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A theoretical study optical scattering off a Silver Nanosphere

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Abstract.

In this study a plane transverse electric polarized electromagnetic (em) wave is exposed on a Silver (Ag) nano-particle on a suitable dielectric substrate. The physical parameters such as scattering cross section and heat loss (or) absorption of the Ag-nanoparticle are computed for a few different values of azimuthal and polar incident angle.

Keywords: *Nanoparticle, Silver, Heat loss, Radiation pattern*

INTRODUCTION

The basics of nanotechnology was first introduced by R P Feynman who is the well know physicist in 1959 [1]. This technology is now widely used in the many diverse areas like nanomedicine, nanobiotechnology, nono warfare and industrial application [2]. Now-a-days, the nanoparticle plays a key role in the modern nanotechnology and this is an active research field among all the scientific communities [3,4]. These nanoparticles have many amazing, optical, magnetic, electrical, physical and thermal properties. A large number of these nanoparticles are produced at an engineering scale and still research is going on at this small scale. A few researchers have studied the behaviour of colloidal metal nanoparticles and studied its interaction with light, in 1857 [5]. Silver nanoparticles have unique properties which is beneficial to develop nano-biosensor for different applications. Therefore, the development of a biosensor, it is necessary to study the nature and properties of Ag- nanoparticle. In this study, the scattering of a plane wave of light off of a silver (Ag) nanosphere has been analysed theoretically. This scattering is calculated for the visible wavelength region over which Ag is modeled as a material nanoparticle with -ve dielectric constant. The heat losses and far-field pattern have also been computed.

COMPUTIONAL METHODOLOGY

In this study, a silver (Ag) sphere of radius 100 nm is irradiated by a plane wave. The free space wavelength are taken in the range 4000Å-7000Å. The refractive index (RI) of silver is complex and taken from the optical materials database. Using this RI, the relative permittivity is calculated by using the following equation:

$$\varepsilon_r = \varepsilon_1 - j\varepsilon_2 = (n_1 - jn_2)^2 \tag{1}$$

Where the ε_1 is real parts and ε_2 is the imaginary parts of the relative permittivity. The skin depth is computed using he following relation for whole range of wavelength:

$$\delta = \frac{1}{\mathrm{Re}\sqrt{-k_0^2 \varepsilon_r}} H \tag{2}$$

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Where k_0 is the wavenumber of free space, and ε_r is the complex dielectric constant. Only 1/4th of the Ag-sphere is modeled (using COMSOL Multiphysics) because of the symmetry nature of the problem. Here the surrounding medium of the sphere is taken as air and the width of the free space is equal to half the wavelength. The outside of the air is taken as perfectly matched layer (PML) domain which acts as an absorber of the scattered field. This PML is not within the reactive near field of the scatterer and is placed $\lambda/2$ away. The heat losses has been computed and finally the far field radiation pattern analysed.

RESULT AND DISCUSSIONS

Using Eq^n.1, it has been found that the real part of ε_r is –ve value for given range of wavelength. By assuming plane wave incidence over the flat surface, the skin depth is computed. The simulation is performed using COMSOL Multiphysics. Fig. 1 shows the variation skin depth over the range from 23 nm to 30.5 nm.

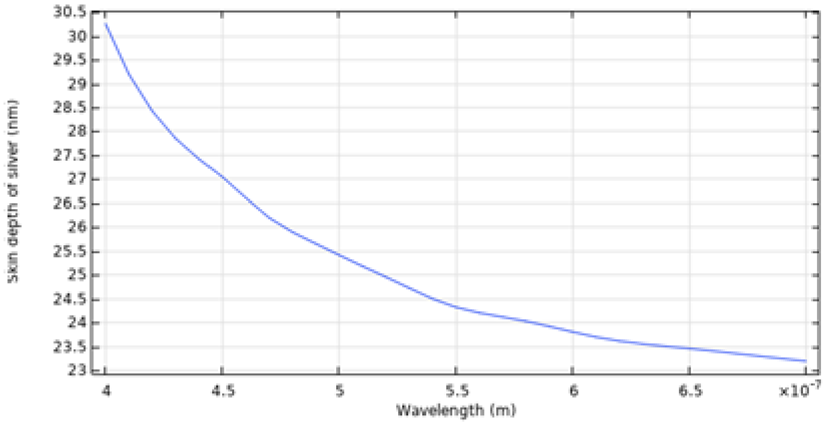

Fig. 1: Skin depth of the Silver nanosphere

Then far field patterns has been computed for the Ag- nanosphere which is shown in the Fig.2. It shows that the Ag nanosphere scatters light in the direction of incident light, at the shorter wavelength region. But the scattered field from the Ag-nanosphere look like the radiation pattern of a dipole antenna in the longer wavelength region. Fig. 2 shows the radiation pattern for a wavelength of 7000Å. Here, the direction of maximum radiation observed in the xz-plane and xy-plane for electric field and magnetic field respectively.

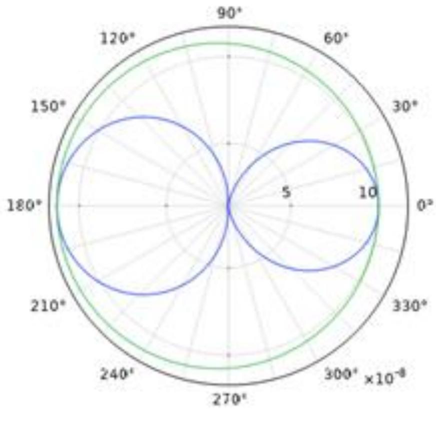

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Fig. 2: Far field radiation pattern

Fig. 3 shows the heat loss pattern for the given range of wavelength. It shows that the Ag nanoparticle specially absorbs more in the shorter wavelength region. The absorption of the different nanosphere can also be observed by varying radius.

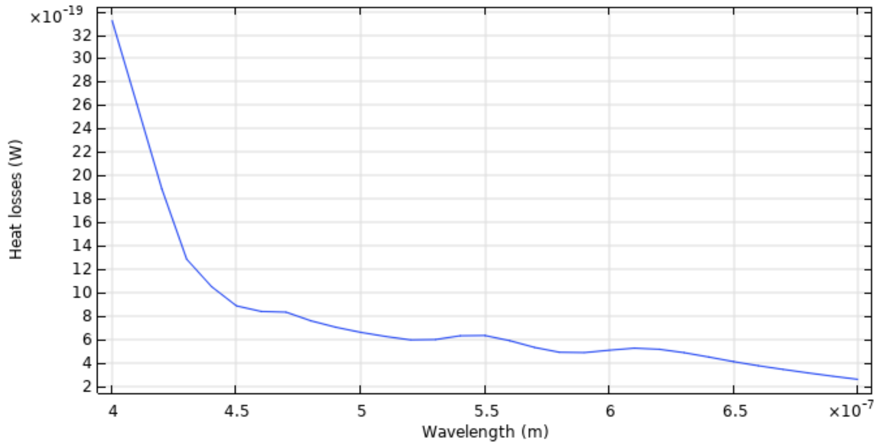

Fig. 3: Heat loss pattern

CONCLUSION

In general, silver (Ag) nanoparticle can be obtained by using various synthesis method. In this study, the dielectric constant of Ag-nanoparticle has been calculated and it gives –ve real dielectric constant which is matched with the experimental result. From the skin depth calculation, it is clear that skin depth value is higher in the low wavelength region. The heat loss is also calculated and it shows that Ag-nano particle preforencially abosrps at the short wavelength region. Finally far field radiation pattern has been computed which is shown in Fig. 2. It gives the basic idea to observe the absorption and radiation pattern for differenet radius of nanosphere.

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