WIDTH OF THE LINE OF THE SURFACE PLASMONIC RESONANCE IN METAL-DIELECTRIC NANOCUPS

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Abstract

The nanoparticles of noble metals have unique optical properties due to the excitation of plasmonic resonances on their surfaces – collective oscillations of conduction electrons, excited by the electromagnetic wave incident on the particle. It is known that the resonance spectra of metallic and metal-dielectric nanoparticles depend significantly on the details of their geometry. The synthesis of nanostructures with different shapes such as nanospheres, nanorods, nanocubes, nanocones, nanoprisms, nanorings and nanoshells allows tuning of resonance frequency from near-infrared to ultraviolet region [1]. The particles of the above mentioned forms are symmetric, so only the plasmonic modes of the same multipolarity are mixed in them. The symmetry breaking removes this restriction and mixing (hybridization) of modes of the different multipolarity becomes possible. One form of nanoparticle with broken symmetry is nanocup, which consists of the dielectric core, only partially covered by metallic shell of the constant thickness. The advantage of these nanoparticles, except the broken symmetry, is also the possibility to influence the enhancement of local fields and anisotropic optical response by changing the height of nanocups and the size of the core and shell.

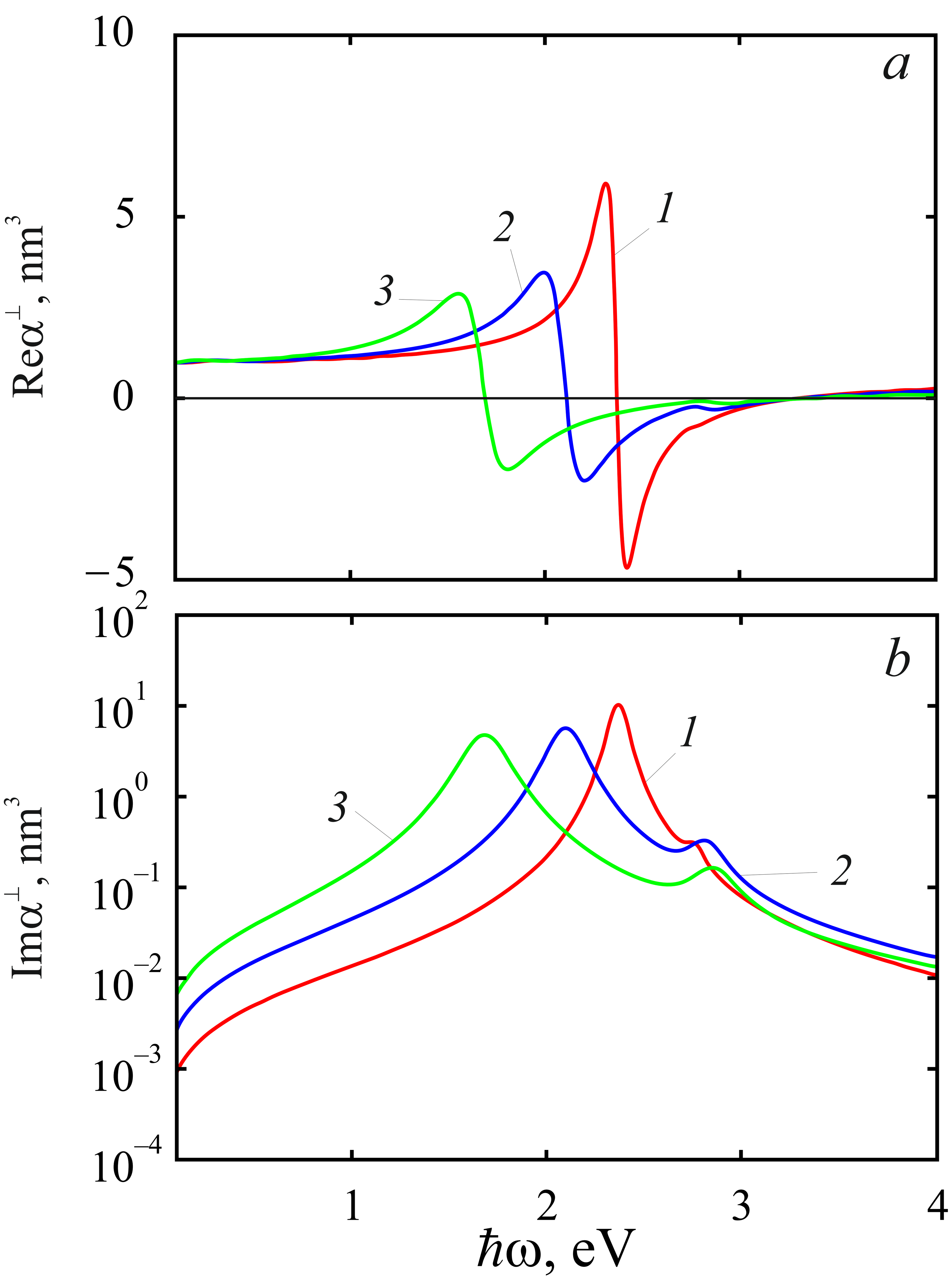
Statement of the problem and results of calculations

The line width of the surface plasmon resonance of nanocups, as in the case of particles of the second form [2], is determined by the transverse component of the tensor of the effective relaxation rate of electrons in the metal shell, which is additively contributed by three mechanisms: volume and surface relaxation, as well as radiation attenuation

$$\gamma_{\text{eff}}^{\perp} = \gamma_{\text{bulk}} + \gamma_{s}^{\perp} + \gamma_{\text{rad}}^{\perp}. \tag{1}$$

Calculations of the frequency dependences of the real and imaginary parts of the transverse component of the polarizability tensor were carried out for nanostructures of composition SiO_2@Au with different values of the radius of the dielectric core (Fig. 1).

Figure 1



Frequency dependences of the real (*a*) and imaginary (*b*) parts of the transverse component of the polarizability tensor of nanocups SiO_2@Au with R = 30 nm, H = 55nm: *1* – R_c = 10 nm; *2* – R_c = 20 nm; *3* – R_c = 25 nm.

Conclusions

It was established that a decrease in the metal content in the investigated nanostructure results in a broadening of the transverse surface plasmon resonance lines and a significant red shift of the first one max$\{\mathrm{Im}\alpha^{\perp}\}$ corresponding to a lower resonance frequency. It is shown that the transverse components of the tensor of the speed of surface relaxation and radiation attenuation, and, accordingly, the width of the transverse surface plasmon resonance line are determined by such a set of geometric parameters as the outer radius of the nanocup; $\beta_c = (R_c/R)^3$, where R_c is the radius of the dielectric core; $h = R_c/H$, where H is the height of the nanocup. In the limiting case $H \to 2R$, the obtained results coincide with the results for a two-layer spherical nanoparticle of the "dielectric core - metal nanoshell" type.

References

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