Magnetic-field-induced Precession in FePt Film

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1. Introduction

Perpendicular magnetic material with high anisotropy energy can sustain thermal fluctuation even in a nano-sized magnetic structure. Therefore magnetic material with high anisotropy energy has been extensively explored. One of the materials with high anisotropy energy together with high saturation magnetization and magneto-optical Kerr effect is $L1_0$-ordered FePt film. Using this material, various fabrication methods have been actively studied in order to realize ultrahigh density storage media. In addition, ultrafast operation of the storage media has needed the understanding of ultrafast spin dynamics of FePt film.

2. Experimental Methods

To study ultrafast working characteristic of FePt film, 10-nm-thick equiatomic FePt film was prepared directly on MgO (100) substrate using dc magnetron sputtering of FePt target with a base pressure of better than 5.1×10^{-6} Torr and the sputtering Ar gas pressure of 5.1 mTorr. Sample was prepared at the substrate temperature of 450℃ heated by homebuilt heater setup.1 The structure of the sample was characterized using the x-ray diffractometry (XRD). Even though the degree of ordering may not be perfect, Fig. 1 shows that the clear FePt peaks in the XRD pattern imply the formation of the L10 ordering of the FePt film. The magnetic property of the sample was characterized using a vibrating sample magnetometer (VSM). In the VSM measurement, we found that the saturation magnetization (M_s) of the sample was 1000 emu/cc, and the coercive field (H_c) was 0.7 kOe. This moderate coercive field was obtained from low annealing temperature of 450℃, compared with the previously-made high-H_c FePt with annealing temperature of 500℃.[1]

In order to generate the precessional motion, current pulse is transferred through the coplanar waveguide (CPW), and magnetic field pulse generated from the current pulse is applied to the FePt sample on top of the CPW. Probe beam has a center wavelength of approximately 400 nm, average power of 40 μW, and a focused spot size of ~1 μm by using objective lens with N.A.=0.5. Pure M_x component of the spin precessional motion is obtained from the difference between signals measured by using polarity-modulated magnetic field pulse. Precessional motion of Mx component is measured by varying the strength of bias magnetic field (H_{bias}) in the direction of z axis.

3. Experimental results

Fig. 2 shows the experimental result, and Fig. 3 shows the simulation result using Landau-Lifshitz-Gilbert (LLG) equation for the experimental result. In the LLG simulation, we used the M_s value of 1000 emu/cc and a pulse shape used in Ref. 2. As the resonance frequency depends on M_s, H_{bias}, and the anisotropy constant K_u, we used the experimental values of M_s and H_{bias}, and tuned the value of K_u to fit the precession frequency. We can easily find the value of $K_u^{eff} = 6.8\times10^6$ erg/cc because of the monotonic proportionality between Ku and precession frequency. Damping behaviors for the three different Hbias are fitted simultaneously by varying the damping constant. From this, we find the value of damping constant ~ 0.2.

4. Discussion

We have also performed an experiment for samples with high coercivity of 2 - 4 kOe with a similar experimental configuration. In this case, we could not observe clear precessional motion. L10-ordered FePt film with high coercivity is expected to need high field strength to excite the spin state which is tightly fixed with the high anisotropic field.[3] As the magnetic field pulse generated from the photoconductive switch is estimated to have about 5-Oe amplitude, we thought this is an important reason why we could not observe clear precessional motion of highly $L1_0$-ordered FePt film using the external magnetic field pulse unless the damping constants of the samples are not considerably different.

5. Conclusion

We studied spin precessional motion in the partially $L1_0$-ordered FePt film by using magnetic field pulse, and analyzed the damping phenomena of the sample by LLG simulation. The analysis revealed that the damping constant of the sample is ~ 0.2. Relatively large damping of this material implies the nearly critical damping after precessional switching. This study suggests the requirement of the ultrafast excitation of perpendicular magnetic material with high anisotropy field for the potential application of the ultrafast switching.

6. References

[1] Hyun Seok Ko, A. Perumal, and Sung-Chul Shin, Appl. Phys. Lett. **82**, 2311 (2003).

[2] Kyeong-Dong Lee *et al*., J. Korean Phys. Soc. **49**, 2402 (2006).

[3] Private communication with Dr. J.-Y. Bigot.

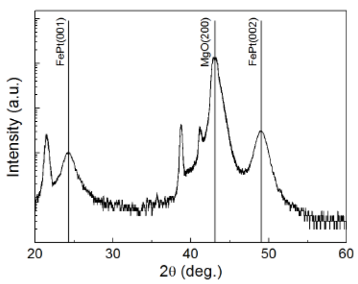

Fig. 1: Θ - 2Θ X-ray diffraction pattern of the sample.

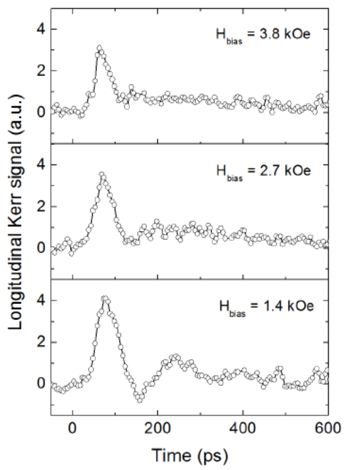

Fig. 2: Precessional motion induced by magnetic field pulse.

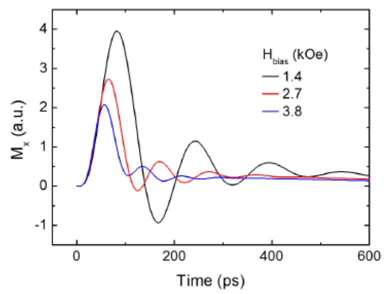

Fig. 3: LLG simulation using magnetic field pulse.