Instrumentation and Technique

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Layer-resolved magnetic structure of Fe/Cu(100) ultrathin films observed by the depth-resolved x-ray magnetic circular dichroism

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Introduction

The magnetic depth profile of 5-11 ML thick Fe/Cu(100) films is one of the most controversial issues in these decades. Qian et al.[1] indicated that the surface two layers are ferromagnetic, while inner layers are in the spin density wave (SDW) state with a wavenumber $q=2\pi/2.7d$. Their approach was still indirect, however, since they measured total magnetization changing the film thickness. Recently, we have developed a depth-resolved x-ray circular magnetic dichroism (XMCD) technique, in which the probing depth is controlled by changing the detection angle for the emitted electrons[2]. It was necessary, however, to record the XMCD spectrum at each detection angle. In the present study, we have significantly improved this technique by using an imaging type detector, and applied it to the Fe/Cu(100) ultrathin films.

Experimental

In the depth-resolved XMCD measurements, the emitted electrons are separately collected at various detection angles, θ_d, by a system illustrated in Fig. 1. Therefore, a series of XMCD spectra with various probing depths are simultaneously recorded.

All the experiments were performed at BL-7A in an ultrahigh vacuum chamber. Fe films were deposited on a clean and ordered Cu(100) single crystal and the film thickness was monitored by an in situ reflection high-energy electron diffraction observation.

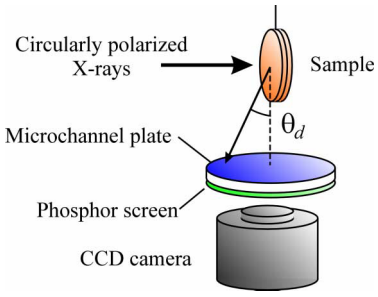

Fig. 1. Layout of the depth-resolved XMCD.

Results and Discussion

Figure 2 gives depth-resolved XMCD spectra for a 7 ML film. The XMCD intensity is reduced as θ_d increases, directly indicating existence of the surface ferromagnetic layers. Note that the XMCD signals at 130 K are smaller than those at 200 K. This is explained by assuming that the inner layers are nonmagnetic at 200 K, while they are in the SDW state with an antiferromagnetic interface coupling at 130 K (see Fig. 3). This interpretation agrees well with the previous study[1], which reported the SDW ordering temperature of ~200 K.

We obtained the SDW wavenumber $q=2\pi/2.6d$ by fitting the observed data, and extracted the XMCD spectra for the surface and inner (SDW) layers as shown in Fig. 3. The magnetic moments estimated by using the sum rules suggest an enhancement of the surface orbital moment. Moreover, in the spectrum for the SDW layers, a small but significant structure appears above the L_{III} peak (indicated by an arrow), which is a typical feature of the XMCD spectrum for bulk Fe.

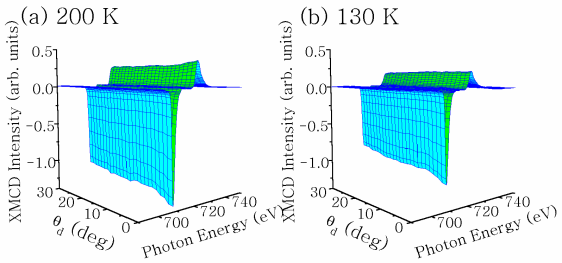

Fig. 2. Fe L-edge XMCD spectra for a 7 ML Fe film taken with various electron detection angles, θ_d.

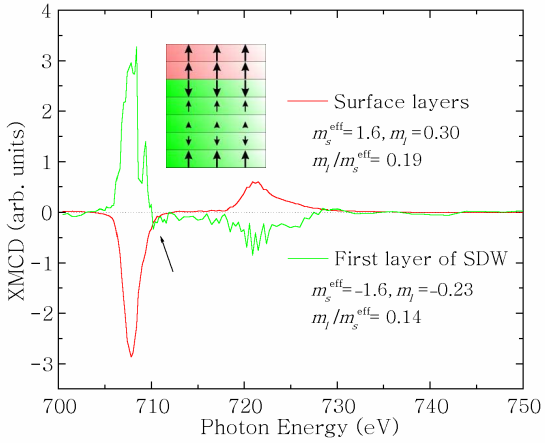

Fig. 3. Fe L-edge XMCD spectra for the surface and SDW layers extracted from the data taken at 130 K, together with the obtained magnetic structure model.

References

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