ANTIFERROMAGNETIC COUPLING IN AMORPHOUS CoSi/Si MULTILAYERS: CHARACTERIZATION AND MODIFICATION BY ION BEAM NANOPATTERNING

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This work is a summary of the main results obtained during the last years by our research group, in collaboration with groups from the European Synchrotron Radiation Facility (ESRF, Grenoble, France) and Institute Néel (CNRS, Grenoble, France), concerning the characterization and modification of antiferromagnetic coupling in amorphous multilayers through semiconducting spacers.

Antiferromagnetic coupling in magnetic multilayers with few nanometer thick metallic spacers has been intensively studied in the last years so that, nowadays, the fundamental aspects of the physics of the process are well established [1]. In addition, the application of the peculiar electronic transport properties of some of these systems to the design of spin-valve type read heads of hard disks has lead to a big increase in their sensitivity and, consequently, to a marked increase of the areal density of information recorded in commercial hard disk drives [1]. However, the case of the magnetic coupling in multilayers with semiconducting spacers has been much less studied. As a consequence, in spite of the strong technological interest of semiconductor materials like Si, the role of this type of spacers in the magnetic coupling is not fully understood.

Our group has been intensively working in this field during the last years. In particular, we have found that amorphous alloys of Co-Si separated by Si spacer prepared by dc-magnetron co-sputtering align spontaneously in an antiferromagnetic configuration when the Si layer thickness is lower than 8 nm [2]. The magnetic field needed to break this alignment is very low, around 1-2 Oe, as deduced from magneto-optical transverse Kerr effect (MOTKE) loops. The coupling strength has been shown to decrease with temperature, what has been used to discuss the compatibility of different possible mechanisms responsible of the coupling with this temperature dependence [3].

Soft x-ray resonant magnetic scattering (SXRMS) measurements have been carried out to further investigate the details of the reversal process. The low field character of the coupling has been unequivocally shown by the disappearance of half order Bragg peaks when around 1-2 Oe are applied to the multilayers. In addition, a new scattering effect, consisting of the shift of antiferromagnetic reflectivity peaks depending on the photons helicity, has been experimentally observed and theoretically explained [4]. This new result means a contribution to the development of a synchrotron radiation based technique, like SXRMS, which is in continuous evolution.

Finally, a simple method has been developed to tune the strength of the antiferromagnetic coupling. It is based on the use of 1 keV Ar^+ ions to pattern Si(100) substrates with structures having several tens of nm wide and few nm height, and, subsequently, growing the magnetic multilayers on top of them. The results show that, using this technique, the coupling can be enhanced by about one order of magnitude (see Fig. 1). In particular, a correlation between ion induced surface roughness and antiferromagnetic coupling strength has been found. The results suggest that magnetostatic effects related to non-magnetic inhomogeneities and to the presence of oblique structures in the films may be affecting the coupling mechanisms [5].

In summary, antiferromagnetic coupling has been observed in amorphous multilayers of Co-Si alloys when the thickness of the Si spacers is lower than 8 nm. The coupling strength has been shown to monotonically decrease with temperature. The low switching field of the coupling has been confirmed by using synchrotron radiation to perform SXRMS measurements. Finally, a simple method, based on ion beam nanopatterning of Si substrates, has been developed to tune the coupling, and a correlation between ion induced substrate roughness and antiferromagnetic coupling strength has been observed.

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Figures:

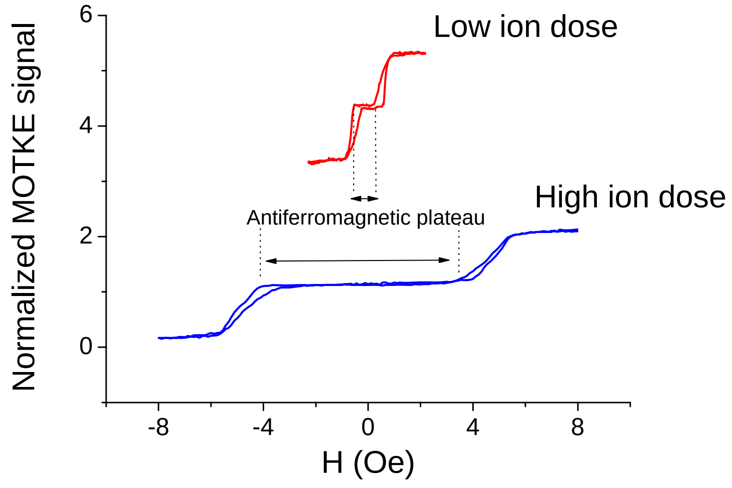

Figure 1. MOTKE signal of two magnetic multilayers grown on Si(100) substrates prepatterned with Ar^+ ion beams leading to rms roughness values of 0.23 nm for the low ion dose case, and to 0.88 nm for the high ion dose case.