PHENOMENOLOGY AND MODELS OF EXCHANGE BIAS IN CORE/SHELL NANOPARTICLES

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Magnetic nanomaterials present new magnetic and transport properties that arise due to a complex interplay between the intrinsic properties of the constituents (such as specifically tailored microstructure and finite size or surface effects) and the interactions among the entities forming them [1]. When reducing the size of magnetic particles to the nanoscale, surface and finite-size effects become fundamental in order to explain their unusual magnetic properties. Moreover, particle surfaces are exposed to environment and are, therefore, easily oxidized, resulting in compound structures with a ferromagnetic core surrounded by an antiferromagnet. When cooling in the presence of a magnetic field the magnetic order established at the shell may result in a pinning of magnetic moments at the interface between the two phases giving rise to the so-called exchange bias (EB) effect [2].

In this contribution, we will review our recent work on the modeling of magnetic nanoparticles focusing mainly on Monte Carlo (MC) simulation methods that we have applied to the study the microscopic origin of surface and EB effects in nanoparticles with core/shell structure [3,4]. The results of the simulations allow us to conclude that the increase of the exchange coupling across the core/shell interface leads to an enhancement of exchange bias and to an increasing asymmetry between the two branches of the loops (as can be seen in the example shown in Fig. 2), which are due to different reversal mechanisms. A detailed study of the magnetic order of the interfacial spins (see Fig. 1) shows compelling evidence that the existence of a net magnetization due to uncompensated spins at the shell interface is responsible for both phenomena and allows quantifying the loop shifts directly in terms of microscopic parameters with striking agreement with the macroscopic observed values. Moreover, our model has been applied to study how the above-mentioned effects are affected by the particle size, shell thickness, magnitude of the cooling field and temperature [5], showing that from the simulation results a deeper understanding of the phenomenology observed experimentally can be gained.

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Figures:

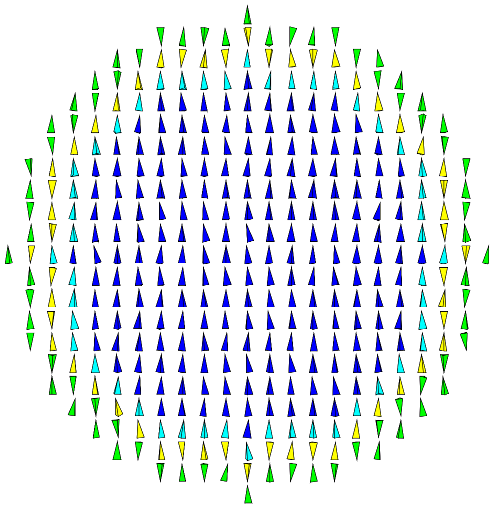

FIGURE 1:.Magnetic configuration of a nanoparticle with FM core/AF shell structure after a field cooling process.

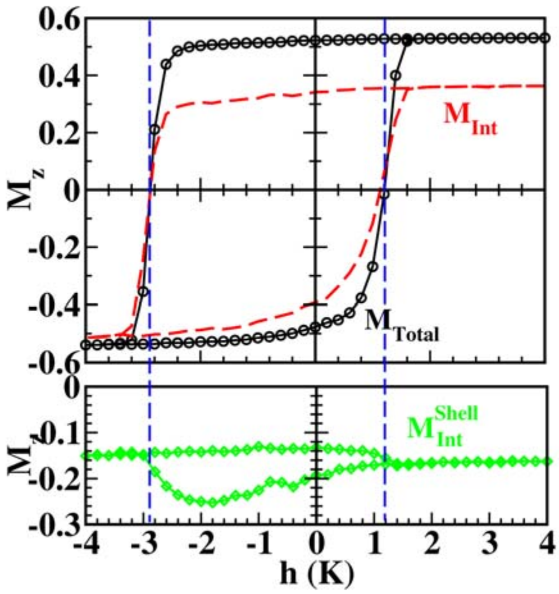

FIGURE 2: Hysteresis loop of a core/shell nanoparticle (M_{Total}) obtained after field cooling displaying a shift in the direction of the applied field. The contribution of the interfacial spins (M_{Int}) is shown in dashed lines.