THERMAL PHENOMENA IN THE NEIGHBORHOOD OF SPHEROIDAL METALLIC NANOPARTICLES UNDER THE EXCITATION OF PLASMO RESONANCES ON THEIR SURFACE

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Abstract

As is well known, the excitation of the surface plasmon resonances in the metallic nanoparticles of various shapes is accompanied by the heating of their neighborhoods. This is due to the conversion of the absorbed light energy into heat energy. It should be pointed out that the thermoplasmonic effects are widely used in nanomedicine, in particular for the thermal destruction of the malignant neoplasms. In [1], the thermoplasmonic phenomena in the metallic nanoparticles of the spherical, cylindrical, and disc shapes were investigated, and the recommendations were presented for the practical use of the overheating in the particles of such shapes. However, the issues related to the heating of the neighborhoods of the spheroidal nanoparticles under the excitation of the surface plasmon resonances remain unexplored and therefore relevant.

Statement of the problem

The study examines the influence of metal nanoparticle geometry and semi-axis lengths on the heating of their surroundings. In this case, superheating is determined by the ratio

$$\Delta T = \frac{C_{\text{abs}} I_0}{4\pi\varkappa\beta R_{\text{eq}}} \tag{1}$$

where C_{abs} is the cross-section of light absorption by a nanoparticle, R_{eq} is its equivalent radius; I_0 is the intensity of laser radiation; $\varkappa$ is the thermal conductivity of the nanoparticle material, and the shape factor

$$\beta = \exp\left\{\sqrt{1 + 0.0416\ln^2\left(\frac{D}{1.85d}\right)} + 0.092\ln\left(\frac{D}{1.85d}\right) - 1\right\} \tag{2}$$

In formula (2), $D = a_t / b_t$, $d = b_t / a_t$ for a prolate/oblate spheroid

Figure 1

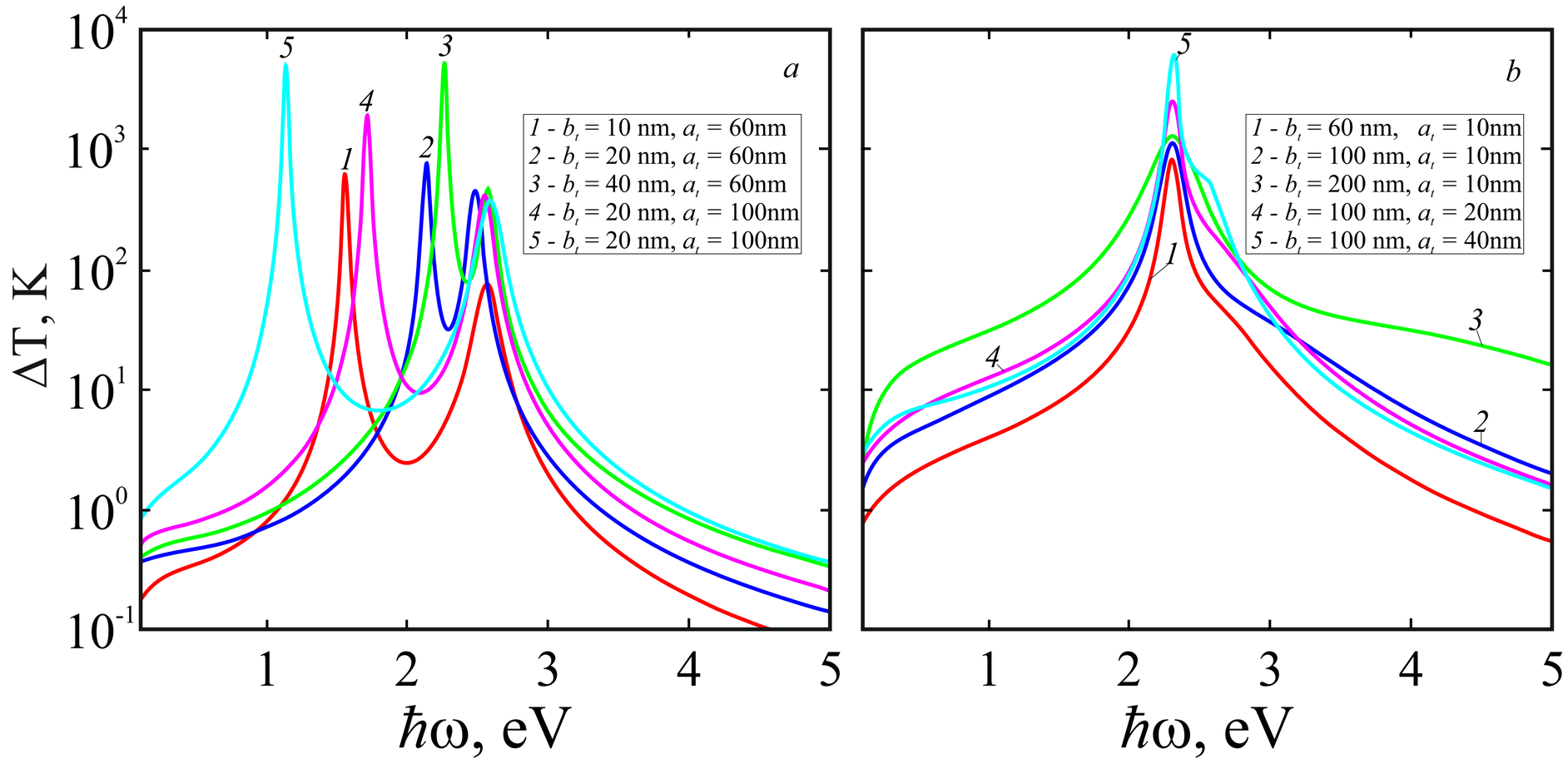

Fig 1. Frequency dependences of superheating in the vicinity of prolate (*a*) and oblate (*b*) spheroidal nanoparticles.

Results of calculations and conclusions.

Calculations (Fig. 1) showed a small (on the order of fractions of a degree or several degrees) overheating near oblate spheroidal nanoparticles and prolate spheroids with low eccentricity (when their shape is close to spherical). At the same time, overheating will be significant near highly prolate spheroids (needles) and highly oblate spheroids (pancakes). Therefore, in practical applications requiring low overheating, it is advisable to use slightly oblate and slightly prolate spheroids, while in applications requiring significant overheating, highly prolate or highly oblate spheroids are preferable. It has been established that at frequencies falling within the first and second biological transparency windows, overheating will be sufficient for photothermal therapy of malignant tumors.

1. V. I. Reva, M. A. Shvydkyi, R. Yu. Korolkov, A. V. Korotun, E. V. Stegantsev and O. S. Hnatenko, J. Nano- Electron. Phys. 17, 02006 (2025).