11th International Conference on Advanced Materials

ICAM 2009

Rio de Janeiro Brazil
September 20 - 25

Exchange Bias Properties and Surface Disorder in Magnetic Nanoparticles

F. G. Silva(1)*, R. Aquino(1), V.Dupuis(2), J. Depeyrot(1), F. A. Tourinho(1) , R. Perzynski(2) and C. R. Alves(1)

(1) Complex Fluids Group, Physics Institute/Universidade de Brasília, Brasília, Brazil, franciscarlos@fis.unb.br.
(2) PECSA, Physics Institute/Université Pierre et Marie Curie, Paris, France.
* Corresponding author

Abstract – ZFC and FC magnetization measurements were carried out on manganese ferrite based nanoparticle with mean size of 3.3 nm. The exchange bias field decreases with the strength of the cooling field and the thermal dependence of the disordered surface contribution decreases exponentially with a freezing temperature which depends on the applied field.

Nanoscale magnetic particles present unique and striking features which make them suited for a large number of applications in quite a diverse range of fields from engineering to biomedicals. Moreover, the spatial confinement modifies their magnetic behavior through the interplay of finite size and interface effects. In this context, we investigate $MnFe_2O_4$ based nanoparticles developed for the synthesis of magnetic nanocolloids [1]. Previous investigations of their magnetic properties support the so-called “core-shell” model, in which a well-ordered ferrimagnetic structure within the inner region of the particle is surrounded by a surface layer of spins randomly frozen in a spin glass-like manner [2]. The thermal dependence of the magnetization is characterized by Bloch-like variations of the core and an exponential-like decrease of the surface contribution related to a freezing temperature T_f. Field and size dependences of this disordered contribution have been studied by Mössbauer spectroscopy measurements and show a progressive spin alignment along the ferrite core [3]. The mean canting angle decreases as the field increases, at a rate which is decreasing as the nanoparticle size increases.

We analyze here Zero Field Cooling and Field Cooling measurements of the magnetization of magnetic nanocolloids based on 3.3 nm sized particles of manganese ferrite. After cooling the sample in the presence of an external field, a shift of the hysteresis loop is observed (see Figure 1). This exchange bias phenomenon indicates the existence of a coupling between the ferrimagnetic ordered core and the disordered surface layer. The exchange bias field, determined from the field offset from the origin, is quantitatively related to the net local exchange fields of the interfacial shell spins that act on the particle core. It decreases with the strength of the cooling field (see Figure 2) since the surface disorder is less pronounced at high cooling field as suggested by Mossbauer measurements [3].

The thermal dependence of the ZFC magnetization has also been investigated for different magnitudes of the applied field. Whatever the field strength, the freezing of the surface spins gives a contribution to the total magnetization which is well accounted for a reduced exponential behavior. Figure 3 indicates that the deduced values of T_f decreases with increasing applied fields. It shows that the energy k_BT_f, intimately related to the superexchange interactions which pin the interacting spins in the frozen disordered layer, is smaller for large applied field. That well agrees with a smaller exchange bias field for larger cooling field and the observed progressive alignment of the surface spins along their core counterparts. It therefore suggests a delicate balance between exchange interaction and local anisotropy at the shell-core interface. The authors acknowledge the Brazilian agencies CAPES, CNPq, FAPDF and FINATEC.

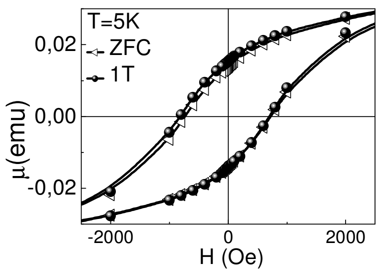

Figure 1: ZFC and FC (1 T) hysteresis loops.

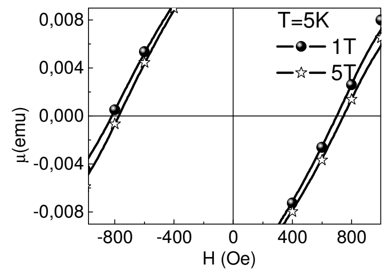

Figure 2: FC hysteresis loops obtained for 1T and 5T.

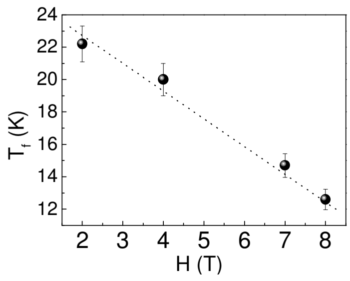

Figure 3: Freezing temperature as a function of the applied field.

References

[1] J. A. Gomes, M. H. Souza, F. A. Tourinho, R. Aquino , Geraldo J. da Silva, E. Dubois J. Phys. Chem. C, 112, 6220 (2008).
[2] R. Aquino, M. H. Souza, F. A. Tourinho, E. Dubois, R. Perzynski . Phys. Rev. B 72, 184435 (2005).
[3] H. R. Rechenberg, E. C. Sousa, J. Depeyrot, M. H. Sousa, R. Aquino, F. A. Tourinho, R. Perzynski, Hyperfine Interact 184, 9 (2008).