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Spin reorientation transitions of Fe/Co/Pd(111) magnetic thin films

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Introduction

The magnetization directions of magnetic thin films are influenced by the existence of surface, interface, and elastic strains for epitaxial growth. Co films on Pd(111) are magnetized perpendicularly below about 4 monolayers (ML)[1]. In this report, the spin reorientation transition (SRT) of Co/Pd(111) induced by Fe deposition was investigated using X-ray magnetic circular dichroism (XMCD) method. In-plane magnetized Co films of 4–6 ML undergo the SRT twice; first, a small amount of Fe deposition causes a transition to perpendicular magnetization. Second, further Fe deposition (about 2 ML in total) causes a return to in-plane magnetization. A perpendicularly magnetized 3 ML Co film also exhibits a transition to in-plane by 2 ML Fe deposition. A precise magnetic anisotropy phase diagram was obtained using a combination of wedge-shaped Co samples and stepwise Fe deposition.

Experiment

Fe and Co films were deposited at room temperature by an electron-beam evaporation on a cleaned Pd(111) with monitoring the thickness by RHEED observations. Wedge-shaped Co samples were fabricated in order to obtain a precise magnetic anisotropy phase diagram. Stepwise deposition of Fe guaranteed that the same thickness of Fe was deposited on each position of the wedge-shaped Co sample, and to reveal the precise phase diagram.

XMCD experiments were performed at BL-7A. The sample was magnetized by a pulsed current through a coil. Circularly polarized (~80%) x-rays were obtained by using the light emitted downwards from the electron orbit of the storage ring. XMCD spectra were obtained by reversing the film magnetization at room temperature. The direction of the magnetization was examined by measuring XMCD spectra at normal (90º) and grazing (30º) x-ray incidences, which are referred to "NI" and "GI", respectively.

Results and discussion

Co *L*-edge XMCD spectra are shown in Fig. 1 taken during a stepwise deposition on 5 ML Co on a Pd(111) substrate. Twice SRTs were observed during the stepwise Fe deposition. The bare 5 ML Co film was magnetized in-plane, and changed the magnetization direction to perpendicular at 0.5 ML Fe deposition through an intermediate state of in-plane and perpendicular magnetization with 0.3 ML Fe. Fe(1.0 ML)/Co(5 ML)/Pd(111) was still magnetized perpendicularly, and the second SRT was occurred when 1.5 ML Fe was deposited. Fe(2.0 ML)/Co(5 ML)/Pd(111) also had in-plane magnetization, and it should be in-plane magnetization when further more Fe was deposited.

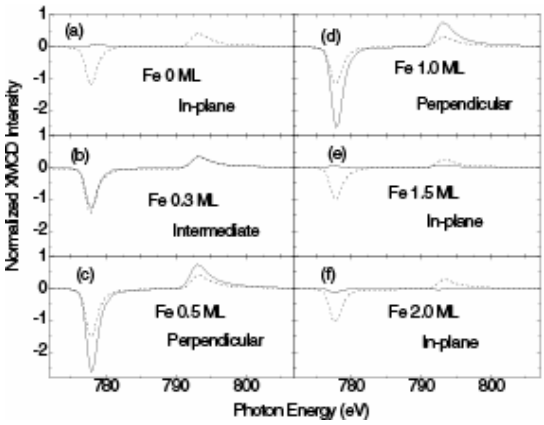

Fig. 1. Co L-edge XMCD spectra during stepwise Fe deposition. Fe deposition amounts are presented in each figure box.

A series of XMCD measurements of Fe/wedge-shaped Co/Pd(111) samples with different Fe thickness yielded a magnetic anisotropy phase diagram of Fe/Co/Pd(111) shown in Fig. 2. Two SRT boundary lines can be drawn with increasing Fe thickness. The first one is the lower line, where the SRT of in-plane to perpendicular occurred for 4–6 ML Co samples with submonolayer Fe deposition. The second one is the other upper line, where the SRT of perpendicular to in-plane occurred for 3–6 ML Co. A SRT to perpendicular magnetization was not observed for 7 ML and thicker Co samples.

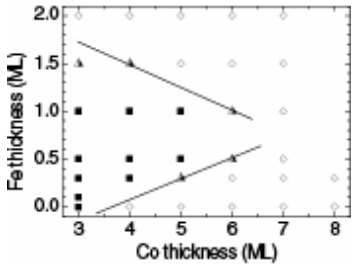

Fig. 2. The obtained magnetic anisotropy phase diagram of Fe/Co/Pd(111).

References

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