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Pt 5d Magnetic States in CoCrPt Thin-Films: An XMCD Study at Pt $L_{2,3}$-Edges

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Introduction

CoCrPt perpendicular magnetization thinfilms are regarded as a promising material for highdensity recording media. Various studies have showed that compositional and structural inhomogeneities play an important role in appearing the magnetic properties. However, there has been a little amount of information about the correlation between Pt 5d magnetic states and the perpendicular anisotropy. To elucidate mechanism of the perpendicular magnetization, it is prerequisite to clarify, (a) how is metallographic state, and (b) how are the Pt 5d magnetic states in the thin-films. X-ray magnetic circular dichroism (XMCD) may be the most effective tool for this purpose, because the Pt L-edge yields relatively large dichroic signal and sensitively depends on magnetic constituents. However, such experiment of thin-films has been restricted because of thinness in nanometer size and existence of glass substrate. We succeeded in the accurate measurement for the CoCrPt thin-films in fluorescent X-ray mode. In this report, we present the Pt L-edge XMCD in the thin-film and bulk samples.

Experimental

$Co_{70}Cr_{20}Pt_{10}$ and $Co_{70}Cr_{18}Pt_{12}$ thin-films (15 or 18 nm thickness) were deposited on glass substrates by dc magnetron sputtering [1]. These thin-films have no Pt capping layer. The ternary alloy fixed 70 at%Co was made by Ar arc-melting furnace.

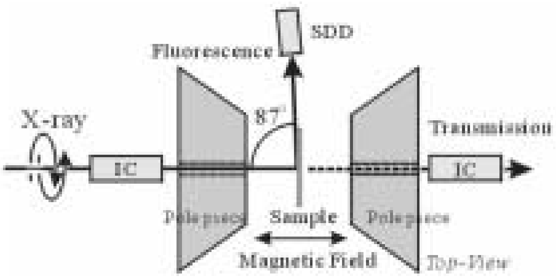

Fig.1. Experimental geometry of XMCD.

Powdered sample was subjected to adequate thermal treatment. Crystal structure was verified to be f.c.c., *i.e*., disordered phase, by powder X-ray diffraction.

The Pt $L_{2,3}$-edge XMCD spectrum was recorded by the helicity reversal method. Experimental geometry is shown in Fig.1. A magnetic field of 0.6T was applied parallel to the direction of incident X-ray beam that was perpendicular to the surface of the thin-films. Pt L_α- or L_β-fluorescent X-ray was discriminated and efficiently measured by silicon- drift detector in low-angle geometry (outgoing-angle was about 87 deg.), which was effective for improving S/BG ratio. The measurement for bulk was made by the conventional transmission method using the powdered sample.

Results and Discussion

Figure 2 shows the Pt $L_{2,3}$-edge XMCD spectra in $Co_{70}Cr_{20}Pt_{10}$ thin-film in comparison with a bulk sample of the similar composition. The L_3- (L_2-) XMCD has a negative (positive) sign, which means that the Pt 5d magnetic moments are aligned parallel to the magnetic field. For the bulk sample, the profile is symmetric and can be satisfactorily fitted by the pseudo-Voigt function. On the other hand, for the thin-film the L_3-XMCD shows an asymmetric profile with a subsidiary structure around +10 eV. Furthermore, it should be noted that the L_3-edge is remarkably reduced in the intensity of the thin-film compared with the bulk, whereas the L_2-edge shows almost the same intensity and profile. These characteristics are more notable in $Co_{70}Cr_{20}Pt_{10}$ than in $Co_{70}Cr_{18}Pt_{12}$ thin-film.

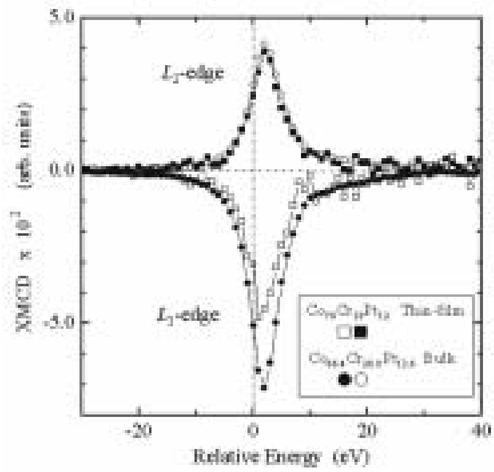

Fig.2. Pt $L_{2,3}$-edge XMCD spectra in $Co_{70}Cr_{20}Pt_{10}$ thin-film and the relevant bulk sample.

(a) Structural inhomogeneity

Let us consider the observed difference in the context of metallographic state. It has been well known that ordered $CrPt_3$ is the only ferrimagnetic phase in Cr-Pt system, and that the Pt XMCD in $CrPt_3$ shows the *positive* sign both at the L_3- and L_2-edges [2]. Hence, the observed reduction in the L_3-edge spectral intensity is possibly ascribed to the formation of $CrPt_3$ phase. It is reasonable that the spectrum consists of two contributions: ferromagnetic Co-Pt and ferrimagnetic $CrPt_3$. We speculate that Co-rich matrix is mainly composed of ferromagnetic Co-Pt solid solution and eutectic $CrPt_3$ ferrimagnetic phase plays a role of separation between the ferromagnetic domains. To clarify the complex domain structure, both crystallogra-phic and morphological characterizations of the thin-films are highly required.

(b) Orbital angular momentum

It is important to examine the correlation between orbital magnetic moment and perpendicular magnetization anisotropy. Then, we applied the magneto-optical sum rules [3] to the XMCD spectra to separate orbital component from spin part in Pt 5*d* moments. For the quantitative discussion, we paid attention to (i) white-line intensity in the X-ray absorption spectrum, (ii) XMCD intensity, and (iii) rescaling of edge-jump at the L_2-edge to the L_3-edge. Expectation value of orbital $\langle L_z \rangle$ and spin $\langle S_z \rangle$ angular momenta in the ground state is empirically evaluated. In the estimation, however, magnetic dipole $\langle T_z \rangle$-term was neglected in both cases of bulk and thin-film, and Pt 5*d* hole-count was fixed to unity ($2p^6 5d^9$). Validity of these assumptions is not trivial; in particular, for the thin-films the $\langle T_z \rangle$-term should be taken into account.

Figure 3 shows the value of $\langle L_z \rangle$, $\langle S_z \rangle$, and their resultant angular momenta thus estimated. The magnitude is increased with Pt composition regardless of the thin-film and bulk samples. Total magnetic moments derived from the data are of 0.2 ~ 0.4 μ_B/Pt. In the thin-films, the Pt magnetic states are not sensitive to thickness but to Pt composition. There is, unexpectedly, no enhancement in the orbital angular momentum in the thin-films. A ratio $\langle L_z \rangle / \langle S_z \rangle$ may be regarded as an index of orbital contribution; as shown in Fig.4, the ratio in the thin-films is rather small compared with those in the bulk sample. Hence the perpendicular magnetization

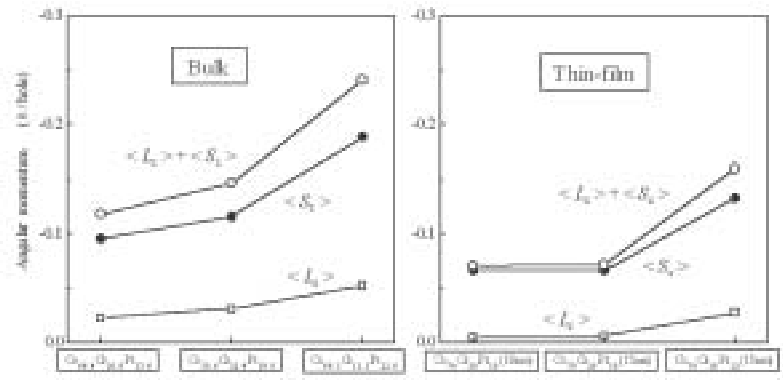

Fig.3. Expectation value of orbital $<L_z>$, spin $<S_z>$, and resultant angular momenta.

is possibly attributed to structural reason as far as the present results. To obtain a better understanding, it is necessary to compare thin-film to bulk sample with the same composition.

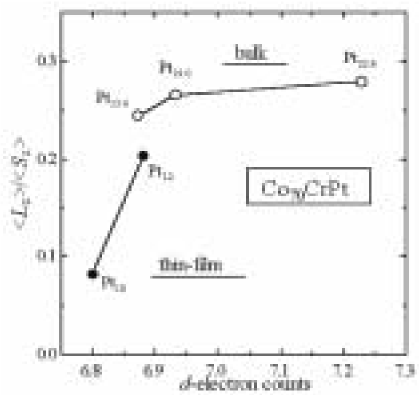

Fig.4. Measure of orbital contribution ($<L_z>/<S_z>$ ratio) as a function of outer *d* electron counts.

Concluding Remarks

For the CoCrPt perpendicular magnetization thin-films, we succeeded in the accurate measurement of Pt *L*-edge XMCD. Since there is no enhancement in the orbital angular momentum, structural inhomogeneity may be closely associated with the magnetic properties, in which the $CrPt_3$ phase is probably a key material. Systematic study on the structural inhomogeneity is necessary.

References

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