II-C Magnetic Structures of Magnetic Thin Films Studied by Using a Depth-Resolved XMCD Technique

Recently, we have developed a depth-resolved x-ray magnetic circular dichroism (XMCD) technique. In the soft x-ray region, an x-ray absorption spectrum is obtained generally by counting the Auger electrons emitted at the core hole relaxation, the number of which is proportional to the x-ray absorption intensity. The electron escape depth changes depending on the direction of emitted electrons. An imaging type microchannel plate is used as the electron detector, which enables us to collect the absorption spectra with various probing depths simultaneously. The XMCD spectra are obtained by reversing the sample magnetization direction at each incident helicity.

This simple technique can be applied to study the depth profile of magnetic structures of magnetic thin films.

II-C-1 Direct Observation of an Oscillatory Behavior in the Surface Magnetization of Fe Thin Films Grown on a Ni/Cu(100) Film

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When a Fe film is deposited on a ferromagnetic (FM) substrate, the interface (bottom) of the Fe film should undergo some magnetic interaction with the substrate. Our aim is to study the magnetic coupling between the surface and interface for the Fe films on 6 ML Ni/Cu(100) as a function of the Fe film thickness with the depth-resolved XMCD technique. Figure 1 shows Fe L-edge XMCD spectra from 4–11 ML Fe films grown on a 6 ML Ni/Cu(100) taken at 200 K with various probing depths, λ_e. Each spectrum was normalized to the edge jump height, so that the XMCD intensity reflects the magnetic moments per atom as an average over the contribution from each Fe layer weighted with the electron attenuation factor. A series of the spectra from the 4 ML film (region I) show almost identical intensity regardless of λ_e, directly indicating a simple ferromagnetic structure. In contrast, the XMCD intensity from the 4.5 ML film is drastically reduced as λ_e increases. Moreover, the XMCD spectra exhibit a positive sign at L_3 edge, indicating that the Fe surface has an opposite magnetization direction with respect to the applied filed. As the Fe thickness increases, the XMCD intensity decreases and almost vanishes around 6 ML, then grows up to 9 ML with an opposite sign. Finally, the XMCD signal almost disappears above 10 ML. These results clearly show that the Fe surface magnetization direction changes as a function of Fe thickness. Assuming that the magnetization of the Fe films consists of the contributions from (1) surface two layers, (2) inner layer and (3) interface layer, observed depth-resolved XMCD spectra were analyzed. The results show that the interface layer gives almost constant magnetization parallel with that of Ni, and the inner layer is almost nonmagnetic, and the surface two layers give the oscillatory magnetization depending on the Fe thickness. This apparent oscillation might come from the rotation of magnetic moment at the surface.

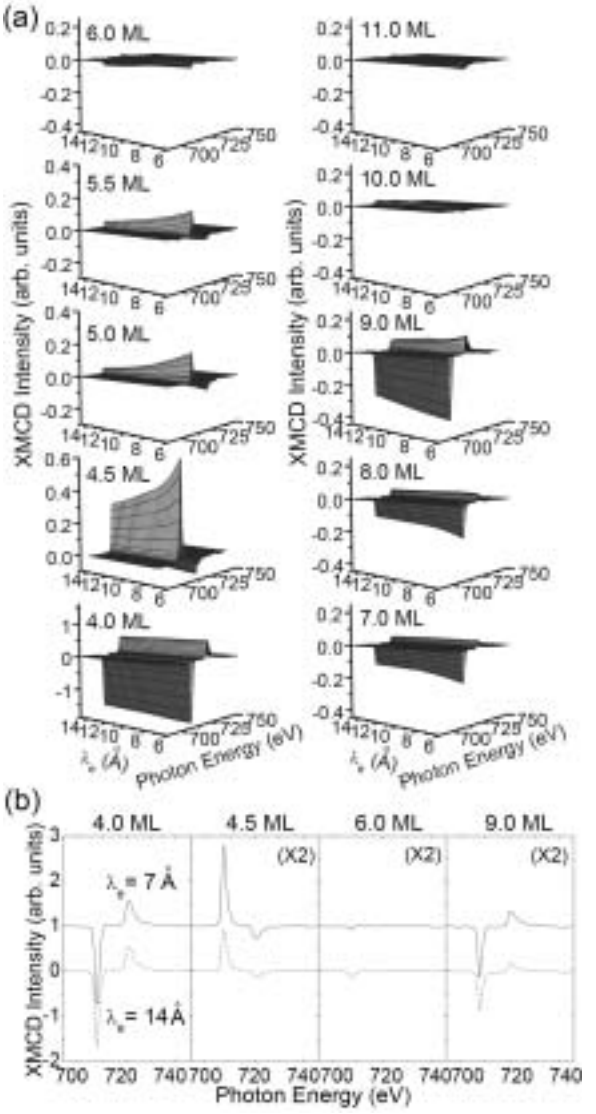

Figure 1. Fe L-edge XMCD spectra from Fe (4-11 ML)/Ni (6 ML)/Cu(100) films taken at 200 K with various probing depths, λ_e (a), together with the selected spectra at λ_e = 7 and 14 Å (b).

II-C-2 Spin Reorientation Transition of Ni/Cu(100) and CO/Ni/Cu(100): Separation of the Surface and Bulk Components of the X-Ray Magnetic Circular Dichroism Spectrum

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The spin reorientation transition of Ni/Cu(100) and CO/Ni/Cu(100) films was investigated with the depth-resolved x-ray magnetic circular dichroism (XMCD) technique. The XMCD spectra from the surface and inner layers were separately extracted. As for the bare Ni films, the in-plane orbital magnetic moment in the surface layer is significantly enhanced. In contrast, the inner layers exhibit larger perpendicular orbital magnetic moment than the in-plane one. Upon CO adsorption, the surface magnetization is drastically reduced, while the inner layers are unaffected. These results directly explain the spin reorientation transition mechanism in Ni/Cu(100) and CO/Ni/Cu(100) systems.