MAGNETIC AND STRUCTURAL CHARACTERIZATION OF CO_XSI_{1-X} / SI MULTILAYERS

L. Zárate, C. Quirós, M. Vélez, G. Rodríguez-Rodríguez, J. I. Martín, and J. M. Alameda
Dpto. de Física, Universidad de Oviedo, Avda. Calvo Sotelo, s/n, 33007 Oviedo, Spain
carquir@string1.ciencias.uniovi.es

Understanding how the magnetic properties of one system evolve when reducing any of its characteristic dimensions to the nanometer range is an interesting topic in magnetism. In this context, Interlayer Exchange Coupling (IEC) of magnetic layers across non-magnetic spacers is one of the phenomena that take place when the thickness of the layers is of the order of few nanometers. In the last years, many efforts have been made to identify systems having IEC and to understand the origin of the coupling, but most of the studies were devoted to the case of metallic spacers, where the presence of ferromagnetic/antiferromagnetic behaviours oscillating with the spacer thickness is well established. However, the case of non-metallic spacers, like Si or Ge, has been much less studied, and a complete theoretical explanation of the obtained experimental results is lacking.

In this work we have studied the magnetic coupling of amorphous 5 nm thick films of Co_xSi_{1-x} alloys through Si spacers ranging from 2 to 15 nm, and we have found that the magnetic layers are antiferromagnetically coupled for thicknesses in the 2-4 nm range [1].The samples have been prepared by dc-magnetron co-sputtering of pure Co and pure Si targets. The structural properties of the films have been studied by x-ray diffraction (XRD) whereas the magnetic behaviour has been carried out mainly by magneto-optical transverse Kerr effect (MOTKE).

The composition of the films has been chosen in the amorphous range, $x < 0.75$, so that magnetically soft films can be used and, consequently, the expected weak IEC can be better detected. Structural characterization made by high angle XRD measurements confirms the amorphous character of the atomic arrangement in the magnetic layers. In addition, low angle reflectivity data show patterns with well defined Kiesseg interference fringes, pointing to the good quality of the interfaces grown, with roughness values, as low as 0.3-0.8 nm.

As already mentioned, the magnetic characterization confirms the presence of antiferromagnetic coupling in multilayers of 10 periods and spacer values around 2-4 nm. Whereas the single layers show square magnetic loops along the easy axis with high remanence values of the magnetization, the corresponding loops of the multilayers indicate that, at remanence, the magnetization along the easy axis falls down to values very close to zero, developing a plateau around zero applied magnetic field. This differences clearly point to the formation of an antiferromagnetically coupled state when the applied magnetic field is reduced to zero. The strength of this coupling is found to be extremely weak, since fields of around 1-2 Oe are enough to break it.

In addition to multilayers of 10 periods, also 2 period structures have been prepared and characterized, since their magnetic behaviour is easier to analyze. Temperature dependent measurements indicate that the Curie temperature of these alloys is slightly higher, but very close to room temperature. The magnetic loops acquired as a function of temperature in the range 15 – 330 K have shown two different behaviours, as can be seen in Figure 1. From 20 to 240 K the loops are similar to the ones of the corresponding single monolayer, showing no indication of AF coupling. Further increase of T above 250 K leads to the appearance of a plateau in the loops that can be assigned to the formation of the antiferromagnetically coupled state. From the magnetic fields defining the plateaus and the onset of the reversal process, the evolution of the coupling strength with temperature can be estimated. The results indicate that J decreases with increasing temperature, so that quantum interference models proposed for non-metallic spacers can be ruled out as being in the origin of the observed coupling, since they predict an increase of J with temperature. On the contrary, the observed temperature dependence is compatible with the presence of impurities or inhomogeneities in the spacer or the interlayers, as can be expected in this type of multilayered systems due to diffusion processes.

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References:

[1] C. Quirós, J. I. Martín, L. Zárate, M. Vélez, and J. M. Alameda, Phys. Rev. B, **71** (2005) 024423.

Figures:

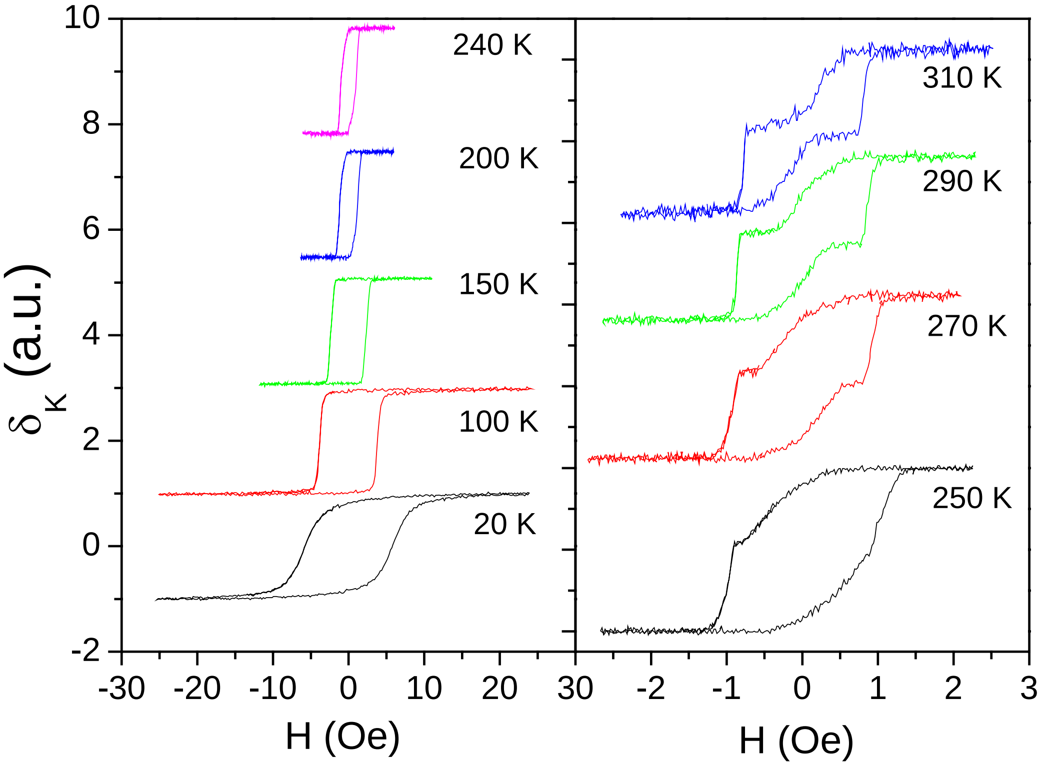

Figure 1. Magneto-optical transverse Kerr effect loops measured in a sample consisting of two magnetic layers of 5 nm $Co_{73}Si_{27}$ separated by 3 nm Si spacer at different temperatures between 20 and 310 K. The loops have been normalized and vertically shifted for clarity. Note the different field axis scale of both pannels.