The effect of shape and structure variation of metallic nanoparticles on localized plasmon resonances

Titus Sandu

National Institute for Research and Development in
Microtechnologies,126A, Erou Iancu Nicolae street, 077190, Bucharest, ROMANIA
titus.sandu@imt.ro

Localized plasmon resonances (LPRs) in metallic nanoparticles have been now studied extensively for more than a decade. They have a wide range of applications like sensing and waveguiding [1,2] or high throughput communications [3] to name a few. To calculate the LPR properties one has to find the solutions of Maxwell's equations with boundary conditions determined by the interface between nanoparticles and the surrounding medium.

Complex computational schemes like discrete-dipole approximation (DDA) [4] or finite-difference time domain (FDTD) [5] are successfully used to predict optical response of arbitrarily shaped nanoparticles. These aforementioned methods offers, however, little inside about the formation, nature, and the behavior of the LPRs with respect to parameters like the shape (geometry) or complex dielectric functions of nanoparticles. To overcome some of these shortcomings, it has been proposed a hybridization model [6], which works very well in the quasi-static limit. On the other hand, in the quasi-static limit, the Maxwell's equations reduce to Poisson equation which can be solved with the Neumann-Poincare operator associated with the Dirichlet and Neumann problems in potential theory [7]. In plasmonic applications, the method based on the Neumann-Poincare operator has been proposed for some time [8]. The method relates the LPRs to the eigenvalues of the Neumann-Poincare operator, but explicit relations are still lacking. Moreover, the method is similar to the operator method applied for calculation of electric polarizability of biological cells in radiofrequency [9].

I use the operator method outlined in Ref. 9 to define the LPRs in metallic nanoparticles. The LPRs are characterized by the eigenvalues of the Neumann-Poincare operator and their weights to the total polarizability of the nanoparticles. Compact formulas, that contain the complex dielectric functions of nanoparticles and the embedding medium, are given not only for homogeneous but also shelled metallic nanoparticles. The effect of geometry is included in both the eigenvalues of the Neumann-Poincare operator and in their weights to the polarizability. Various trends in LPRs, which otherwise are calculated more expensively with DDA and FDTD, are predicted by simple analysis of these formulas. The effect of geometry variation on LPRs is considered by analyzing the variation of the eigenvalues of the Neumann-Poincare operator and their weights to the nanoparticle polarization. Finally, I consider the case of graded nanoparticles, where their complex dielectric function is not homogeneous but may have a space variation.

References

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