Absorption and Scattering of Gold Nanoparticles

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Abstract

The interest to study the nanoparticles absorbed on the dielectric or semiconductor substrate is caused by the multiple practical applications of these systems such as nanosensors, electronic devices and lately in PV elements for improving of their efficiency [1, 2]. The author suggests a method of examining the properties of the nanosurface with the absorbed nanoparticle by calculating the absorption and scattering of the electromagnetic field by such system based on construction of its effective electric susceptibility. It was built based on the Green's function approach [3,4,5]. It was shown that the Raman scattering and the light absorption can be increased by orders with the use of metal nanoparticles, in particular the noble metal nanoparticles such as Au or Ag. If the scatterer is suspended in the free space or in the homogeneous medium, the background field is simply what you are sending, such as Gaussian or a plane wave. For the scatterer placed on the substrate, the analytical expression becomes more complicated. The superposition of an incident and reflected waves in the free space domain, and transmitted wave in the substrate should be taken into account. The amplitudes of the waves should obey the optical theorem. The calculations show the enhancement of the optical absorption in the system under consideration. Also it allows for investigation of the photocurrent in a semiconductor film via the excitation of surface plasmon polaritons in the substrate and resonance picks' emergence.
The optics and semiconductor features of the COMSOL Multiphysics® software was used to create the simulation of the system under consideration. (Fig.1-3). A plane electromagnetic wave is incident on a gold nanoparticle on a semiconductor substrate. The absorption and scattering cross sections of the particle were computed for a few different polar and azimuthal angles of incidence. It was shown that the presence of the nanoparticle on the substrate significantly increases the light absorption. The scattering profiles were also analyzed.
These observations suggest a variety of approaches for improving the performance of devices such as photodetectors, imaging arrays, integrated optics, biosensing and photovoltaics.

Reference

1. D. Schaadt et al. “Enhanced semiconductor optical absorption via surface plasmon excitation in metal nanoparticles,” Appl. Phys. Lett. 86 (6): 063106 (2005).
2. K. R. Catchpole and A. Polman. “Plasmonic solar cells,” Opt. Express 16, 21793-21800 (2008).
3. B. I. Khudik, I. V. Nazarenko-Bariakhtar, et al. “Macroscopic electrodynamics of ultra-thin films,”Phys. Stat. Solidi (b), 153, 167 (1989).
4. V. Z. Lozovski, “The Effective Susceptibility Concept in the Electrodynamics of Nano-Systems,” J. of Comp. and Theor. Nanos 7: 1–17 (2010).
5. I. V. Bariakhtar, et al. Interaction between localized-on-nanoparticles plasmon polaritons and surface plasmon polaritons. J. Opt. Soc. Am. B 30(4), 1022 (2013).

Figures used in the abstract

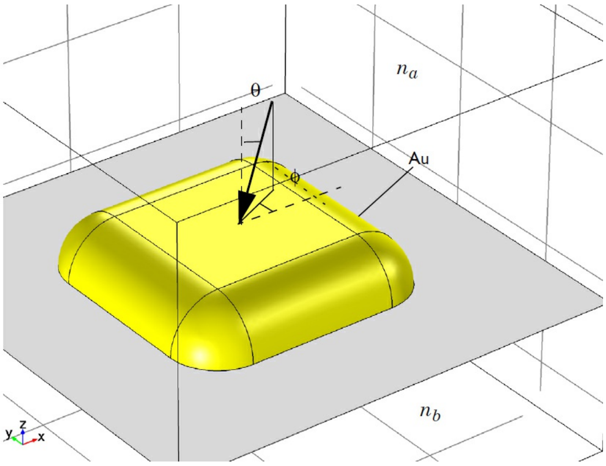

Figure 1: The modeled geometry. The gray boundary represents the surface of the substrate. The electric field vector of the incident wave points in the direction, orthogonal to the plane of incidence. The scattering nanoparticle is made of gold.

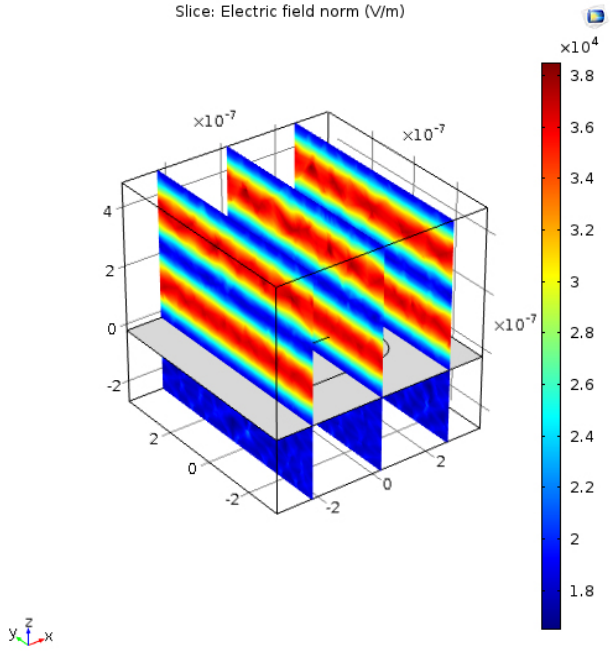

Figure 2: Background electric field (y-component) for φ = π/4, θ = π/6, on three slices parallel with the yz-plane.

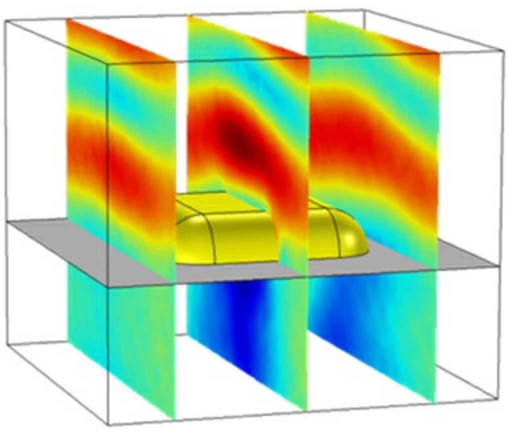

Figure 3: The norm of the total electric field for the same angles of incidence, after it has been influenced both by the material interface and by the nanoparticle Slice plot of the y-component of the total electric field for φ = π/4, θ = π/6