

Study of Plasmonic Resonance of Gold through Refractive Index

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Abstract

This effect suppresses absorption and increases radiation abilities of larger particles within plasmon mechanism. This is manifested in the corresponding absorption and scattering efficiencies. This creates a simple, yet robust, platform which can be used to investigate the properties of nanoparticles, for sensing, spectroscopy, and optical switching applications. Plasmon resonance related peak, as well as broadening of the plasmon resonance was observed. The efficiency of the photoelectric conversion of gold nanoparticle layers is increased as the intensity of surface plasmon resonance increases.

Keywords: Plasmonic resonance; Nano particles; Gold nanocrystals; Nanocubes

Introduction

There are several approaches to identify far field optical detection of individual metal nano particles. It would be based on the generation of new wavelength by particles either in a linear photo luminescence process or in non linear process. Explosion of research in nanocrystals has been so dramatic that very few of the modern practitioners seem to be aware of the glorious past of colloid science. The progress has been helped in the advances of instrumentation that have helped in fully characterizing nanomaterials. Today, it is possible to prepare and study nanocrystals of metals, semiconductors and other substances by various means. Advances in both experimental and theoretical methods have led to an understanding of the properties of nanocrystals. Among various noble metal nano crystals, gold nanocrystals exhibit high chemical stability and large biological compatibility. Moreover, their Plasmon resonance wavelengths can be synthetically tuned from visible to near infrared spectral regions. In this thesis, a systematic study on the localized surface Plasmon resonances of gold nano crystals is presented, both experimentally and theoretically [1].

Absorption and scattering of gold nano particles

The refractive index sensitivity of gold nanocrystals is a key factor in their practical sensing applications. The index sensitivity was found to be generally increased as the plasmon resonance wavelength for a fixed nanocrystal shape becomes longer and as the curvature of the nano crystals gets larger Gold nano particles absorb and scatter light with extraordinary efficiency [2]. The refractive index change-based plasmonic sensing with noble metal nanocrystals has been demonstrated in a number of studies. The refractive index sensitivity and merit of noble metal nanocrystals are two key parameters for this type of plasmonic sensing. It has low refractive index in the visible region but high absorption index was observed when passes through gold will appear greenish-blue because gold reflect (570-580 nm) Orange (585-620 nm) red light (630-740 nm) [3] (Figure 1a).

Result and Discussion

A comparison between the Ag and Au nanocubes was done and the particle sizes and dipolar plasmon resonances in a similar spectral region shows that the index sensitivity of the Ag nanocubes is about twice that of the Au nanocubes. The effect of the metal on the index sensitivity is further confirmed by coating an Ag shell around Au nanorods, where the index sensitivity of the Au-Ag core-shell nanobars is determined to be larger than that of the uncoated Au

nanorods that have a longitudinal dipolar plasmon wavelength close to that of the core-shell nanobars [4]. The experimentally observed overall trend in the index sensitivity is also in agreement with that revealed by electrodynamic calculations. Their strong interaction with light occurs because the conduction electrons on the metal surface undergo collective oscillations when they are excited by light at specific wavelength.

At a specific wavelength (frequency) of light, collective oscillation of electrons on the gold nanoparticle surface cause a phenomenon called surface plasmon resonance resulting in strong extinction of light. The particular wavelength, or frequency, of light where this occurs is strongly dependant on the gold nanoparticle size, shape. Noble metal nano crystals have attracted much interest due to their rich optical properties, which arise from the localized surface Plasmon resonances, the collective oscillations of free electrons confined on the nanoscale (Table 1).

The study demonstrates that the systematic studies on the dependence of the index sensitivity on the shapes and sizes of gold nanocrystals that is varying plasmon resonance wavelengths. The study further demonstrates that the dependence of the index sensitivity on

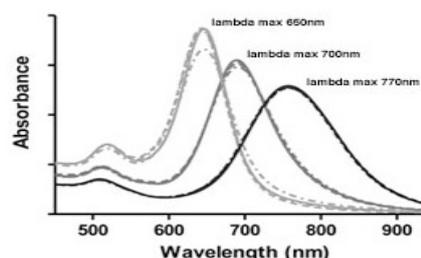


Figure 1a: Absorption versus wavelength.

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| S.no | Wavelength | Refractive index |
|------|------------|------------------|
| 1 | 0.1 | 1.2 |
| 2 | 0.2 | 1.427 |
| 3 | 0.3 | 1.8 |
| 4 | 0.4 | 1.658 |
| 5. | 0.5 | 0.855 |
| 6. | 0.6 | 0.24874 |
| 7. | 0.7 | 0.16111 |
| 8 | 0.8 | 0.1808 |
| 9. | 0.9 | 0.2155 |
| 10. | 1 | 0.25702 |

Table 1: Shows value of Refractive index.

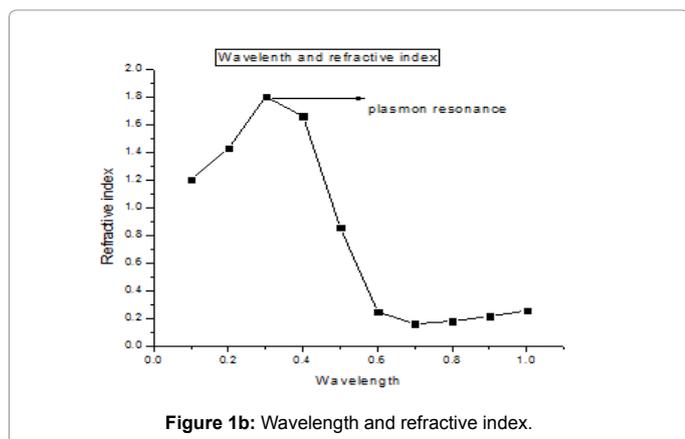


Figure 1b: Wavelength and refractive index.

the different shapes of gold nanocrystals have the same longitudinal plasmon resonance wavelength. The refractive index sensitivities have been found vary with the nanocrystal shape [5]. The study was performed on these nanocrystals to reveal the origin of this dependence. A linear relationship was found between the index sensitivity and the product of the electric polarizability with the curvature (Figure 1b).

Assembly of noble metal nanocrystals gives rise to extraordinary plasmonic properties that are distinct from those of isolated ones. We have prepared clusters that are composed of two-dimensionally-ordered gold nanocubes on flat substrates and investigated their plasmonic properties [6]. It was found that the plasmon resonances of the nanocube clusters are highly dependent on both the number and ordering of the nanocubes in the clusters. Finite-difference time-domain calculations reveal that the rich plasmon modes in the clusters originate from the interparticle couplings in the cluster and the couplings between the entire clusters and the substrate.

It was further investigated the coupling between gold nanocrystals and substrates with different dielectric properties, including insulating, semiconducting, and metallic ones. It was found that the substrates play an important role in both the scattering patterns and scattering spectra of the supported gold nanocrystals. Specifically, Fano-type resonances can be observed for large nanocrystals sitting on silicon substrates that have a large dielectric constant.

Photothermal conversion of gold nanocrystals can be applied in the areas of photothermal polymerization, photothermal imaging, drug release from capsules, and photothermal therapy. This oscillation is known as surface Plasmon resonance and it causes the absorption and scattering intensities of gold nano particles. Gold nano particles absorption and scattering properties will be changed by controlling the

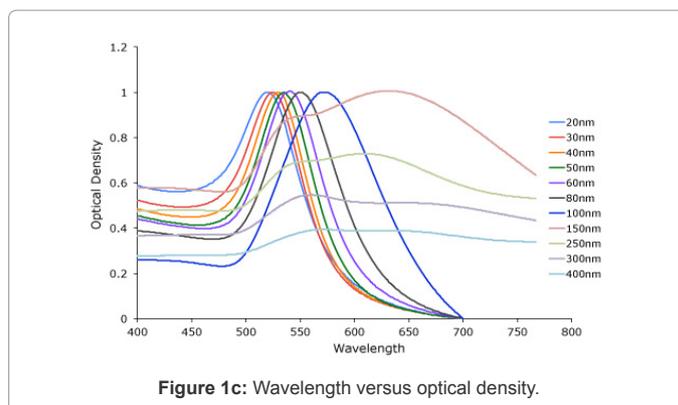


Figure 1c: Wavelength versus optical density.

size of the particle, shape and local refractive index near the particle surface. The optical properties of gold nano particles are highly depend on the nano particle [7] (Figure 1c).

A major determinant of the optical properties of gold nano particles is their shape. By synthesizing gold nano particles of different shapes, the surface plasmon resonance can easily be tuned to give absorption maxima from around 500 nm into the near-infrared part of the spectrum. Particles with sizes above 100 nm have broader peaks spanning into the 600 nm range due to the presence of both transversal and longitudinal surface plasmon resonances. In comparison, gold nano particles with diameters below 2 nm do not exhibit surface plasmon resonance [8].

Conclusion

The wavelength to which the plasmon responds is a function of the size and spacing of the particles. These fascinating properties bring about a variety of applications, including plasmonic sensing, plasmonic wave guiding, surface-enhanced Raman scattering, Plasmon enhanced fluorescence, photothermal cancer therapy, and plasmonic-enhanced energy harvesting. The scattering and absorbance cross-sections describe the intensity of a given frequency to be scattered or absorbed. Many fabrication processes exist for fabricating such nano particles, depending on the desired size and geometry. Gold nanoparticles have been extensively used for applications both in biology (e.g. bio-imaging) and technology (e.g. photonics) due their unique optical properties. When fabricating plasmonic devices, such as waveguides, optical switches, plasmonic sensors, and plasmon-enhanced solar cells. The interactions between gold nano crystals and the substrates can strongly modify the plasmonic responses of the nano crystals and therefore need to be taken into account when designing of various plasmonic devices.

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