Magneto-optical study of the dipolar coupling between magnetism and plasmonic nanoparticles

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The magneto-optical (MO) properties of nanomaterials that combines localize surface plasmon resonances (SPR) with magnetic properties is the centre of this study. In the last years an intense activity is being devoted to interconnect two different nanowords: the optic and the magnetic ones. Nanomaterials that exhibit SPR or photoluminescence in simple combination with magnetic properties or, more interesting, in which the magnetic and optical properties are in synergy so one part can be controlled by the counterpart are being looking for. The development of novel photo-detectable, photoswitchable and in general multifunctional nanomaterials are quite interesting for biomedicine, spintronics and data recording. The expected effect of the SPR on the magnetic properties is the change of its MO features. The few studies in hybrid core-shell nanoparticles [1] hetero-dimers nanostructures [2] or simply plasmonic dots on magnetic surfaces [3] have shown effects like enhancement of the MO signal and/or changes in the MO spectra in correspondence to the SPR. The origin of these phenomena is under discussion, they can be due to the effect of the strong electromagnetic fields (EMFs) linked to the localized plasmons but also can be related to the electronic and structural changes at the interface of the two parts. It is well known that the EMFs generated by the SPR gives rise to changes in the optical properties of the structures/compounds near the particles like the huge enhancement of Raman activity or the enhanced photoluminescence. Instead the influence of the plasmonic resonance on MO activity has not been investigated.

In this work we present one combination of magnetic and magneto-optical characterizations of composite films containing magnetic and plasmonic nanoparticles well dispersed in a transparent matrix. Cobalt ferrite ($Co_{0.5}Fe_{2.5}O_4$) and Au nanoparticles were synthesized by colloidal methods. TEM characterizations reveal that the two type of nanoparticles exhibit narrow particle size distributions being the average particle sizes: 8.6 nm for Cobalt ferrite and 7.0 nm for Au nanoparticles. Both nanoparticles are capped by 2.0 nm size shell of oleylamine and oleic acid. The reference nanocomposite has 3%wt of the Co-ferrite nanoparticles in polystyrene matrix. Three spin-coated films including also the gold nanoparticles were prepared with 1/4, 3/8, and 1/2 weight of Au with respect to the cobalt ferrite content, that corresponds to packing factors of 0.035%, 0.05%, and 0.07% respectively.

The optical extinction spectra of the three Au-cobalt ferrite films exhibit similar structure characterized by one broad SPR peak centred around 570 nm with a large tail that extends to the nIR. Magnetic circular dichroism (MCD) spectra and MCD hysteresis loops were recorded in the 400 -1000 nm spectral range and applying a maximum field of 1.3 T. In opposite to the optical properties, the MO properties are strongly depending on the Au content (Figure 1). We observe a decreasing of the MO strength when include Au nanoparticles that depends on the Au content. Moreover, in the spectral region in coincidence with the SPR, the line-shapes change including the sign. We record also MCD hysteresis loops at different wavelengths. This allows to observe the presence of different MO contributions in the different spectral regions. Considering the different transitions involved in the MO spectrum of the cobalt ferrite [4] we conclude that the EM field generated by the plasmons coincide with Charge-transfer transitions of the Co-ferrite giving rise to their strong dumping and to a new type of MO

transitions are activated. Also crystal-field transitions are dumped even if plasmon resonance are very weak. Such changes depend in one non-linear way of the Au concentration. The differences in the MO spectral with the Au-contain precludes the use of MO techniques due to the sensibility and selectivity to different magnetic and optical environments.

References

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Figures

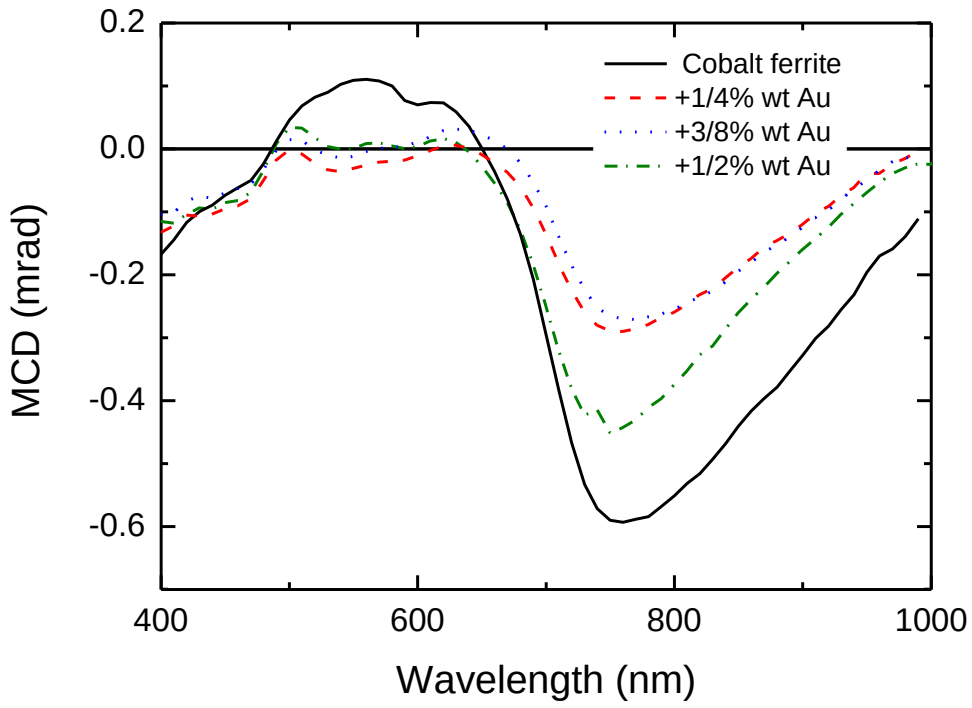

Figure 1. Magnetic circular dichroism spectra of the films containing only Cobalt ferrite nanoparticles and of the films including ¼%wt. , 3/8% wt. and ½% wt. of Au nanoparticles.