Depth-resolved XMCD study on Fe/Cu(001)

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Introduction

Fe/Cu(001) ultrathin film is one of the most widely investigated systems because of the large variety of its structural and magnetic properties that depend on the Fe film thickness. Between 5 to 10ML, it takes a fcc structure with reconstructed surface fct layers. The surface 2 layers are known to be ferromagnetic (out-of-plane) [1], while the inner layers are either anti-ferromagnetic or in a SDW (spin-density-wave) state [2].

In this report, we have developed a novel depth-resolved XMCD (x-ray magnetic circular dichroism) method and applied to this system to clarify the magnetic structures of this system.

Experimental

Cu(001) single crystal was cleaned by repeated cycles of Ar^+ sputtering and annealing to 900K. Fe was deposited by an e-bombardment heating of Fe-rod, and the film thickness was monitored by *in situ* RHEED observation. The sample was cooled down to 110K and magnetized perpendicular to the film surface by a pulsed current through a coil.

All the XMCD experiments were performed at BL-7A. Circularly polarized x-rays were obtained by using x-rays emitted above (or below) the electron orbit plane of the storage ring by 4mrad ($P_C \approx 0.8$). For the depth-resolved XMCD measurement, a slit was mounted above the microchannel plate (MCP) to count the electrons emitted only along the detection angle θ_d. The acceptance angle of MCP was 5° (see inset of Fig. 1).

Results and discussion

Fe-L XMCD spectra for the 8ML Fe film were measured at detection angles θ_d =0, 4, 8,12, and 15°. We also estimated the probing depth λ for each θ_d by the Fe-L edge jump height (@740eV) of each θ_d as a function of the film thickness. A self-absorption effect of x-rays was also taken into account. Estimated probing depth λ ranges from 2.1d to 3.9d depending on θ_d. (Note that d denotes the interlayer distance of the Fe film.)

The XMCD spectrum measured at a certain detection angle is the sum of contribution from each layer weighted by an exponential decay function of the depth. Thus we can, in principle, extract the XMCD spectra corresponding to each single layer. However, as for the 8ML film, we divided the film into two regions of different magnetic property; the surface two layers and the rest inner 6 layers. Then we assumed that the magnetic structure of the inner layers is in a SDW state and the SDW wave number is optimised as a parameter. Note that this assumption covers collinear anti-ferromagnetic states and non-magnetic states as the extreme cases. The fitting is optimised when the wave number $q=2\pi/2.4d$. The collinear anti-ferromagnetic states ($q=2\pi/2d$)is unlikely to be adopted. The magnetic structure obtained by the fitting result is shown in Fig.2.

[1] M.Straub et al., PRL 77(1996) 743
[2] D.Qian et al., PRL 87(2001) 227104
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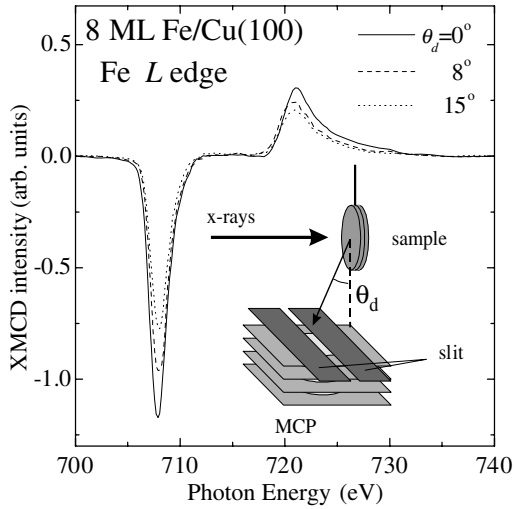

Fig.1 The setup of depthresolved XMCD and obtained spectra

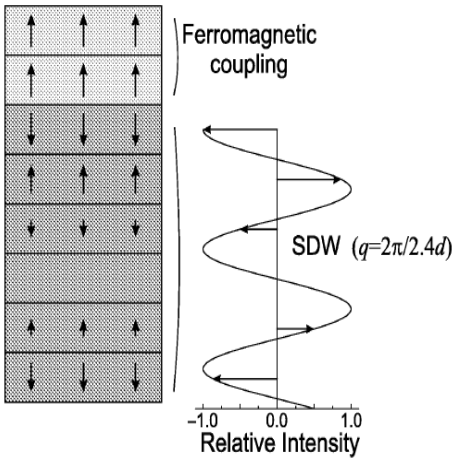

Fig.2 Schematic magnetic depth profile of the 8ML Fe film.