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Nature of the Interfacial Regions in the Antiferromagnetically-coupled Fe/Si Multilayered Films

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A strong antiferromagnetic coupling in Fe/Si multilayered films (MLF) has been recently discovered and much consideration has been given to whether the coupling in the Fe/Si MLF system has the same origin as in the metal/metal MLF. Nevertheless, the nature of the interfacial iron silicide is still controversial. On one hand, a metal/semiconductor structure was suggested with a narrow band-gap semiconducting ε-FeSi spacer that mediates the coupling. However, some features show that the nature of coupling can be well understood in terms of the conventional metal/metal multilayered system. It is well known that both magneto-optical (MO) and optical properties of a metal depend strongly on their electronic structure that is also correlated with the atomic and chemical ordering. In this study, the nature of the interfacial regions is the Fe/Si multilayers has been investigated by the experimental and computer-simulated MO and optical spectroscopies.

The Fe/Si MLF were prepared by rf-sputtering onto glass substrates at room temperature with the number of repetition N=50. The thickness of Fe sublayer was fixed at 3.0 nm while the Si sublayer thickness was varied from 1.0 to 2.2 nm. The topmost layer of all the Fe/Si MLF is Fe. In order to carry out the computer simulations, the information on the MO and optical parameters of the materials that may constitute a real multilayered structure should be known in advance. For this purpose, we also prepared Fe, Si, $FeSi_2$ and FeSi samples. The structural characterization of Fe/Si MLF was performed by low- and high-angle x-ray diffraction with a Cu-K_α radiation and by transmission electron microscopy. A bulk ε-FeSi was also investigated. The MO and optical properties were measured at room temperature in the 1.0 - 4.7 eV energy range. The theoretical simulations of MO and optical properties for the Fe/Si MLF were performed by solving exactly a multireflection problem using the scattering matrix approach assuming various stoichiometries of a nonmagnetic spacer separating the antiferromagnetically coupled Fe layers. The simulated spectra of a model structure of $FeSi_2$ or ε-FeSi as the spacer turned out to fail in explaining the experimental spectra of the Fe/Si MLF in both intensity and shape. Thus, the decisive disagreement between experimental and simulated MO and optical properties rules out the hypothesis of $FeSi_2$ and ε-FeSi as the nonmagnetic spacer. By supposing the spontaneous formation of a metallic β-FeSi, a reasonable agreement between experimental and simulated MO and optical spectra was obtained.