OPTICAL RESPONSE OF CHAINS OF OBLATE METAL NANOSPHEROIDS ON A DIELECTRIC SUBSTRATE

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Abstract

Currently, a targeted search is being carried out for nano-sized structures of different geometries, characterized by certain possibilities for adjusting their optical properties. These structures include nanogrooves on a flat surface, stripes, ridges, and chains of spherical and spheroidal nanoparticles. Chains of metal nanoparticles of different shapes are of particular interest because they can be used to transmit modulated optical signals with a high degree of spatial confinement. Therefore, studying the optical properties of chains of spheroidal nanoparticles on a dielectric substrate is an urgent task.

Statement of the problem and results of calculations

Let us consider a chain of oblate metal nanspheroids oriented on a dielectric substrate with permeability ϵ_d in such a way that their minor axes lie in the plane of the substrate. In the local field approximation, taking into account the interaction of nanospheroids with each other and with image dipoles, under the condition of normal light incidence on the substrate, the transverse component of the chain polarizability tensor is determined by the relation

$$\alpha_{\perp}^{\text{chain}} = \frac{\alpha_{\perp}(\omega)}{1-\frac{\alpha_{\perp}(\omega)}{d^3\epsilon_m}\left(\mathcal{S}_{\perp}^{d}+\frac{\epsilon_d-\epsilon_m}{\epsilon_d+\epsilon_m}\mathcal{S}_{\perp}^{i}\right)} \qquad (1)$$

where d is the distance between the centers of neighboring spheroids (a chain period); ϵ_m is permeability of an environment; $\alpha_{\perp}$ is the transverse component of the polarizability tensor of a spheroidal nanoparticle; $\mathcal{S}_{\perp}^{d}$ and $\mathcal{S}_{\perp}^{i}$ are chain sums determined by the contributions of other particles of the chain and image dipoles

$$\mathcal{S}_{\perp}^{d} = 4\zeta(3), \qquad (2)$$

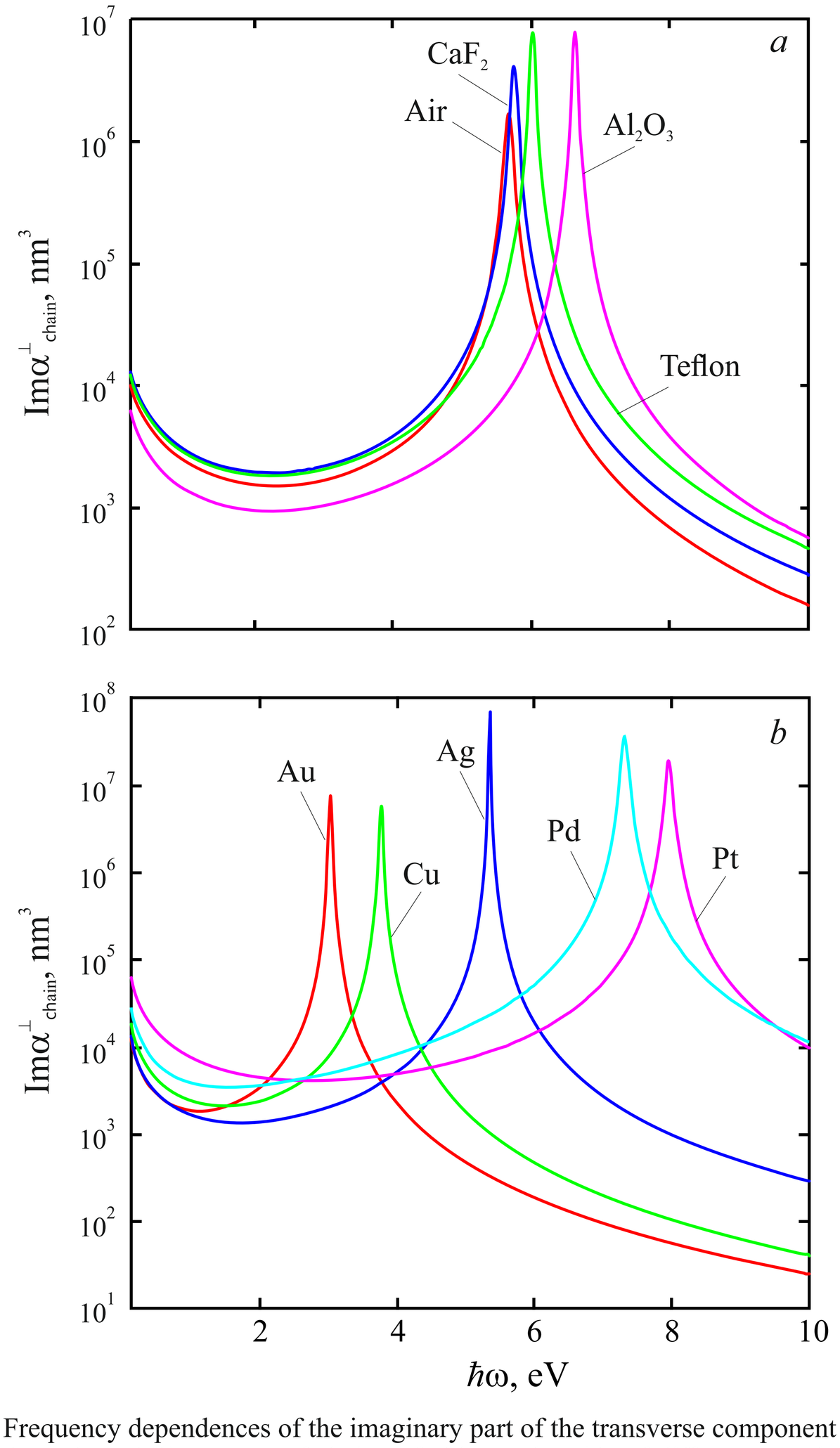
$$\mathcal{S}_{\perp}^{i} = \frac{\pi d}{z_0}\sum_{m=1}^{\infty} m\left\{K_1\left(4\pi\frac{z_0 m}{d}\right)-\frac{\pi d}{z_0}m^3 K_2\left(4\pi\frac{z_0}{a_l}m\right)\right\}. \qquad (3)$$

Here m are the numbers, numbering spheroidal nanoparticles in the chain; $\zeta(z)$ is the Riemann zeta function ($\zeta(3)\approx1.202$ is the Apery constant); $K_\nu(x)$ is the McDonald function of the of the ν-th order; z_0 is the distance between the substrate surface and the layer, which contain image dipoles.

Calculations of the frequency dependences of the imaginary part of the transverse component of the polarizability tensor were carried out for chains of oblate spheroids of different metals in Teflon and chains of Au spheroids located in different dielectric media (Fig. 1). The calculation results indicate a blue shift $\max\{\text{Im}\alpha^{\text{chain}}_{\perp}\}$ with increasing permeability of the surrounding dielectric in the sequence Air→CaF_2→Teflon→Al_2O_3, and, when the environment is Al_2O_3, $\max\{\text{Im}\alpha^{\text{chain}}_{\perp}\}$ is in the near ultraviolet region of the spectrum.

In the case of chains of particles of various metals $\max\{\text{Im}\alpha^{\text{chain}}_{\perp}\}$, it lies in the visible range of the spectrum only for Au spheroids, for chains of other metals (Ag, Cu, Pt, Pd) - in the ultraviolet region of the spectrum. This fact indicates a significant blue shift of the maxima of the imaginary part of the chain polarizability for chains of spheroidal particles of these metals compared to isolated particles.

Figure 1



Frequency dependences of the imaginary part of the transverse component of the polarizability tensor of chains of oblate spheroids of different metals in Teflon (*a*) and chains of oblate Au spheroids located in different dielectric media (*b*)

Conclusions

Relations have been obtained for the frequency dependence of the transverse component of the polarizability tensor for a chain of metal oblate nanospheroids located on a dielectric substrate.It has been established that in the case of chains of particles from different metals, the maxima of the imaginary part of the chain polarizability are in the ultraviolet region of the spectrum, except for chains of gold spheroids, which is caused by a “blue” shift of these maxima compared to the case of isolated nanoparticles.