Tunnel magnetoresistance and giant Hall effect in nanocomposites

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The Hall effect in magnetic metals consists of two parts. One is due to the Lorentz force. The other, extraordinary contribution originates from asymmetry of magnetic scattering, and is thus proportional to magnetization, as well as a power of resistivity. The giant Hall effect (GHE) is a remarkable property of granular metal-dielectric systems, initially observed in cermets where the metallic component was ferromagnetic [1]. It was found that near the critical concentration of metal in the composite where a metal-insulator transition occurs, the extraordinary Hall resistivity can be a factor up to 10^4 greater than in the metallic regime. Since the discovery of GHE, several experimental investigations have contributed to the understanding of the phenomenon with systematic studies in different granular metals [2-4]. Taking into account the experimental results new theoretical models have also been introduced [2, 4].

A comprehensive review of the giant Hall effect will be presented, with the emphasis on novel experimental data obtained in Ni, Fe and Co/SiO_2 films prepared by co-sputtering. GHE, as well as tunnel magnetoresistance, are clearly correlated with the nanostructure (investigated by means of transmission electron microscopy, small angle x-ray scattering and x-ray diffraction) of granular samples near the metal-insulator transition. The most important feature of the microstructure, which is believed to be associated with GHE, is extremely fine dispersion of metal particles embedded in insulating matrix.

It is important to notice that GHE is observed close to, and on both sides of, the metal-insulator transition. At this composition (approximately 50% volume fraction of metal for co-sputtered materials) connectivity of percolation clusters is very loose. From the point of view of microscopic conduction mechanisms, this means a crossover from metallic conductivity with weak localization to tunneling, or hopping between separate granules across insulating barriers. On the other hand, magnetic percolation is also interrupted at this concentration of metal, leading to superparamagnetic behavior of the composite and blocking phenomena. In our recent study, we compare temperature dependences of magnetization and the extraordinary Hall coefficient in the composites near the critical concentration, and find both similarities and differences. In metallic samples, the extraordinary Hall is directly proportional to the total magnetization, due to side jump or skew scattering. In a metal-insulator composite, only those electrons traveling in conduction critical paths can contribute to the Hall signal, thus only magnetization of the material belonging to these paths is important in the Hall measurements. Comparison with the magnetic results leads to new possibilities in understanding the both the electronic and magnetic properties of granular nanocomposites.

References

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