Optimizing light harvesting for high magneto-optical performance in metal-dielectric magnetoplasmonic nanodiscs

Alfonso Cebollada, Juan Carlos Banthí, David Meneses, Fernando García, María Ujué González, Antonio García-Martín, and Gaspar Armelles

IMM-Instituto de Microelectrónica de Madrid (CNM-CSIC), Isaac Newton 8, PTM, E-28760 Tres Cantos, Madrid, Spain
alfonso@imm.cnm.csic.es

The term magnetoplasmon, or magnetoplasma surface wave, was first introduced in the early 70's, motivated by a renovated interest in surface plasmons in metals and degenerate semiconductors [1,2]. At that time, the effect of an external magnetic field on the dielectric function of a solid, and as a direct consequence on the surface plasmons, seeded a number of investigations which in the case of semiconductor structures continues to our days. Later in the 80's [3,4,5,6,7] and 90's [8,9] different groups studied the effect of bulk and surface plasmon resonances respectively on the magneto-optical (MO) activity of a number of materials systems.
Nowadays, the phenomenology associated to systems where plasmonic and MO properties coexist has become an active area of investigation, and an increasing number of research groups have explored this phenomenology from the experimental and theoretical viewpoints.The so called magneto-plasmonic systems have opened new routes for the development for example of higher performance gas and biosensing platforms [10,11] as well as the exploitation of non-reciprocal effects [12] in devices with potential applications in the telecomunications area.

In magnetoplasmonic structures, magnetic and plasmonic properties are intertwined, allowing for example plasmonic properties to become tunable upon de application of a magnetic field (active plasmonics) [13], or the MO effects to be largely increased by plasmon resonance excitation, as a consequence of the enhancement of the electromagnetic (EM) field in the MO active component of the structure [14].

In this last case, the study of the enhanced MO activity in structures with subwavelength dimensions is especially interesting since they may be viewed as nanoantennas in the visible range with MO functionalities. The light harvesting properties of these systems upon plasmon resonance excitation bring as a consequence an enhanced EM field in its interior, and more interestingly in the region where the MO active component is present. At this stage, optimizing the EM field distribution within the structure by maximizing it in the MO components region while simultaneously minimizing it in all the other, non MO active, lossy components, will allow for the development of novel systems with even larger MO activity with reduced optical losses , becoming an alternative to state of the art dielectric MO materials, like garnets.

In this presentation, our current understanding of this phenomenology and our approach to face this problem will be presented. We will show how the insertion of a dielectric layer in Au/Co/Au magnetoplasmonic nanodisks induces an EM field redistribution in such a way to concentrate it in the regions of interest of the nanostructure. In figure 1 we show the nanodisk structures fabricated by hole mask colloidal lithography and evaporation. Two structures, with a SiO_2 layer attached to the upper and lower Au layer were fabricated respectively, together with a fully metallic structure, i.e. without SiO_2. Figure 2 shows as an example experimental and theoretical optical extinction and MO activity for the system with the SiO_2 layer attached to the upper Au layer and for the fully metallic structure. The metallo-dielectric system ***exhibits large MO activity and low optical extinction*** in the high wavelength range (around 780 nm). It will be demonstrated how this is due to the specific EM field redistribution at this wavelength, controlled by the insertion of the dielectric layer.

Acknowledgements
The authors acknowledge funding support from the EU (NMP3-SL-2008-214107-Nanomagma), the Spanish MICINN ("FUNCOAT" CONSOLIDER INGENIO 2010 CSD2008-00023, MAGPLAS MAT2008-06765-C02-01/NAN and PLASMAR MAT2010-10123-E) and the Comunidad de Madrid ("NANOBIOMAGNET", S2009/MAT-1726 and "MICROSERES-CM", S2009/ TIC-1476, and JAE Doc fellowship for D. Meneses-Rodríguez).

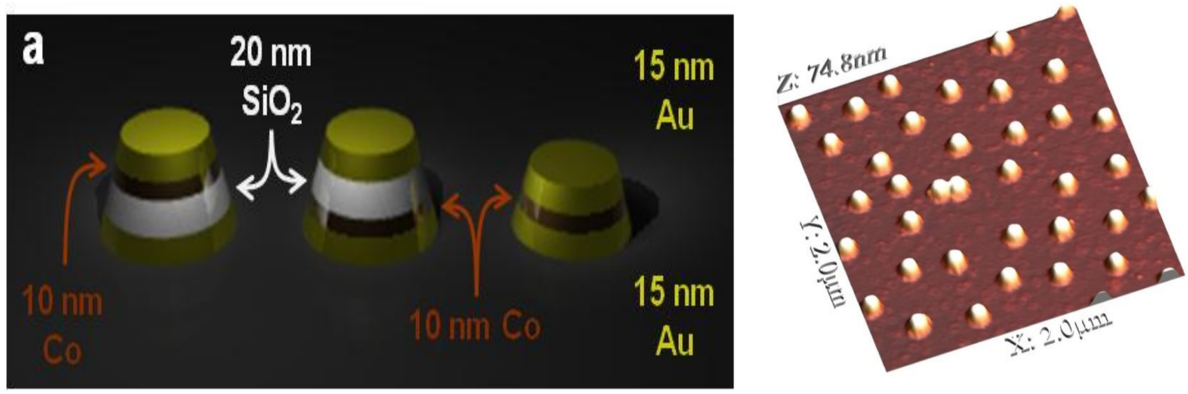

Figure 1: Sketch of the fabricated structures, and representative AFM image of one of them.

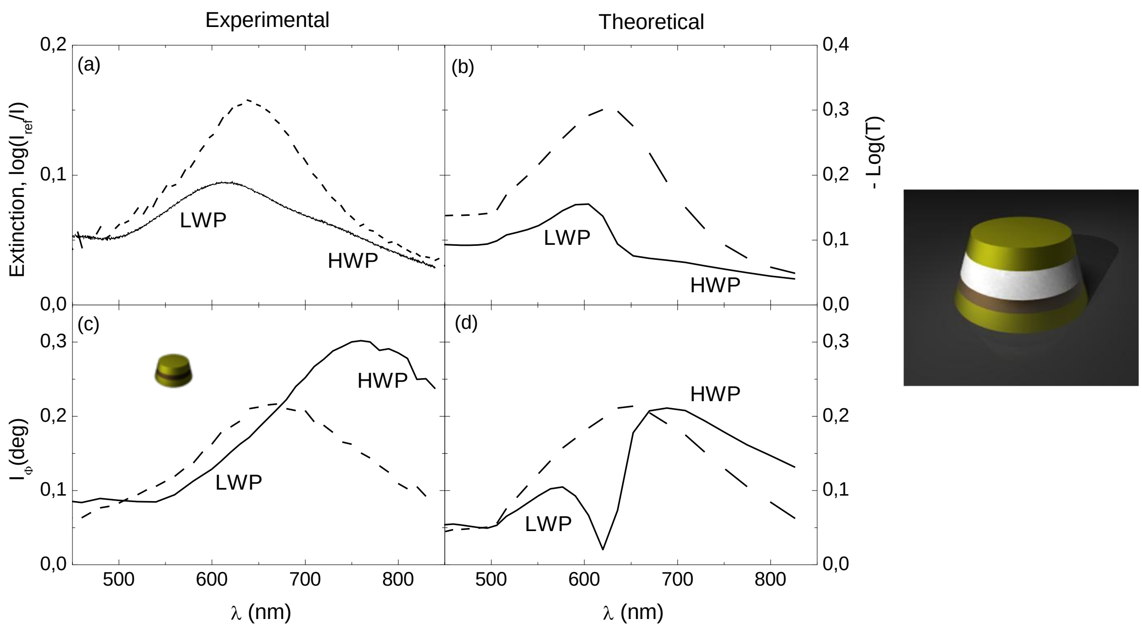

Figure 2: Experimental and theoretical optical extinction and MO activity for the structure with the SiO_2 layer attached to the upper Au layer (continuous lines) and for the fully metallic structure (dashed lines).

References:

[1] K.W.Chiu and J.J.Quinn, Physical Review **5** (1972) 4707.
[2] E.D.Palik et al., Physics Letters **45A** (1973) 143.
[3] W.Reim et al, JAP **55** (1984) 2155.
[4] H.Feil and C.Haas, PRL **58** (1987) 65.
[5] T.Katayama et al., PRL **60** (1988) 1426.
[6] McGahamn et al APL **55** (1989) 2479.
[7] Reim and Weller IEEE Trans Magn **25** (1989) 3752.
[8] V.I.Safarov et al, PRL **73** (1994) 3584.
[9] C.Herman et al, PRB **64** (2001) 235422.
[10] B.Sepúlveda et al., Opt. Lett. **31** (2006) 1085.
[11] M.G.Manera et al., Journal of Materials Chemistry **21** (2011) 16049.
[12] J.B.González-Díaz et al., Phys. Rev. B **76** (2007) 153402.
[13] V.V.Temnov et al., Nature Photonics, **4** (2010) 107.
[14] G.Armelles et al., J. Opt. A: Pure Appl. Opt. **11** (2009) 114023.