Kinetics of Ordering Transformation in FePt Thin Films

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INTRODUCTION

Particular interest in chemically ordered $Fe_{1-x}Pt_x$ ($x \simeq 0.5$) thin films for longitudinal media arises from high magnetocrystalline anisotropy ($K_u \simeq 10^8$ erg/cm^3) and large thermal switching volume ($K_u V/kT \gg 100$)[1]. To this end, (111) textured, partially ordered FePt thin film with moderate H_c are of technological interest.

As high K_u is obtained in ordered $L1_0$ (CuAu-I) phase, FePt thin film has been obtained by deposition either at high temperature ($\gg 500°C$) for spontaneous ordering or at ambient temperature followed by post-deposition annealing in vacuum. The order-disorder transformation, in principle, can be martensitic-like since it does not involves composition change. Manifestation of twins, stacking faults and other defects in favor of martensitic transformation have been demonstrated in various system. In reality, however, most of order-disorder transformation is first order nucleation and growth type which is governed by long-range diffusion. Balanced between the two extremes, the kinetics of order-disorder transformation of FePt thin film can mark delicate difference in the thermal and temporal efficiency of the transformation, as well as in magnetic and structural properties of resulting FePt thin films.

We demonstrate that controlling the kinetics of ordering transformation in FePt thin film (by subtrate temperature in the present research) is critical to obtain FePt thin films with desible properties for longitudinal recording media, as well as in lowering the overal processing temperature.

EXPERIMENTAL

$Fe_{1-x}Pt_x$ ($x \simeq 0.5$) thin films were fabricated by 6 inch DC magnetron sputter system on Corning 7059 glass substrate. Deposition was put forward at 50 W under the base pressure of 3×10^{-7} Torr or better and working Ar pressure of 1 mTorr. Films were deposited at ambient temperature or 300°C, then annealed *in-situ* by a quartz lamp in vacuum (2×10^{-6} Torr) in a separated load-lock chamber at $350 \sim 550°C$ for 1 hours.

High resolution X-ray diffractometer employing double crystal monochromator was used to characterize the films. Magnetic properties were characterized by commercial vibrating sample magnetometer (VSM) sweeping magnetic field up to 15,000 Oe.

RESULTS AND DISCUSSION

Figure 1 displays the change of coercivity (H_c) with annealing temperature. The film deposited at 300°C are clearly hardened faster than that deposited at ambient temperature. Bragg-Williams long-range ordering parameter (S) defined as

$$S \;=\; \frac{r_{Fe(Pt)} - x_{Fe(Pt)}}{1 - x_{Fe(Pt)}} \qquad\qquad (1)$$

where $r_{Fe(Pt)}$ is the fraction of site occupied by right atom and $x_{Fe(Pt)}$ is the atomic fraction of Fe(Pt), was experimentally determined from the off-axis X-ray integrated intensity of fundamental (002) and superlattice (001) reflection based on Warren's analysis[2]. Inset of Figure 1 shows annealing temperature dependence of S of two films, which is in coincidence with the variation of H_c. The difference of transformation efficiency of two films may be explained by the difference in short-range ordering (i.e., the polpulation of unlike atom pair) of the films, which can be enhanced by sufficient atmoic mobility at higher substrate temperature.

As a transient state to the fully ordered $L1_0$ phase, partially ordered state can be either two phase compring fully ordered and fully disordered subphases, or single phase which is literally "partially" ordered. The former cause serious media noise problem as can be inferred from soft magnetically keepered media, thus, need to be avoided. Figure 2 shows X-ray diffraction specular scan on (111) reflection of the partially ordered films, one deposited at 300°C and annealed at 400°C and the other at ambient temperature and annealed at 450°C. Compared to the film deposited at 300°C, (111) reflection of the film deposited at ambeint temperature is broader and assymetric, and can be deconvoluted to two sublet. This is a sign of the presence of two phases as a result of dominant nucleation and growth transformation mechanism. In contrast, the film deposited at 3. 0°C has well-defined single diffraction peak. Such films exhibit homogeneous magnetic hysteresis, free from shoulders which is indicative of co-presence of hard and soft subphases.

[1] K. R. Coffey, M. A. Parker and J. K. Howard, *IEEE Trans. Magn.* **31** 2737 (1995)

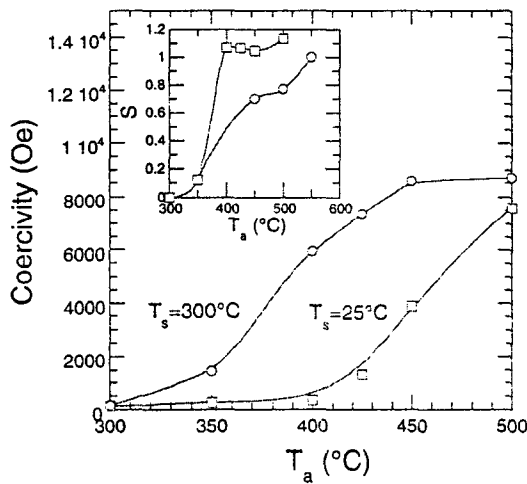[2] B. E. Warren, X-ray diffraction, Dover Publisher, New York (1990).
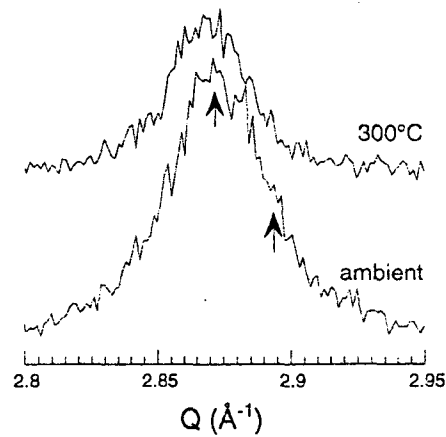
Fig.1 H_c as function of annealing temperature.   Fig.2 Specular XRD scan on (111) reflection.