SCATTERING MATRIX APPROACH FOR THE ANALYSIS OF MAGNETO-PLASMONIC PERIODIC LATTICES

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Localized surface plasmons are under intensive study since long ago because they play a very important role in the optical properties of metallic systems. In particular, they become especially relevant in the optical properties of nanostructures, such as tiny particles embedded in dielectric matrices or nanoperforated membranes. The intensity as well as the spectral position of these resonances strongly depends on a variety of parameters such as the size, the shape, or the concentration of the metallic particles/holes or the refractive index of the matrix.[1] The vast majority of the studies have been so far devoted to study noble metal particles/holes since their free electron contribution to the optical properties in the infrared and visible spectral range is predominant, exhibiting also a low damping constant. In other metals such as palladium, platinum, cobalt, nickel or iron, the free electron contribution to the optical properties is smaller, and have a higher damping constant, therefore their surface plasmon resonances appear broader and less defined.[2] On the other hand, ferromagnetic metals posses spontaneous magnetization which enables them to present magneto-optical properties, which are absent in noble metals. This characteristic can be used to design new kind of plasmonic structures. Moreover, different theoretical works have suggested that surface plasmon resonance of magnetic metallic nanoparticles/holes could enhance the magneto-optical activity with respect to that of a continuous medium.[3] However, the size of the nanoparticles/holes under consideration is always much smaller than the wavelength of light and the interaction between the particles/holes was rarely not considered. But the particle/hole size[1] and the radiative coupling between them strongly modify the optical properties of the system[4] and, therefore, it may also modify its magneto-optical response. This is precisely the scope of this work, where we theoretically analyze the dependence of the magneto-optical properties on the size of a system consisting on periodically arranged Ni nanowires embedded in a dielectric environment and on the *negative* of this structure, i.e. metallic Ni membranes with nanometer scale periodic perforations. Such systems have already shown to exhibit interesting effects, such as an enhancement of the magneto-optical Kerr rotation and faraday[5]. We will show that the enhancement is due to a surface plasmon resonance of the Ni nanowires/pores, its spectral position depending on the wire diameter.

In the figure we show the magneto-optical part of the reflectivity (r_{ps}) as a function of the energy of the incoming wave (normal incidence) normalized to that of the Ni bulk. The left panel corresponds to the Ni nanowires array in two different environments, and shows a peak in each one revealing the position of the plasmonic structure. The right one corresponds to the Ni perforated membrane, where the pores have the same geometrical parameters as the nanowires in its "positive" counterpart. The peak in each curve appears at the very same position, meaning that the plasmonic structure is one that travels along the wire/pore and will depend on its geometrical parameters.

On a different framework, the impact of the dielectric environment holding (filling) the nanoparticles (nanoholes) on the magneto-optical properties of such kind of systems is also of great interest. A previous study has been focused on how the magneto-optical response is affected when the whole surrounding environment changes.[6] However, in many cases the environment shows a characteristic non isotropic profile. For example, the growth of nickel nanowires in an alumina matrix membrane obtained by anodization processes. A recent work[7] presents a clear difference between the optical properties of the alumina close to the wires and that related to the bulk alumina matrix. We will address the magneto-optical response dependence of periodic Ni nanowires arrays (and its *negative* structure perforated Ni membranes) on localized dielectric changes consisting on a shell surrounding (filling) the wires (pores), whose refractive index different to that of the whole dielectric medium.

References:

[1] K.Lanve Kelly, E. Coronado,L.L. Zhao and G. C. Schatz, *J. Phys. Chem B* **2003**,107, 668

[2] S. Coyle, M. C. Netti, J. J. Baumberg, M. A. Ghanem, P. R. Birkin, P. N. Bartlett, and D. M. Whittaker, *Phys. Rev. Lett.* ***2001***, 87, 176801

[3] P.M. Hui and D. Stroud, *Appl. Phys. Lett*. *1987*, 50, 950

[4] M. Meier, A. Wokaun, and P.F. Liao, *J. Opt. Soc. Am. B* ***1985***, 2, 931; E. M. Hicks, S. Zou, G. C. Schatz, K. G. Spears, R. P. Van Duyne, L. Gunnarsson, T. Rindzevicius, B. Kasemo, and M. Käll, *Nano Lett.* ***2005***, 5 1065

[5] S. Melle, J. L. Menéndez, G. Armelles, D. Navas, M. Vázquez, K. Nielsch, R.B. Wehrspohn, and U. Gösele, *Appl.Phys. Lett.* ***2003***, 83, 4547; A. García-Martín, G. Armelles, S. Pereira, *Phys. Rev. B* **2005**,71, 205116

[6] J.B. González Díaz, A. García-Martín, G. Armelles, *Adv. Mat.* (submitted)

[7] J. Choi, Y. Luo, R. B. Wehrspohn, R. Hillebrand, J. Schilling, and Ulrich Gösele *J. App. Phys.* **2003**,94,4757

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