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Antiferromagnetic coupling in ferrimagnetic hard-soft core/shell nanoparticles[1]

JOSEP NOGUES, ICREA and ICN2 - Institut Catala de Nanociencia i Nanotecnologia, Barcelona, Spain

The coupling between different magnetic layers in thin film bi-layers and multilayer systems is usually ferromagnetic (FM) (layers parallel to each other). However, other types of couplings such as antiferromagnetic (AFM) (i.e., antiparallel layers) have also been reported. In contrast, the magnetic properties of bi-magnetic core/shell nanoparticles remain relatively unexplored. While Monte Carlo simulations have probed the effects of different types of interface couplings from the theoretical point of view (e.g., FM vs. AFM coupling), experimental work so far has only reported ferromagnetic coupling between the counterparts. Here we present the existence of an interfacial AFM coupling in ferrimagnetic (FiM) soft/hard and hard/soft core/shell nanoparticles based on iron and manganese oxides [1]. Narrow size distributed Fe_3O_4/Mn_3O_4 and Mn_3O_4/Fe_3O_4 core/shell, soft/hard and hard/soft, were synthesized by seeded growth. In contrast to conventional systems, the temperature dependence of the magnetization, M, and the ferromagnetic resonance field, H_R, show a downturn at the magnetic ordering temperature of the hard Mn_3O_4 phase ($T_C(Mn_3O_4)$ =40 K). This decrease in M and H_R can be linked to an antiferromagnetic coupling between both phases. Moreover, element selective X-ray magnetic circular dichroism (XMCD) spectra and hysteresis loops confirm that the magnetization of the Mn-containing phase lies opposite to the Fe-containing phase. Magnetometry hysteresis loops show that for small cooling fields the loop shifts towards negative fields similar to exchange bias in conventional FM/AFM systems. However, for large cooling fields the loops shift to the opposite direction, i.e., positive exchange bias. Finally, Monte Carlo simulations clearly confirm that an AFM interface coupling leads to a magnetization decrease at low temperatures and a positive exchange bias for large cooling fields.

[1] M. Estrader et al. Nat. Commun. 4, 2960 (2013)

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