Specular and diffuse X-ray reflectivity study of surfactant mediated Co/Cu multilayers

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The discovery of the giant magnetoresistive effect in ferromagnetic/non-ferromagnetic superlattices offers a route to small bit size random access memories. The strength of the antiferromagnetic coupling between the layers depends on the spacer thickness and can be disrupted by significant interface roughness. The non-destructive X-ray techniques are sensitive to thin films of atomic dimensions and they can provide a very appropriate way to obtain structural information on thin films and multilayers. In this paper we present the application of X-ray techniques to the interface roughness determination.

The effect of a pre-deposited ultrathin film of Bi and Pb surfactants introduced into Co/Cu multilayers on the interface structure of multilayers has been studied. The $[Co(1\ nm)/Cu(2nm)]_{10}$ multilayers were thermally evaporated at very low deposition rates with a small amount of Bi and Pb surfactant (about 0.2 ML) introduced at each Cu layer. The reference sample of Co/Cu multilayers without surfactant was also prepared. The specular reflectivity as well as off specular reflectivity of Co/Cu multilayers has been measured. The spectra prepared with the use of surfactants showed the pronounced Bragg peaks due to the periodicity of the multilayers in contrary to the reference system where Bragg peak was much smaller. Bilayer periodicity as obtained from the position of this peak agreed very well with the nominal periodicity. A detailed analysis of the reflectivity pattern, besides layer thickness value, gives also information about the electron density in various layers and the rms roughness of interfaces. The true specular reflectivity patterns were fitted using Parratt's formalism [1]. It was seen that the multilayer with surfactants had roughness of the order of 1–2ML, but the multilayer without them had much larger roughness and strongly mixed interfaces, the result confirmed by the very small Bragg peak. In all studied specimens, the off-specular reflectivity replicates some of the features of specular reflectivity. In system with Bi the total thickness oscillations and Bragg peak are clearly visible, the sample with Pb showed only Kiessig oscillations, and reference sample demonstrated only weak traces of Bragg peak. It is known that the presence of total thickness oscillations in off-specular reflectivity signifies a high degree of correlation of the interface structure from layer to layer [2]. Thus in samples prepared with Bi surfactant the interface structure of successive layers is highly correlated, while in sample prepared with Pb and in reference sample the interfaces are weakly correlated. X-ray reflectivity as well as X-ray diffuse scattering measurements showed a distinct variation in the structure of the multilayers as the surfactant addition leads to well-ordered structures with small roughness.

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