Magnetic properties of high permittivity dielectric nanoparticles applied to optical metamaterials.

Ramón Paniagua-Domínguez*, F. López-Tejeira*, José A. Sánchez-Gil*, L. Jelinek+, R. Marqués++.

*Instituto de Estructura de la Materia, Consejo Superior de Investigaciones Científicas, Serrano 121, 28006, Madrid, Spain

+Department of Electromagnetic Field, Czech Technical University in Prague, 166 27, Prague, Czech Republic

++Departamento de Electrónica y Electromagnetismo, Universidad de Sevilla, 41012, Sevilla, Spain

ramon.paniagua@iem.cfmac.csic.es

In the last decade, great deal of attention has been brought to artificially tailored materials exhibiting electromagnetic properties non-attainable in naturally occurring media. The so called metamaterials can present extraordinary properties such as a negative refractive index [1]. One of the current open issues in this field is pushing these properties from the microwave range of the electromagnetic spectrum to the visible range [2]. One major difficulty in this task is achieving a strong magnetic response capable of generating a magnetic moment strong enough as to obtain a negative effective permeability. Most of the many attempts are based on designs with a profound analogy with the canonical split-ring design, but taking advantage of the plasmonic behaviour of metals at visible frequencies [3,4]. One important drawback of these designs is the inherent absorption of metals, which prevents from making an effective bulk material.

Our theoretical proposal is, instead of using metals, to take advantage of the strong confinement of the field that happens in high-permittivity dielectrics. Following the proposal of L. Jelinek and R. Marqués [5] we present several designs that could lead to the realization of left-handed bulk media in the IR-visible frequencies. These include the SiC torus configuration, the SiC spherical-shell (see Fig.1) for the magnetic response in the IR regime, and the α-hexagonal Si spherical-shell for the visible regime.

Finally, a 2D medium is also shown to exhibit left-handedness in the near-infrared based exclusively in dielectric cylinders. The effect is a consequence of the excitation of dipolar magnetic resonances together with an appropriate election of the lattice spacing (see Fig.2).

The authors acknowledge support both from the Spain Ministerio de Ciencia e Innovación through the Consolider-Ingenio project EMET (CSD2008-00066) and NANOPLAS (FIS2009-11264), and from the Comunidad de Madrid (grant MICROSERES P2009/TIC-1476). R. Paniagua-Domínguez acknowledges support from CSIC through a JAE-Pre grant.

References

[1] V. Veselago, Sov. Phys. Uspekhi, **10** (1968) 509-514.
[2] V. M. Shalaev, Nature Photonics, **1,** (1968) 509-514.
[3] Soukoulis et al., Science, **315,** (2007) 41-48.
[4] A. Alú, A. Salandrino, N. Engheta, Optics Express, Vol. 14, **4**, (2006) 1557-1567.
[5] L. Jelinek, R. Marqués, J. Phys.:Condens. Matter, 22, (2010) 025902(6pp)

Figures.

(a) **(b)**

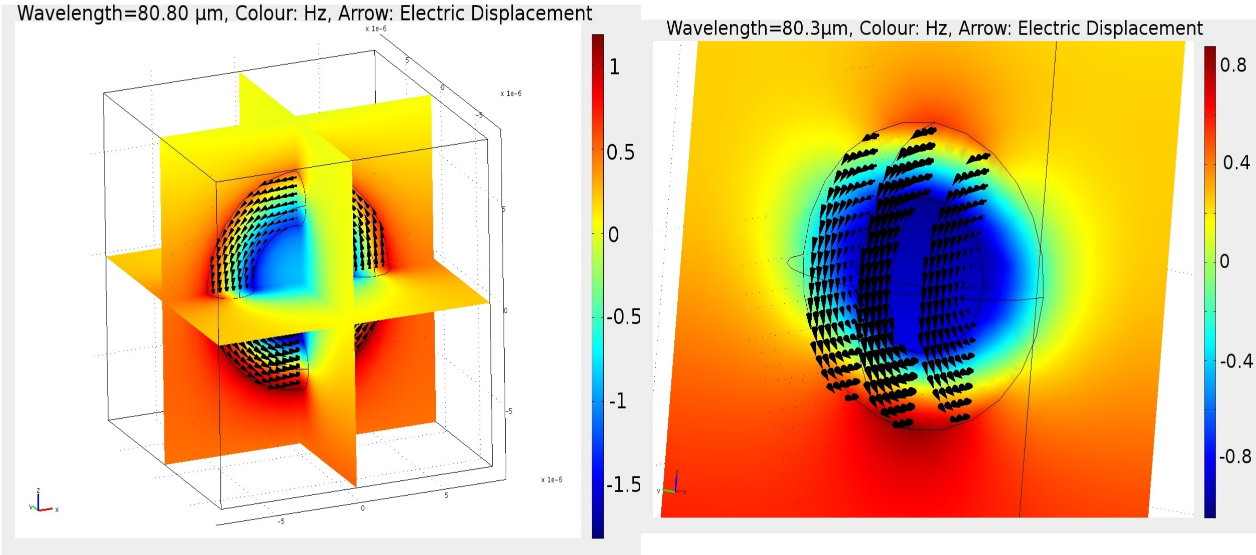

Fig.1: Dielectric Ring (a) and Shell (b) made of SiC. The incident magnetic field is directed along the y-axis. The induced displacement currents generate a strong magnetic response reversing the field inside the structures.

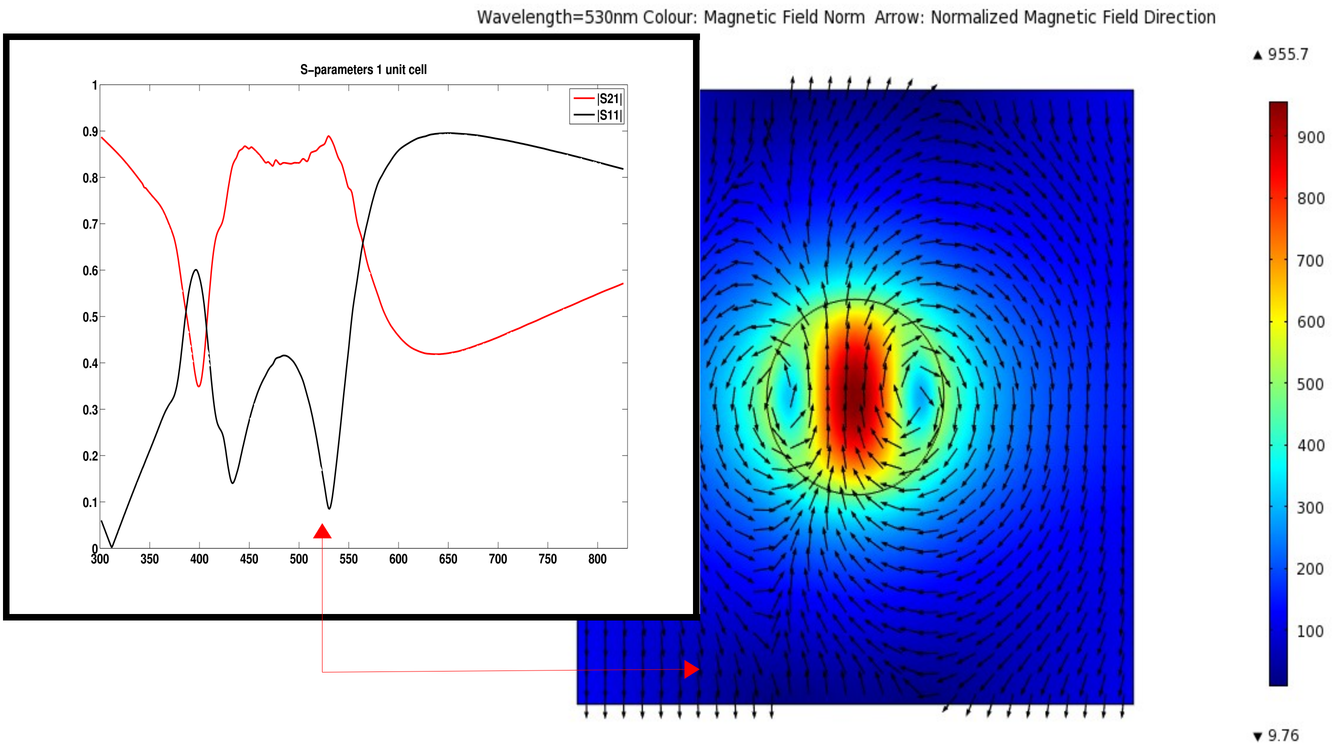

Fig.2: Dielectric cylinder made of Si with R=50nm serves as the unit cell for the 2D left-handed medium. The incident magnetic field is directed along the y-axis. As is readily observed a strong magnetic dipolar mode is excited in the structure.