Fe L$_{2,3}$-edge x-ray magnetic circular dichroism of FePt thin films with controlled L1$_0$ order

Keisuke Ishigami$^{1,*}$, Goro Shibata$^1$, Takeshi Seki$^2$, Yukio Takahashi$^1$, Toshiharu Kadono$^1$, Shoya Sakamoto$^1$, Tsuneharu Koide$^3$, Koki Takanashi$^2$ and Atsushi Fujimori$^1$

$^1$University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
$^2$Institute for Materials Research Tohoku University, Aoba-ku, Sendai 980-8577, Japan
$^3$KEK-PF, 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan

1 Introduction

There has been increasing demand to decrease the size of and to increase the capacity for magnetic recording media. For this purpose, perpendicular magnetic anisotropy is necessary to increase the recording density. FePt with the L1$_0$ structure shows particularly strong perpendicular magneto-crystalline anisotropy and is a promising candidate material for high-density magnetic recording media because the magnetic anisotropy constant $K_u$ of the L1$_0$-ordered FePt reaches as large as $5 \times 10^7$ erg/cc. The degree of L1$_0$ order $S$ in the FePt thin films can be controlled by changing the annealing temperature and time [1].

As a general property of magneto-crystalline anisotropy, Bruno [2] has proposed that $K_u$ is proportional to the difference in the orbital magnetic moment between the in-plane and out-of-plane magnetic field directions. If L1$_0$ ordered FePt thin films follow the Bruno formula, the anisotropy of the orbital moment of Fe 3$d$ electrons plays a key role in their magneto-crystalline anisotropy.

In this work, we have measured x-ray magnetic circular dichroism (XMCD) of FePt films at the Fe L$_{2,3}$ edge in order to obtain the orbital and spin magnetic moments for various directions of magnetic field from in-plane to out-of-plane.

2 Experiment

FePt thin films were fabricated on MgO (100) single crystal substrates using an ultrahigh vacuum magnetron sputtering. The stacked structure is MgO subs./Fe (1nm)/Au (30nm)/FePt (20nm)/Au(2nm). The deposition and annealing temperature ($T_s$ and $T_A$) was varied in the range from room temperature to 600 °C. The composition of the FePt layer was Fe$_{43}$Pt$_{57}$ as determined by electron probe x-ray microanalysis. The degree of L1$_0$ order was examined by 2$\theta$-2$\theta$ scans of x-ray diffraction (XRD) with Cu-K$_\alpha$ radiation. The crystal orientation was also monitored by reflection high energy electron diffraction (RHEED) during the film growth.

Fe L$_{2,3}$-edge XMCD spectra were taken in the total electron yield mode at room temperature under a magnetic field of 1.0 T with changing the field direction from in-plane to out-of-plane of the film surface.

3 Results and Discussion

Figure 1 shows the XMCD intensities as functions of magnetic field direction for the FePt thin films annealed at 600 °C ($S=0.7$), 500 °C ($S=0.5$), 300 °C ($S=0.4$), and un-annealed one ($S=0.0$). The angular dependence is seen to strongly depend on the degree of L1$_0$ order $S$. The larger $S$ is, the weaker the angular dependence becomes, reflecting the stronger magnetic anisotropy with the perpendicular easy magnetization axis.

References


* ishigami@wyvern.phys.s.u-tokyo.ac.jp