Depth-resolved XMCD study on spin reorientation transitions of Fe/Ni/Cu(001)

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Introduction

It has been reported that the Ni films on Cu(001) exhibit an in-plane magnetization below 8 ML, and a perpendicular one between 9-37 ML [1]. It is also known that the magnetic anisotropy is sensitive to surface or interface structures. For instance, H or CO adsorption stabilizes the perpendicular magnetic anisotropy [2].

In the present study, we investigated Fe/Ni/Cu(001) magnetic films to clarify the magnetic anisotropy and the depth profiles of the nickel orbital magnetic moment.

Experiments

XMCD experiments were performed at BL-7A. Fe and Ni films were deposited on a cleaned Cu(001) by an electron-beam evaporation. The thickness was monitored by an RHEED observation. To obtain the magnetic anisotropy phase diagram, wedge-shaped Ni samples were employed. The slope was 1-2 ML/mm. The sample was magnetized by a pulsed current through a yoke coil.

Circularly polarized x-rays (circular polarization factor ~80%) were obtained by using the light emitted downwards from the electron orbit of the storage ring. The total electron yield mode was adopted to determine the total magnetization. In order to reveal the depth profiles of the Ni orbital magnetic moment, depth-resolved XMCD study [3] was performed in the partial electron yield mode by using a microchannel plate detector. XMCD spectra were obtained by reversing the film magnetization. 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

Fig. 1a shows a series of XMCD spectra taken during a stepwise Fe deposition on a Ni(7.5 ML)/Cu film. The spectra show in-plane, perpendicular, and in-plane magnetization as the Fe thickness increases. From a series of XMCD measurements for the wedged Ni samples, a magnetic anisotropy phase diagram of Fe/Ni/Cu was obtained (see Fig. 1b). Note here that in-plane magnetized Ni films (<9 ML) undergo twice spin reorientation transitions (SRTs). The first one to perpendicular occurs even with a small amount (<0.5 ML) of Fe deposition. In contrast, the perpendicularly magnetized Ni/Cu film (< 16 ML in the present experiment) shows a SRT to in-plane magnetization by 1-2 ML Fe film deposition.

The probing depth dependence of the Ni orbital magnetic moment was obtained from depth-resolved

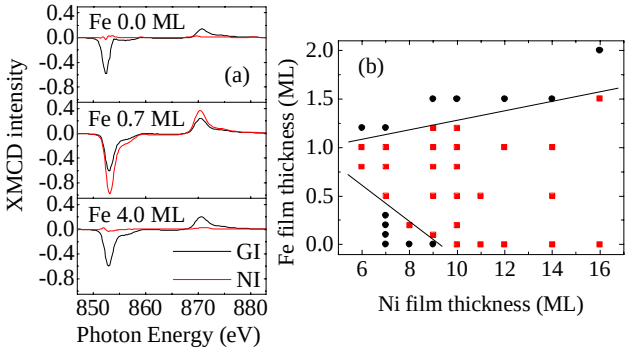

Fig. 1. (a) Ni *L*-edge XMCD spectra of Fe(x ML)/Ni(7.5 ML)/Cu(001). (b) The magnetic anisotropy phase diagram of Fe/Ni/Cu(001).

XMCD study, as shown in Fig. 2 for Ni(8 ML)/Cu. In this in-plane magnetized film, the orbital moment increases as the probing depth decreases. Then we adopted a simple model, where Ni layers were divided into the top layer and the other inner layers. A curve fitting analysis suggested that the orbital magnetic moment of the top Ni layer is ~0.08 μ_B, while that of the inter layers is ~0.04 μ_B. In contrast, the moment did not depend on the probing depth, in the perpendicularly magnetized films such as Fe(0.4 ML)/Ni(8 ML)/Cu and Ni(10 ML)/Cu. In the latter case, the moment was estimated to be 0.06 μ_B over the whole layers. From a comparison between 8 and 10 ML Ni films, it is directly confirmed that the top layer has in-plane anisotropy, and the inner ones perpendicular.

In order to clarify the origin of the first SRT to the perpendicular magnetization, we compared Ni(8 ML)/Cu with Fe(0.4 ML)/Ni(8 ML)/Cu, leading to the conclusion that Ni top layer does not favor the perpendicular magnetization even after Fe deposition. We consider that this SRT is due to the perpendicular magnetic anisotropy of the Fe film below 1 ML.

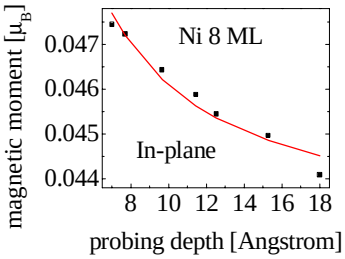

Fig. 2. Depth profile of the Ni orbital magnetic moment of Ni(8 ML)/Cu(001).

References

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