Magnetic interactions and interface phenomena on Fe_xAg_{100-x} granular thin films

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Magnetic nanostructured thin films present a rich variety of spin arrangements, which depend on, among other factors, the interparticle magnetic interactions. These interactions play a fundamental role in the magnetic behavior of the system and are related to the size, concentration of nanoparticles and the interface between them and the matrix. In order to carry out a thorough study of the role of the interactions, and their evolution with the concentration of nanoparticles, one needs to be especially careful with the selected system. Metallic granular systems, with magnetic nanoparticles embedded in a metallic matrix, are especially suitable to study the role of these interactions since there is no oxide layer surrounding the nanoparticles, which could affect their magnetic behavior, and the sample is stable and can be used repeatedly. Therefore, we have prepared Fe_xAg_{100-x} granular thin films, with Fe-concentration $15 \leq x \leq 50$, by sputtering deposition technique. Binary Fe_xAg_{100-x} granular thin films are ideal to study these phenomena since Fe and Ag present, a high value of positive alloy formation energy (28 kJ/mol), thereby being highly immiscible. This fact allows obtaining samples consisting of an assembly of Fe nanoparticles embedded in a diamagnetic metallic Ag matrix.

X-ray Diffraction, High Resolution Transmission Electron Microscopy and Extended X-ray Absorption Fine Structured spectroscopy have enabled a comprehensive structural description of the system. This arrangement consists of Fe nanoparticles, mostly around 2-3nm in diameter, inside the *Ag* matrix with grain diameter around 11nm.

The magnetic behavior has been characterized both by DC magnetic measurements in SQUID magnetometer. We have found that with increasing the Fe content a change in the collective magnetic behavior of the Fe-Ag thin films is observed, related to a change in the relevance of the different interparticle magnetic interactions that are playing an important role at these concentrations: long-range dipolar and/or RKKY interactions below 30-35 %, and short-ranged strong direct exchange interactions above that threshold. Therefore, it can be considered that around a 30-35 at. % of Fe a magnetic percolation takes place, giving rise to a crossover from a Superspin Glass to a Superferromagnetic behavior [1]. This study has allowed us to propose a magnetic phase diagram presented in figure 1.

For comparison, we have also analyzed the effect the interface on the magnetic coupling between Fe nanoparticles. To this end, we have prepared $Fe_{50}Ag_{50}$ thin films by Pulsed Laser Deposition technique. With this technique we were able to prepare Fe bcc nanoparticles around 2-3nm in diameter surrounded by an amorphous interface, well observed with Transmission electron microscopy and confirmed by EXAFS measurements. Depending on the magnetic state of the interface, we modify the coupling between the magnetic nanoparticles, changing the coercitivity and remanence of the system. If the interface is in the ferromagnetic state, the triggering of interparticle coupling is achieved and the coercive field is small, Hc=7Oe and the normalized remanence is high, Mr/Ms=0.9. By contrast, at temperatures above the Curie temperature of the interface, T>200K, the interface enters in the paramagnetic state and as a consequence the magnetic interaction between nanoparticles is broken down. As a result, the coercitivity of the system increase up to 30Oe and the remanence decrease down to 0.5. In this way, the interface acts as a switch between the Fe nanoparticles [2].

References

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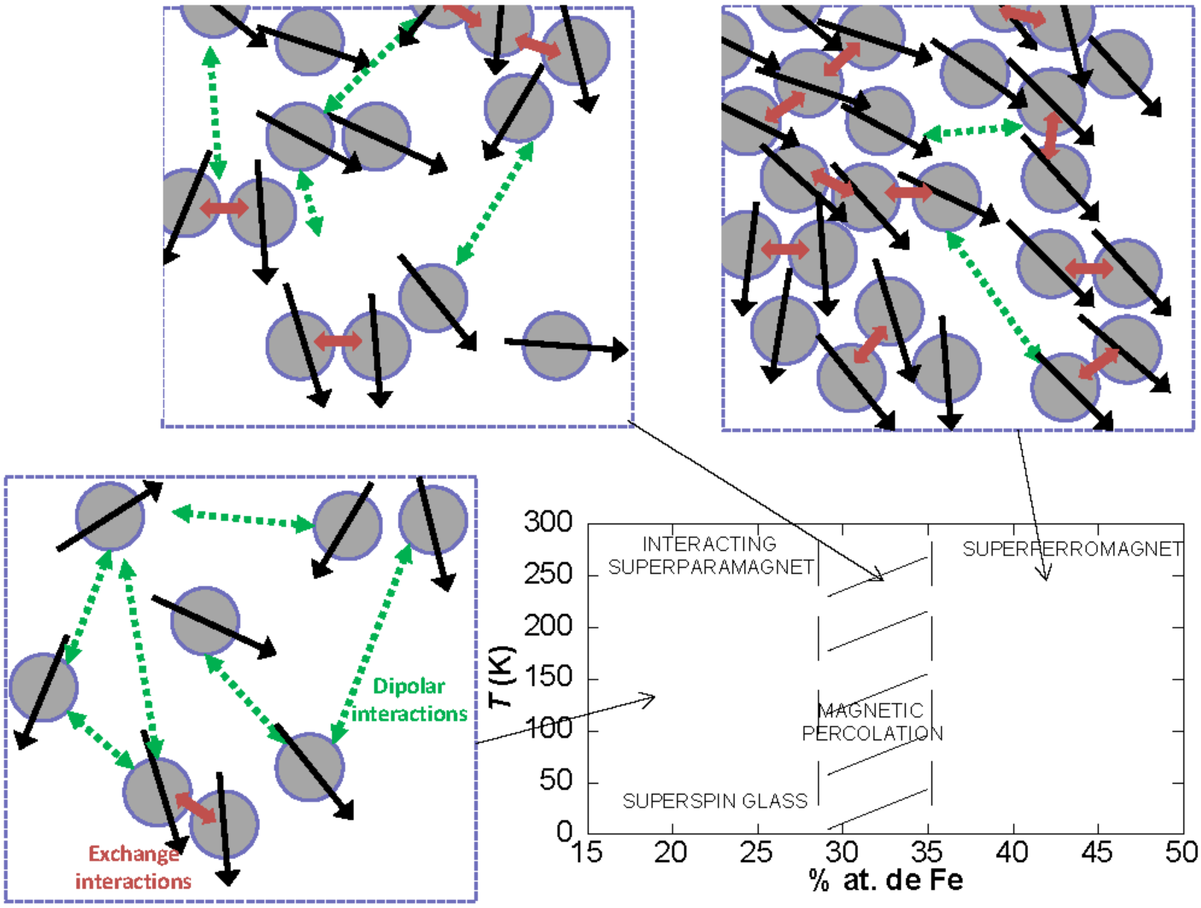

Figure 1: Phase diagram obtained for Fe_xAg_{100-x} thin films, as a function of the at. % of Fe and the temperature. Simplified pictures of the magnetic moments arrangement are also included