ELECTROMAGNETIC WAVES ON THE SURFACE OF A COMPOSITE WITH SPHEROIDAL NANOSHELLS

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Abstract

The study of the waves, which propagate at the interface between a composite with the inclusions of different geometry and composition and the surrounding environment is the relevant problem related to the applications in optoelectronic and nanophotonic technologies. It should be pointed out that virtually all available scientific literature is devoted to the study of the optical properties of the composites with the monometallic inclusions of the different shapes. The use of the shell nanoparticles as the inclusions is of interest due to the additional possibilities for controlling the optical properties of the particle inclusions (and thus the entire nanocomposite) by changing the materials and sizes of the core and shell.

Statement of the problem

Let us consider the composite with the spheroidal metallic nanoshells randomly embedded into the matrix dielectric. Applying the effective medium theory and assuming a low concentration of the particle inclusions, the following formula can be obtained for the frequency dependence of the effective permittivity of the nanocomposite, which is under the study

$$\epsilon_{\text{eff}}(\omega) = \epsilon_{\text{m}} \frac{a_4\epsilon_{\text{s}}^4 + a_3\epsilon_{\text{s}}^3 + a_2\epsilon_{\text{s}}^2 + a_1\epsilon_{\text{s}} + a_0}{b_4\epsilon_{\text{s}}^4 + b_3\epsilon_{\text{s}}^3 + b_2\epsilon_{\text{s}}^2 + b_1\epsilon_{\text{s}} + b_0} \tag{1}$$

where ϵ_{m} is the permittivity of the matrix dielectric; the coefficients a_{i} and b_{i} depend on the depolarization factors, electrophysical characteristics of the matrix dielectric and the dielectric core of spheroid, the volume content of the dielectric in the particle and the particles in the composite, and the dielectric function of the spheroid shell material $\epsilon_{\text{s}}(\omega)$ is determined by Drude formula in the dissipation-free approximation.

It should be pointed out that the obtained formula (1) differs significantly from similar formulas for the composites with the spherical shell and spheroidal monometallic particles. Thus, unlike the above cases, the numerator and denominator in (1) contain fourth-degree polynomials with respect to ϵ_{s} and, respectively, eighth-degree polynomials with respect to the frequency. However, each of these polynomials has three pairs of the complex conjugate roots and two real roots, which correspond to the longitudinal and transverse optical modes. In addition, the equation $\epsilon_{\text{eff}}(\omega_{SP}) = -\epsilon_{\text{h}}$ (where ϵ_{h} is the permittivity of the medium bordering the nanocomposite) also has two real roots, which correspond to the resonances at the composite/environment interface.

Figure 1

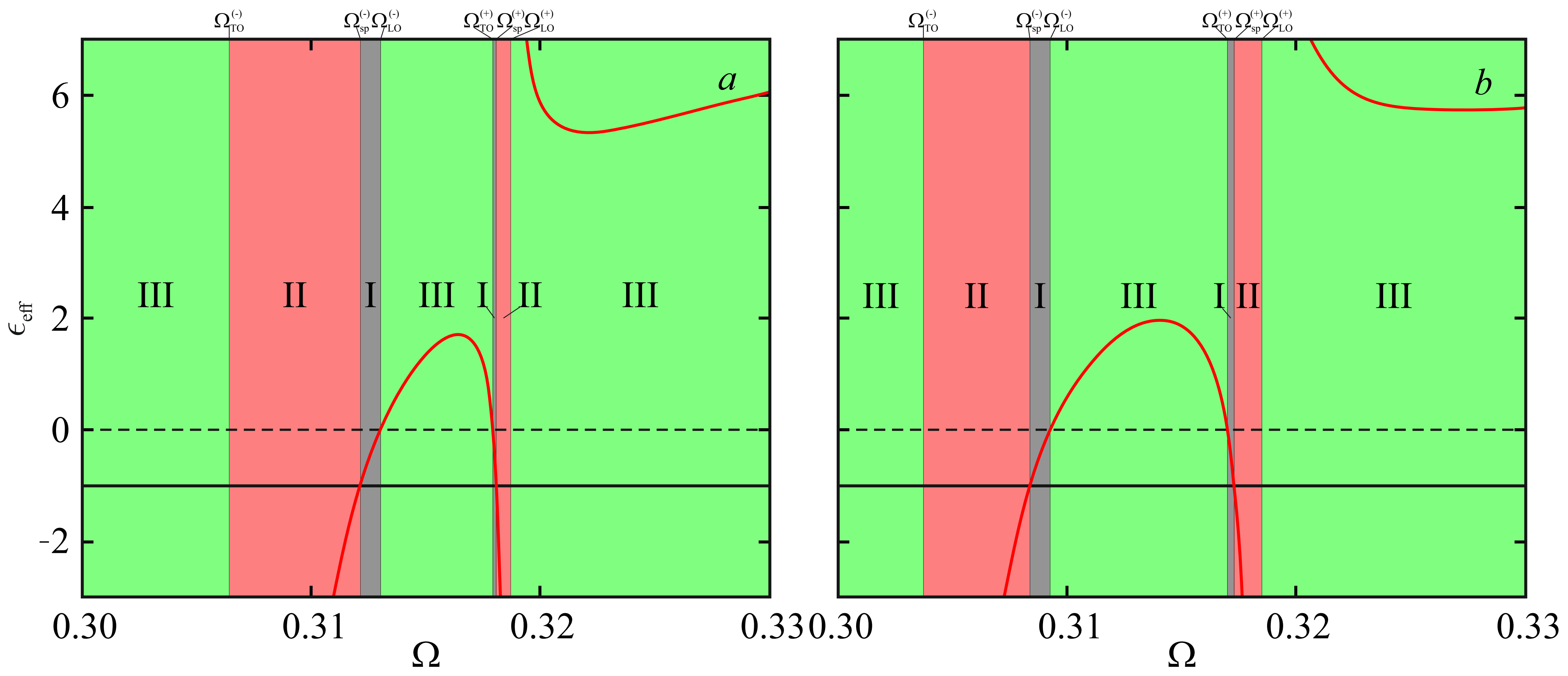

Fig. 1. Maps of electromagnetic waves propagating at the air-composite interface with randomly distributed elongated (a) and flattened (b) spheroidal Au nanoshells.

I: -1 < ϵ_{eff} < 0; II: ϵ_{eff} < -1;III: ϵ_{eff} > 0.

Results of calculations and conclusions.

Thus, as in the case of the composites mentioned above, we have six characteristic frequencies that divide the frequency range, which is under the study, into seven regions (Fig. 1), three of which contain surface electromagnetic waves, two regions contain surface plasmon polaritons, and two regions are the forbidden zones – the frequency regions at which the electromagnetic waves cannot propagate along the boundaries between the composite and the surrounding environment.