Analysis of directionality effects in magnetodielectric core-shell nanoparticles by means of polarimetric techniques.

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Abstract-The influence of increasing the core size of a Ag-Si core-shell nanoparticle has been investigated by using the values of the linear polarization degree at right angle scattering configuration, $P_L(90º)$. Changes in dipolar resonances and Scattering Directionality Conditions as a function of the core radius (R_{int}) for a fixed shell size (R_{ext} = 230 nm) have been analyzed. An empirical formula to obtain the ratio R_{int}/R_{ext} by monitoring the influence of the magnetic dipolar resonance in $P_L(90º)$ has been found.

In spite of the good response of metallic nanoparticles (NPs) in visible and infrared ranges, their inherent ohmic losses make them useless in many practical applications. High Refractive Index (HRI) dielectric NPs have been proposed to address this issue. Some of their most important advantages are that light can travel through them without being absorbed and that they can present magnetic effects even for non-magnetic ($\mu = 1$) NPs, [1]. This magneto-dielectric behavior is responsible for interesting directionality properties. Under certain conditions of the electric permittivity ε and magnetic permeability μ, proposed by Kerker et al [2, 3], the forward and backward scattered intensity is almost null or null respectively. Those conditions are also known as either Kerker's conditions or Scattering Directionality Conditions. Metal-dielectric core-shell HRI NPs have been proposed during last years for controlling the direction of the scattered radiation because they support tunable electric and magnetic resonances [4]. In this work, using the linear polarization degree at right angle scattering configuration $P_L(90º)$, we have analyzed the influence of increasing the core size of an Ag-Si core-shell NP on both its dipolar resonances and the SDCs. Furthermore, we have obtained an empiric formula to reckon either the core radius R_{int} or the ratio R_{int}/R_{ext} by means of the footprint of the magnetic dipolar resonance in the $P_L(90º)$ spectra.

In Fig. 1 it is represented the spectral location of the dipolar magnetic resonance in $P_L(90º)$ as a function of the ratio R_{int}/R_{ext}, while R_{ext} was fixed to 230 nm. The theoretical data have been fitted to a cubic function ($\lambda(\min[P_L(90º)]) = A\,(R_{int}/R_{ext})^3 + B$, where A = −1686 nm and B = 1676 nm). The shadowed region represents R_{int}/R_{ext} in the interval 0.25 to 0.45, where a_1 and b_1 overlap. In this region $P_L(90º) \sim 0$ and the magnetic dipole resonance cannot be identified using $P_L(90º)$.

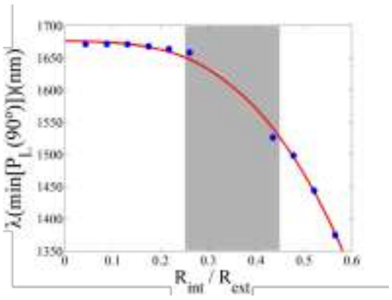

Figure 1. Location of $P_L(90º)$ minimum (corresponding to the dipolar magnetic resonance) as a function of R_{int}/R_{ext}.

In Fig. 2 we show the scattering diagrams for the first (blue) and second (red) SDCs. Core radii R_{int} correspond to a) 10 nm, b) 50 nm, c) 70 nm, d) 80 nm, e) 90 nm, and f) 130 nm.

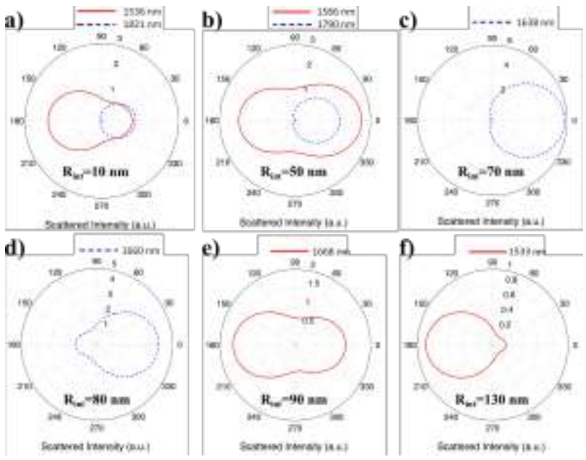

Figure 2. Scattering diagrams for the first (blue) and second (red) SDCs for different core radii.

As shown in Fig. 2, low ratios R_{int}/R_{ext} lead to good performance for the near zero-forward intensity SDC, whereas $R_{int}/R_{ext} > 0.4$ produce more directional scattering patterns, but with lower efficiencies. On the contrary, in the zero-backward SDC, low ratios give good scattering patterns but medium ratios (i.e. $R_{int}/R_{ext} \sim 0.3$) lead to an improved efficiency. Therefore, the performance of the SDCs can be tailored (optimized and spectrally tuned) by changing the core-shell ratio R_{int}/R_{ext}.

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