

## EXCHANGE BIAS IN INVERTED ANTIFERROMAGNETIC-CORE|FERRIMAGNETIC-SHELL NANOPARTICLES

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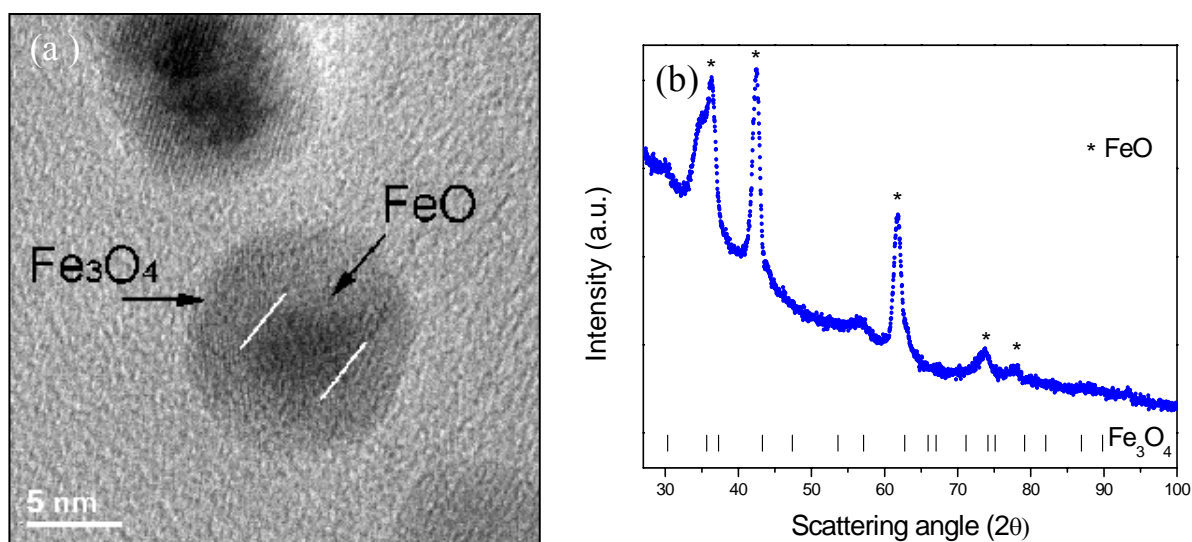
Passivated ferromagnetic (FM) nanoparticles coated with the corresponding antiferromagnetic (AFM) oxide shell have been extensively investigated [1]. However, studies of core-shell nanoparticles with AFM cores are rather scarce [2]. Here we present the study of inverted AFM-core|FiM-shell systems (MnO| $\gamma$ -Mn<sub>2</sub>O<sub>3</sub> and FeO|Fe<sub>3</sub>O<sub>4</sub>) as opposed to the typical FM-core|AFM-shell obtained from oxidation of transition metal cores. The nanoparticles have been prepared by thermolysis of the corresponding metal organic salt leading to the AFM-core (MnO or FeO) which is passivated under air yielding to the corresponding FiM-shell ( $\gamma$ -Mn<sub>2</sub>O<sub>3</sub> or Fe<sub>3</sub>O<sub>4</sub>) [2,3]. The dependence of the magnetic properties of core-shell nanoparticles as a function of the AFM core size are systematically addressed for the first time, in contrast to the archetypical FM metal-core|AFM metal oxide-shell configuration where the magnetic properties are usually studied as a function of the FM size.

Narrowly size distributed MnO|Mn<sub>3</sub>O<sub>4</sub> nanoparticles with different core sizes (2-20 nm) and fixed shell thickness (~3 nm) were synthesized. This system may be considered as *double inverted* since it is composed of a MnO-AFM core with  $T_N = 122$  K and a  $\gamma$ -Mn<sub>2</sub>O<sub>3</sub>-FiM shell with  $T_C = 39$  K (i.e.,  $T_C < T_N$ , as opposed to conventional exchange biased systems). On the other hand, monodispersed 11nm FeO|Fe<sub>3</sub>O<sub>4</sub> particles (Figure 1), with easily tuneable ratio between the core diameter and the shell thickness were prepared by controlling the passivation conditions. In this case  $T_C(\text{Fe}_3\text{O}_4) > T_M(\text{FeO})$ , thus the system can be considered *single inverted*. The samples were characterized by means of X-ray and neutron diffraction, transmission electron microscopy, electron energy loss spectroscopy and magnetic measurements.

In both systems the coupling at the AFM|FiM interface leads to strong exchange bias effects (e.g., large loop shift,  $H_E$  and coercivities,  $H_C$ ) at low temperatures. Moreover, the magnetic properties depend in a complex way on the core and shell sizes. Interestingly, in both systems the temperature dependence of the exchange bias properties is mainly controlled by the counterpart with lowest critical temperature ( $\gamma$ -Mn<sub>2</sub>O<sub>3</sub> or FeO).

**References:**

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[2] G. Salazar-Álvarez, et al. J. Am. Chem. Soc. **129** (2007) 9102.  
[3] A. E. Berkowitz, et al. Phys. Rev. B. **77** (2008) 024403; A. E. Berkowitz, et al. J. Phys. D. **41** (2008) 134007; I. Djerdj, et al. J. Phys. Chem. C. **111** (2007) 3641; D. W. Kavich, et al. Phys. Rev. B. **78** (2008) 174414.

**Figures :**

**Figure 1** : (a) HRTEM image of  $\text{FeO}|\text{Fe}_3\text{O}_4$  core-shell nanoparticle. (b) XRD diffractogram of  $\text{FeO}|\text{Fe}_3\text{O}_4$  core-shell particle. The lines below show the position of the reflections corresponding to cubic  $\text{Fe}_3\text{O}_4$  phase.