Plasmonics with new materials: Gallium. A comparison between experiment and a numerical model based on the Discrete Dipole Approximation (DDA)

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The optical properties of metal nanoparticles (NPs), especially those made of silver and gold, have attracted the interest of many researchers during the last fifteen years for their use in many nanotechnology applications. These include biosensing, optical communications, nanocircuitry, SERS, microscopy, emission and absorption enhancements of photonic devices and plasmonic waveguiding [1-8]. Unlike gold and silver nanoparticles, which exhibit localized surface plasmon resonances (LSPR's) primarily in the visible and IR wavelengths, other elements, like Gallium, present an interesting resonant behavior in the UV spectral region [9]. Recently, it has been shown that such material deposited on substrates can be an interesting alternative for the development of new plasmonic devices working at UV photon energies [10].

One of the tasks of this research is to analyze numerically the plasmon resonances shown by Gallium NPs deposited on Sapphire substrates, as measured by Wu et al. [10] (Fig. 1). We explore the behavior of these resonances as a function of different system parameters, such as particle size and geometry, polydispersity, particle geometrical distribution, etc. (Figs 2 a,b). The numerical simulations have been performed using the Discrete Dipole Approximation (DDA) method, [11]. This has proven extremely useful when dealing with NPs interacting with substrates [12, 13].

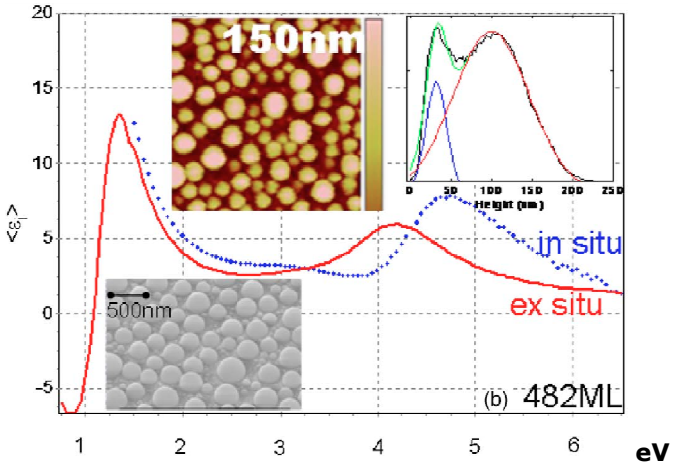

Fig 1. (a) Absorption spectrum of Ga nanoparticles deposited on sapphire substrates (see bottom inset of a SEM image). Upper right inset shows a sample histogram from AFM images (upper left inset) that reveals a bimodal distribution of particle sizes (see ref [10] for more details).

Our DDA simulations show the dependence of different aspects of morphology on the resulting spectra. The spectra can be interpreted as the result of a combination of different effects. Our results shown in Figure 2 suggest that the small particles (≈ 40 nm) contribute mainly to the high energy resonance (Fig. 2a), and the large particles (≈ 100 nm) contribute to the low energy peak (Fig. 2b). Interaction between NPs also plays a role, as the orientation of interacting NPs transverse or longitudinal to the incident scattering plane may shift the resonances or enhance certain regions of the spectra. Finally, transverse and longitudinal effects due to the incident polarization (circularly polarized in the experiment) were considered (a contribution to the explanation of these effects was already suggested in [10]).

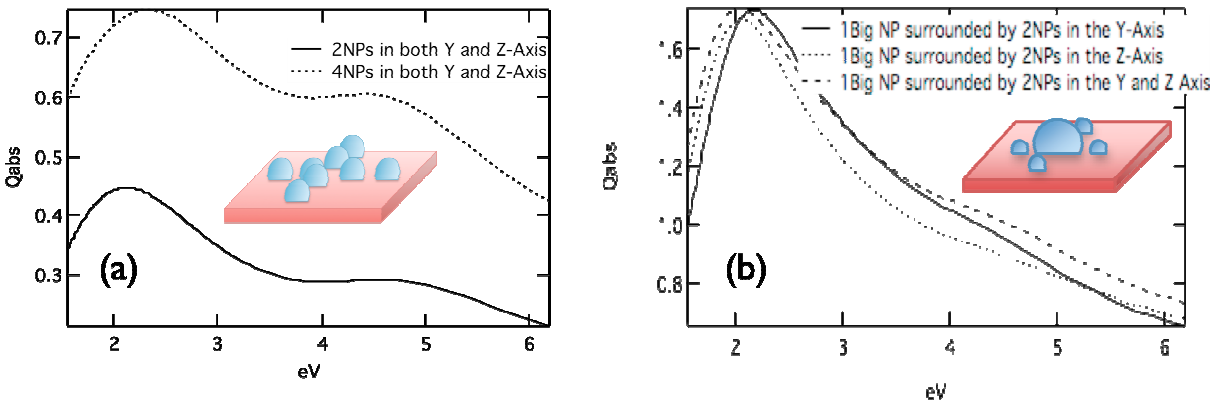

Fig. 2 Numerical DDA calculation of the absorption efficiency for the geometrical configuration shown in each respective inset (see text for details). a) Small-particle configuration. b) Large-small particle configuration.

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