recording media, with the potential to achieve a storage density above 1 Tbit/in^2 [1]. Unfortunately, FePt films deposited at room temperature (RT) exhibit only the face-centered cubic (fcc) A1-phase and a subsequent heat treatment is required to achieve the face-centered tetragonal (fct), ferromagnetic $L1_0$ phase.

In the present experiment, *in-situ* grazing incidence X-ray diffraction (GI-XRD, $\lambda = 1.54$ Å, $\alpha_i = 1°$) was used to characterize the $A1 \rightarrow L1_0$ phase transition of dc-magnetron sputtered Fe_xPt_{100-x} films [$x = (50 \pm 2)$] during post annealing treatments at $T_A \leq 350$°C in vacuum ($p < 5\times10^{-6}$ mbar). The FePt films of about 70 nm thickness were deposited at RT with a sputtering rate of (0.54 ± 0.03) Å/s from elemental targets [Fe (3.5N) / Pt (5N)] onto SiO_2(1.5 µm)/Si(111) substrates of 15×15 mm^2 size. Some specimens were irradiated with He-ions (50 keV, 0.1 - 30×10^{16} cm^{-2}) at RT or at 250°C. This treatment should lower the disorder-order transformation temperature due to the creation of point defects and, therefore, decrease the activation energy for reordering[2].

Figure 1 shows GI-XRD patterns for FePt films during annealing. Already at 310°C the $L1_0$ phase starts to form. The $A1 \rightarrow L1_0$ transformation is characterized by the appearance of the superstructure peaks [(001)/(110)] and by a peak splitting [(200)/(002)&(220)/(202)] due to the tetragonal distortion. At 325°C the $L1_0$ transition is almost complete which is confirmed by the long range order parameter $S = 0.9$ [3]. The mean grain size continuously increases with the annealing temperature, from 6 nm (as-deposited) to 11 nm (325°C). The films are non or only weakly textured.

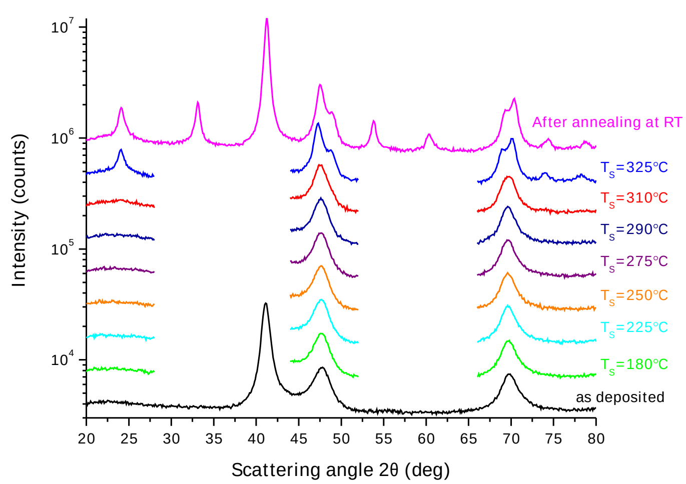

Fig. 1: GI-XRD patterns ($\alpha_i = 1°$) collected during vacuum annealing. The $L1_0$ contribution starts to be detected at 310°C by the splitting (200)/(002) and (220/(202).

Magnetic hysteresis loops (recorded by SQUID at RT) confirm the $L1_0$ ferromagnetic phase transition after

annealing. As reported in Fig. 2, in both parallel and perpendicular hysteresis loops, the coercive field is 5 kOe. There is no easy and hard axis which is a proof for the random orientation of the grains and the magnetic domains.

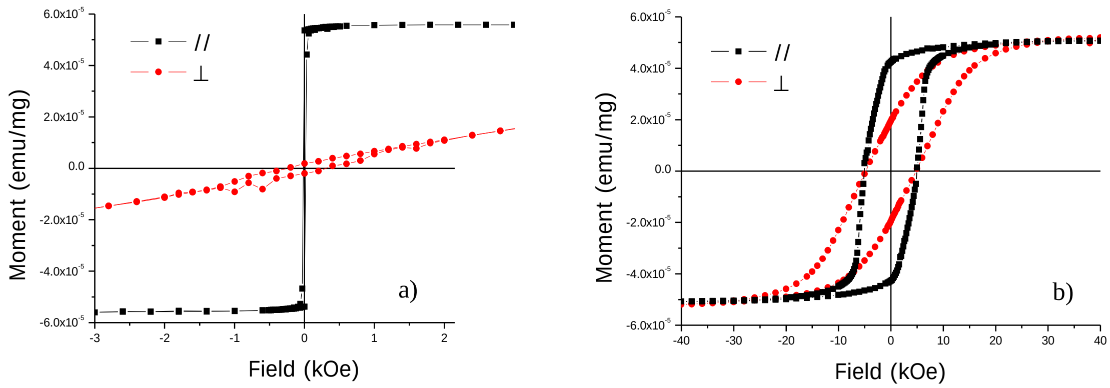

Fig. 2: Magnetic hystheresis loops of FePt films: a) before annealing; b) after annealing at 325°C.

As shown in Fig. 3, after He^+ irradiation (RT or 250°C) the films are still in the paramagnetic A1 phase and no decrease of the transition temperature has been found with respect to the not irradiated samples. In addition, the calculated long range order parameter and the average grain size do not differ significantly from the samples without He irradiation.

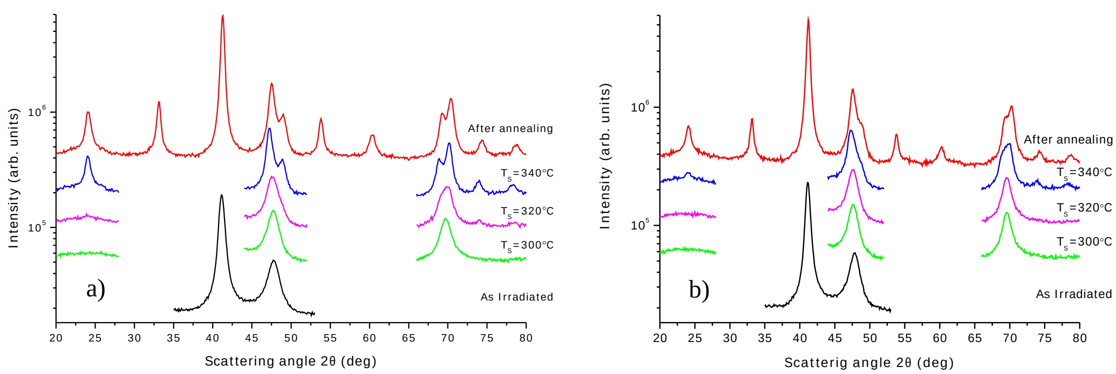

Fig. 3: GI-XRD patterns ($\alpha_i = 1°$) of ion-irradiated films (He^+, 50 keV, 3×10^{16} cm^{-2}) collected during vacuum annealing a) irradiation at RT; b) irradiation at 250°C.

These results pointed out that the disorder-order transition is not effected by He^+ irradiation for films deposited by magnetron sputtering. Calculations reveal that for our deposition conditions (p = 0.3 Pa, $V_T \approx 400$ V, target-substrate distance: 10 cm) no thermalization of the sputtered atoms and reflected Ar neutrals (from the sputter gas) occurs. Thus, the atoms arriving on the substrate have hyperthermal (sputtered atoms) or much higher (reflected neutrals) energies leading to an increased surface adatom mobility or even vacancy formation. In particular, the Ar neutral, reflected by the Pt target, have energies which exceed the displacement energy of Fe, Pt atoms in the film. We suppose that the films exhibit a high density of point-defects (vacancies) already after deposition which explains the low $A1 \rightarrow L1_0$ transition temperature as well as the insensitivity against further ion irradiation.

In conclusion, we succeded in the preparation of FePt layers by dual magnetron sputtering characte-rised by a very low transition temperature of about (325 ± 25)°C.

References:

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