Surface plasmon frequency spectrum in a system of two spherical dielectric coated metallic nanoparticles

T.Makaryan[1], A.Melikyan[2], and H.Minassian[3]

[1] *Faculty of Radiophyiscs, Yerevan State University, Yerevan, Armenia*
[2]*Russian-Armenian (Slavonic) State University, Yerevan, Armenia,*
e-mail: amelikyan@shen.am
[3]*Yerevan Physics Institute after A.Alikhanyan, Yerevan, Armenia*

The system of two almost touching spherical nanoparticles is of special interest, since in such structures substantial change of surface plasmon (SP) frequency can be realised by varying the interparticle distance. Strong SP frequency dependence on the interparticle distance is demonstrated experimentally in [1]. However the calculation of the SP frequency of this system using only analytical methods is not possible.

If the size of the system is much smaller than the wavelength corresponding to SP frequency, it is possible to neglect the retardation effects, and then the problem is reduced to the standard boundary problem of electrostatics with the bound in the form of two spheres, for solving of which various approximate methods are applied. Thus, in [2] starting from Laplace equations in bispherical coordinates a complicated recurrent equation is obtained, which is solved numerically. In the papers [3, 4] the boundary problem of electrostatics is converted into an integral equation, which is solved using finite element method. In [5] in the multipole expansion of the solution of Laplace equation the first ten or more terms are kept, and the truncated system of linear algebraic equations are solved numerically as well.

In this work a semi-analytical method of calculation of SP frequency of a system of two almost touching coupled dielectric coated metallic nanospheres with equal radii is developed based on physical reasoning. The method allows to transform the problem to numerical solution of two simple algebraic equations for arbitrary values of parameters – particle radius, distance between sphere centers, dielectric permittivity of the matrix and metals. It is especially easy to get the obvious graphical solution.

The main point of the method is that the point inside the particle, with respect to which the multipole expansion of the charge distribution is performed, may be chosen in a way that the quadrupole moment becomes zero. Naturally, this point is shifted from the centre of the sphere along the axis of symmetry of the system. It is proved, that the magnitude of this shift is determined by the ratio of quadrupole and dipole moments calculated with respect to the centers. The contribution of the higher order multipole moments is analyzed.

The SP frequencies of longitudinal and transversal oscillations of the system are calculated and good agreement with the experimental results of [1] is achieved.

References

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