INTERFACE-EFFECTS ON THE MAGNETIC MOMENT OF CO AND CU IN COCU NANOGRANULAR ALLOYS AND ITS INFLUENCE ON GIANT MAGNETORESISTANCE RESPONSE.

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The study of granular alloys composed of magnetic nanoclusters embedded in a metallic non-magnetic matrix has experienced a growing interest in the last decade. Their magnetotransport properties are attractive from a technological point of view because of potential magnetic recording applications. The main mechanism that generates the GMR is the spin-dependent scattering of the conducting electrons at the interfaces of the magnetic clusters [1]. It is generally accepted that the maximum interfacial area enhances the GMR. However, the exact correlation between the microstructure and the GMR response of the systems is still missing. In fact, in Co-Cu system, there are evidences of the degrading of the GMR due to interfacial roughness both in Co-Cu multilayers [2] and in Co nanoclusters embedded in a Cu matrix [2, 3]. The degree of interfacial roughness must influence the magnetic moment of the interfacial atoms because it affects their local geometry and the hybridization between the Co and Cu *3d* bands. Accordingly, the interfacial roughness affects the GMR response through its influence on the magnetic moment of the Co clusters.

Aimed to clarify the relationship between the annealing temperature, the interfacial roughness and the GMR, we have studied the melt-spun Co_5Cu_{95} granular alloys annealed between 300 and 650^{o}C. The effect of the annealing treatment on the microstructure of the samples has been determined by the combined study of x-ray diffraction, magnetic (hysteresis loops) and extended x-ray absorption fine structure spectroscopy (EXAFS) measurements at ESRF facility [3, 4]. The annealing treatment makes the Co atoms segregate from the Cu matrix and form superparamagnetic nanoclusters. As the annealing temperature increases, both the number and mean size of the Co nanoclusters, which ranges between 2 and 4 nm, increase at the expense of the number of Co diluted atoms. At the same time, there is an additional effect of the annealing treatment, which is that it improves the quality of the nanoclusters interfaces. However, in the CoCu system in particular, above 500 ^{o}C the Co and Cu become slightly miscible and this effect roughens the interfaces, masking the effect of the annealing temperature as interface-definer and the magnetoresistance response drops.

In order to study the effect of the interfacial roughness on the local magnetic moment of both Co and Cu atoms in the Co_5Cu_{95} system we have performed x-ray magnetic circular dichroism (XMCD) experiments at the $L_{2,3}$ absorption edges of both atoms at Spring-8 facility. The atomic-selectivity properties of XMCD makes possible to determine the influence of the interface of the Co clusters, i.e. of the annealing temperature, on the GMR by monitoring: i) the thermal dependence of Co and Cu magnetic moments, and ii) by disentangling the spin and orbital contributions to the magnetic moment. We have found that the orbital, m_L, and spin, m_S, magnetic moment of the Co atom increases with increasing the annealing temperature (fig. 1a) due to the progressive clustering of the diluted Co atoms. Despite that the enhancement is approximately linear for m_L and m_S, the increment is significant steeper at 450 ^{o}C. It should be noted that in addition to the clustering of the diluted atoms, the annealing treatment smooth the cluster interface. The degree of interfacial roughness is critical in both

m_L and m_S because it affects the hybridation between Co and Cu *3d* bands. On the one hand, m_S increases upon the *3d* bands narrowing, as the electrons get more localized. On the other hand, theoretical and experimental works report on the enhancement of the orbital moment at the surfaces due to the reduction of the coordination and the local symmetry at these sites [5]. This means that the smoothest the interfaces the highest both the coordination reduction and the concomitant symmetry breaking around the interfacial Co atoms, which leads to a less effective quenching orbital moments by crystal field. Further confirmation of the influence of the interfacial roughness on m_L and m_S can be obtained by analyzing the orbital-to-spin ratio $R=m_L/m_S$ (fig.1b). With the exception of the sample annealed at 450 ^{o}C, *R* remains unchanged at a value (R≈ 0.14) that is consistent with the one calculated for Co-Cu interfaces [6]. This means that, as expected, changes due to size effects are negligible or slowly variable in 2-4 nm sized clusters. The point at which *R* deviates from the general trend (450 ^{o}C) matches with the maximum of the GMR, which is the point at which the interfaces are smoothest. This is a confirmation of the importance of the interfacial roughness on the magnetic moment.

Finally, we have also observed an induced ferromagnetic moment mainly of spin character in the Cu interfacial atoms. This results on the Cu $L_{2,3}$ edges point towards the existence of a long-range magnetic interaction between the Co clusters through the Cu matrix.

References:

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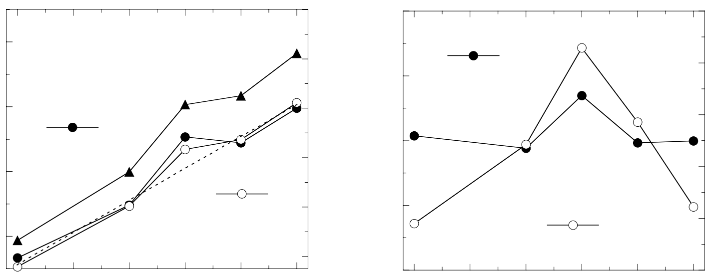

Fig. 1 Dependence on annealing temperature of a) the Co orbital, m_L, and spin, m_S, magnetic moment and b) comparison between the Co $R=m_L/m_S$ ratio and the GMR in Co_5Cu_{95} granular alloy