Study of the Properties of Au/Ag Core/Shell Nanoparticles and its Application

Sara Mohammadi Bilankohi¹, Majid Ebrahimzadeh^{1*} and Tooraj Ghaffary²

¹Department of Physics, Payame Noor University, Iran; pasiran@gmail.com ²Department of Physics, Shiraz Branch, Islamic Azad University, Shiraz, Iran; tooraj_gh@gmail.com

Abstract

Light absorption and scattering by nanoparticles has interesting history in physics and one of basic problems of advanced electrodynamics and it is an interesting subject for which Mie theory was developed long ago. In this article, we report the optical extinction, absorption and scattering properties of Au and Au/Ag nanoparticles. These nanoparticles can be applied as coating materials. Results showed that optical properties of Au/Ag core/shell nanoparticles are highly dependent on many factors such as size, index of environment, intrinsic properties, and surface chemistry. Also, when Au nanoparticles diameter is kept constant at 10 nm, the spectrum has a peak at visible area. If the shell thickness is increased, the peaks arise to the high and become more intense. Thinning the silver shell layer has a high increase in polarization at the sphere boundary, which yields the more intense extinction peaks. We expect that the Au/Ag nanospheres can be used in nanophotonics industry based on the near-field, optical devices, medical and solar energy.

Keywords: Core, Extinction, Optical Properties, Scattering, Shell Nanoparticles

1. Introduction

Nanoparticles have special properties with many applications. The use of nanoscience in biotechnology combined the fields of nanomaterial science and biology¹. Gold and Silver nanoparticle have high potential application in medical, biotechnology and optical devices²⁻⁴. Au nanoparticles according to the size and physical dimensions have interesting interaction with electromagnetics wave. At the visible spectrum, Au nanoparticles have strong oscillation of electron charges, according to the electric fields of an electromagnetics wave that propagate near an Au nanoparticle surfaces. These oscillations are defined as surface plasmon⁵. Also, light absorbing and scattering of Au nanoparticles can be occurred with high efficiency because the free electrons on the Au surface when the Au nanoparticles excited by light at special wavelengths6. Au nanoparticle optical properties can be control by the particle size, shape, and the local refractive index of nanoparticles near the particle surface⁷⁻¹¹. However, Ag nanoparticles have especial optical, electrical, and thermal characteristics. In this paper, we simulated the optical properties of Au/Ag core/shell nanospheres using the Mie theory.

2. Simulation Method

The Mie theory is a very useful method for simulation of optical properties in practice. Also with Mie theory, we can simulate the light scattering by nanospheres with arbitrary radius. Within the Mie solution, the cross-sections for scattering, extinction and absorption can be expressed by following formulas:

$$Q_{scattering} = \frac{2}{q^2} \sum_{l=1}^{\infty} (2l \ 1) \{ |a_l^2| \ |b_l^2| \}$$
(1)

^{*}Author for correspondence

$$Q_{extinction} = \frac{2}{q^2} \sum_{l=1}^{\infty} (2l+1) \operatorname{Re}(a_l + b_l)$$
(2)

$$Q_{absorption} = Q_{extinction} - Q_{Scattering}$$
(3)

The scattering parameters a_1 and b_1 are defined as follows:

$$a_{l} = \frac{F_{a}^{e}(l)}{F_{a}^{e}(l) + iG_{a}^{e}(l)} and \quad b_{l} = \frac{F_{b}^{m}(l)}{F_{b}^{m}(l) + iG_{b}^{m}(l)} \quad (4)$$

Where $F_{a}^{e}(l)$, $F_{a}^{e}(l)$, $G_{a}^{e}(l)$ and $G_{b}^{m}(l)$

are related to the Bessel and Neumann functions.

3. Results and Discussion

The optical properties of Au/Ag nanoparticles are highly dependent on the nanoparticles diameter. The extinction and scattering cross section area curves of Au/Ag core/ shell nanoparticles with core diameter of 10 nm at various shell diameter are displayed in the Figure 1 and Figure 2. Au/Ag core/shell nanoparticles scatter the light and have peaks near 400 nm (Figure 2). All spectra have a high resonance at violet spectrum, caused by the oscillations of the nanoparticle electrons on surface. If the core diameter and shell thickness is increased, scattering and absorption cross section curves are wide and peaks at visible spectrum (Figure 3 and Figure 4).



Figure 1. Extinction cross section area for Au/Ag core/ shell nanopheres of varying diameter.



Figure 2. Scattering cross section area for Au/Ag nanoparticles of varying diameter.



Figure 3. Cross section area for Au/Ag nanoparticles (core diameter is 30nm and Shell thickness is 20nm).



Figure 4. Cross section area for Au/Ag nanoparticles (core diameter is 40nm and shell thickness is 20nm).



Figure 5. Absorption cross section area for Au/Ag core/ shell nanoparticles of varying diameter (Core diameter is 10nm).

Figure 5 shows the absorption cross sectional area for gold/silver core/shell nanoparticles at different shell thickness. The gold nanoparticles diameter is kept constant at 10 nm. The spectrum with a peak at visible area. As the shell thickness is increased, the peaks arise to the high and become more intense. Thinning the shell layer produces a large increase in polarization at the sphere boundary, which yields the more intense extinction peaks.

4. Conclusions

We have studied the Mie theory of light absorption, extinction and scattering properties for Au/Ag core/shell nanospheres. It is extraordinary that some of the basic aspects of the Mie theory are more than 110 years old, there continue to be new, unexpected and useful developments, such as spacers, medical and optical devices based on it. New aspects of Mie theory showed extremely interesting near field behavior. Also, we study the absorption and scattering of electromagnetics wave in spectrum much smaller than the wavelength in Au/Ag core/shell nanospheres. These effects are being utilized to yield worthy of attention intersecting nanoscale behavior and various applications in different science areas and industrial, such as high-resolution optical imaging, small-scale sensing techniques, light-activated cancer treatments, enhanced light absorption in photovoltaic and photo catalysis, and numerous biomedical applications.

5. References

- Kelly KL, Coronado E, Zhao LL, Schatz GC. The optical properties of metal nanoparticles: The influence of size, shape, and dielectric environment. J Phys Chem B. 2003; 107(3):668–77.
- 2. Mie G. Contributions to the optics of turbid media, especially colloidal metal solutions. Ann Phys; 25(3):377–445.
- 3. Lin H. Size dependency of nanocrystalline TiO₂ on its optical property and photocatalytic reactivity exemplified by 2-chlorophenol. Appl Catal B Environ. 2006; 68(1):1–11.
- Rivero PJ, Goicoechea J, Urrutia A, Matias IR, Arregui FJ. Multicolor Layer-by-Layer films using weak polyelectrolyte assisted synthesis of Core/Shell Nanoparticles. Nanoscale Research Letters. 2013; 8:438.
- Ghaforyan H, Ebrahimzadeh M, Ghaffary T, Rezazadeh H, Sokout Jahromi Z. Microwave absorbing properties of Ni nanowires grown in nanoporous anodic alumina templates. Chin J Phys. 2014; 52(1):233–8.
- Mohammadi BS, Ebrahimzadeh M, Ghaforyan H. Simulation of optical characteristics of nickel and nickel/ titanium dioxide. World Appl Program. 2015; 5(7):109–12.
- Ghaforyan H, Ebrahimzadeh M, Mohammadi BS. Study of the optical properties of nanoparticles using Mie theory. World Appl Program. 2015; 5(4):79–82.
- Soni S, Tyagi H, Taylor RA, Kumar A. Investigation on nanoparticle distribution for thermal ablation of a tumor subjected to nanoparticle assisted thermal therapy. J Therm Biol. 2014; 43:70–80.
- Fleming LAH, Tang G, Zolotovskaya SA, Abdolvand A. Controlled modification of optical and structural properties of glass with embedded silver nanoparticles by nanosecond pulsed laser irradiation. Optical Materials Express. 2014; 4(5):969–75.
- Yan H, He L, Zhao W, Li J, Xiao Y, Yang R, Tan W. Poly β-Cyclodextrin/TPdye nanomicelle based two-photon nanoprobe for caspase-3 activation imaging in live cells and tissues. Anal Chem. 2014; 86(22):11440–50.
- Matzler C. MATLAB functions for Mie scattering and absorption. Technical report, Research Report No. 2002– 08. Institute of Applied Physics, University of Bern. 2002; 8:5–7.