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Atomic order dependence of the Fe 3*d* orbital magnetic moment in $L1_0$-ordered FePt thin films studied by Fe *L*-edge XMCD

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1 Introduction

In order to achieve much higher recording density of magnetic recording media, materials with strong perpendicular magnetic anisotropy (PMA) are required. $L1_0$-ordered FePt is well known as a candidate for such materials because of its magnetic anisotropy constant K_u as large as 7×10^7 erg/cc [1]. The value of K_u changes with degree of $L1_0$ order S. Seki *et al*. have shown that S can be controlled by changing the deposition and annealing temperatures [2].

Despite its importance, the origin of the strong magnetic anisotropy energy (MAE) of $L1_0$-ordered FePt is still not fully understood. Bruno has shown a simple relationship that MAE is proportional to the difference of the orbital magnetic moments between the out-of-plane and in-plane directions using perturbation theory within the tight-binding approximation [3]. On the other hand, Solovyev *et al*. have indicated that not only the Fe 3*d* orbitals but also the Pt 5*d* orbitals contribute to MAE from first-principles calculation [4]. Hence, element-specific measurements of magnetic moments are important in order to distinguish contributions from each element and to reveal its role in MAE.

In this work, we have performed angle-dependent x-ray magnetic circular dichroism (XMCD) measurements of FePt thin films at the Fe $L_{2,3}$-edge in order to obtain the magnetic moments for various degrees of $L1_0$ order S.

2 Experiment

FePt thin films were grown on MgO (100) substrates by the ultrahigh vacuum magnetron sputtering method. The structure of the sample was MgO subs./Fe (1nm)/Au (30nm)/FePt (20nm)/Au (2nm). The deposition temperature (T_S) and annealing temperature (T_A) ranged from room temperature (R.T.) to 600 ºC (see Table 1).

Table 1: Sample preparation conditions and the degrees of $L1_0$ order.

T_S (ºC)	T_A (ºC)	Order degree S
R.T.	-	0
300	500	0.5
300	600	0.7

The degree of the $L1_0$ order S was determined from the x-ray diffraction intensity ratio of the FePt 001 superlattice peak to the FePt 002 fundamental peak [2,5].

Fe $L_{2,3}$-edge spectra were measured by the total electron yield (TEY) method under a magnetic field of 5 T at room temperature. We refer to $\theta = 0º$ and $\theta = 60º$ as the out-of-plane and in-plane directions, respectively, where θ is the angle between the sample normal axis and the external magnetic field direction. We measured the magnetization curve of each sample by PPMS.

3 Results and Discussion

Figure 1 shows the XMCD spectra at the Fe $L_{2,3}$-edge with various degrees of $L1_0$ order S for the in-plane and out-of-plane directions. Anisotropic behavior grows with increasing S at the L_3-edge, while the XMCD intensity is kept nearly isotropic at the L_2-edge. According to the XMCD orbital sum rule [6], the orbital magnetic moment is proportional to the difference between the XMCD intensities at the L_3 and L_2 edges. Therefore, the above result indicates that anisotropy of the orbital magnetic moment is enhanced with increasing S.

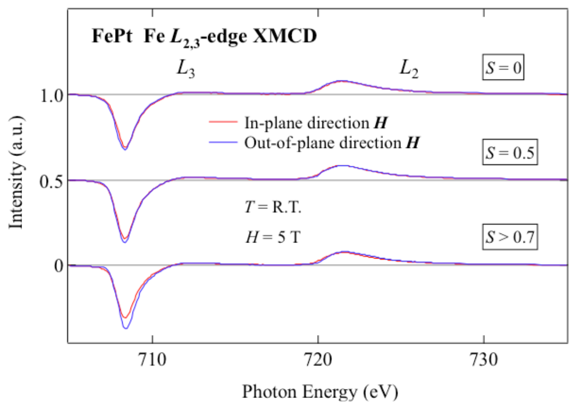

Fig. 1. XMCD spectra at the Fe $L_{2,3}$-edge with various degrees of $L1_0$ order S for the in-plane and out-of-plane directions.

Figure 2 shows the relationship between the MAE estimated from the Bruno model by using the orbital magnetic moments measured by XMCD and the MAE from the magnetization measurements. The MAE estimated from the Bruno model as well as that estimated from the magnetization measurements increases with *S*, although the former is larger in magnitude than the latter. This means that the relationship between the MAE and the orbital magnetic moment anisotropy estimated from Fe $L_{2,3}$-edge XMCD is qualitatively consistent with the Bruno model, but is quantitatively different. This result suggests that not only Fe atoms but also Pt atoms play an important role in the MAE.

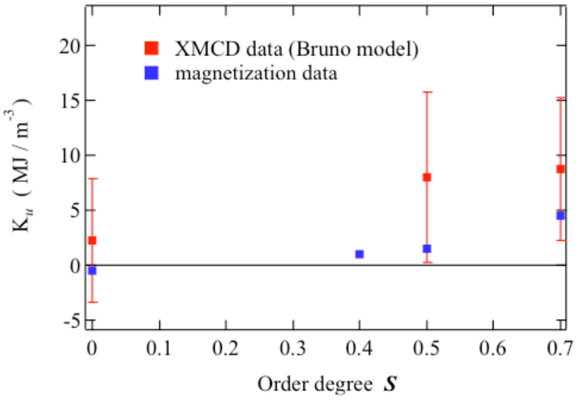

Fig. 2. Magnetic anisotropy energies estimated from the Bruno model by using the orbital magnetic moments measured by XMCD and from magnetization measurements.

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