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Precise determination of layer thicknesses in Co/Cu and Fe/Cu multilayers

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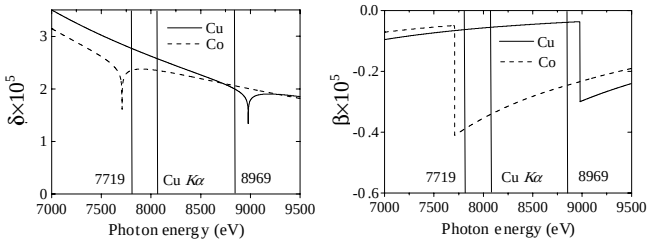
Introduction

A change of 1 AL in Cu thickness switches the magnetic coupling in multilayered Co/Cu and Fe/Cu from ferromagnetic to antiferromagnetic. X-ray reflectivity profile is a good technique to precisely determine the mean Cu thickness over a sample area. This can hardly be done, however, at a classical X-ray source since the scattering factors for these metals are close at the characteristic-line energies. To overcome the difficulty, one can modify the scattering contrasts with the use of anomalous dispersion effects near the absorption edges.

Experiment

Energy selection



The scattering contrast in multilayered Co/Cu is dictated by the refractive index parameters δ and β, where $1-n=\delta+i\beta$, for fcc Co and Cu. In view of the above figures, calculated using Cromer-Liberman's atomic scattering factors, we selected 7719 and 8969 eV for the X-ray energy. At the latter energy, the contrast originates only from β. A similar consideration encouraged us to work at 7112 and 8969 eV in multilayered Fe/Cu.

Investigated samples

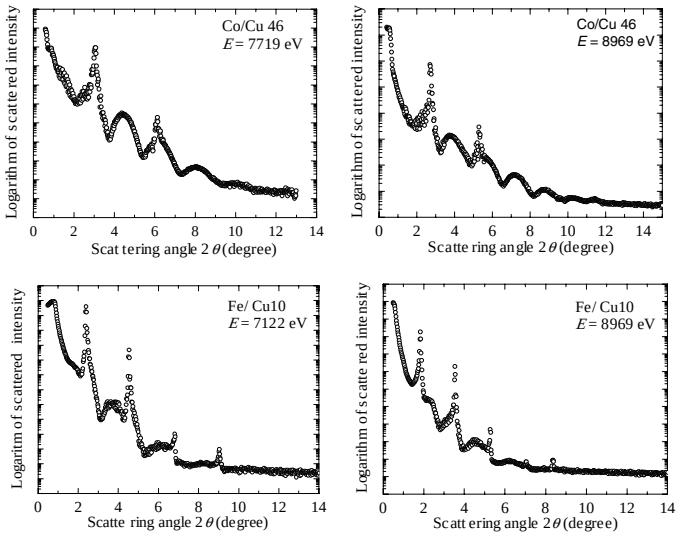
The samples investigated include those shown in Tables 1, grown on silicon wafers by magnetron sputter deposition. A 5 nm-thick Ta layer forms a buffer for multilayered Co/Cu. All multilayers are protected by a Cu cap against oxidation. These Co/Cu samples are those of which we keep XMCD data showing a specific dependence of the Cu moment on the interlayer thickness [1]. The present measurement was motivated to obtain a further insight in the induced Cu magnetization and the oscillatory coupling of the Co moments as a function of the Cu thickness.

Table 1: Investigated samples (layer thickness in nm)

Sample No.	Co or Fe	Cu	Pair No.
Co/Cu46	1.2	1.8	50
Co/Cu63	1.2	1.4	50
Co/Cu64	1.2	1.7	50
Co/Cu66	1.2	1.9	50
Co/Cu71	1.2	1.7	50
Co/Cu6	1.4	1.7	50
Fe/Cu10	1.5	2.5	50

Results

A few examples of reflectivity profiles observed in the May 2004 run are shown below. Interestingly, the β contrast (8969 eV) in the Co/Cu resulted in a profile as sharp as the one due to the δ and β contrast (7719 eV). The Bragg peaks are due to the multilayer period. The change in the relative intensities of the first and second peaks is not large but will allow us to precisely determine the Cu/Co thickness ratio by least-squares fits. The thickness determination appears to be easier in the Fe/Cu, where the intensity change is larger and Bragg reflections are observed up to the fourth order.



The beam time was also used to collect diffuse data, which will allow us to determine the interface roughness. The magnetic coupling in Co/Cu and Fe/Cu is believed to be affected by the interface structure.

References

[1] K. Ishiji et al., 59th Ann. Meeting of The Phys. Soc. of Japan, 28aXR-7, March (2004).

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