LSPR Tunable Light Enhancement of Carbon@Gold Nanoparticles

Amit Bansal, Jagmeet Singh Sekhon, SS Verma

Department of Physics, Sant Longowal Institute of Engineering & Technology, Longowal-148106, District-Sangrur, Punjab (India)
Email: ssverma@fastmail.fm

Abstract

The photon absorption characteristics of carbon (as graphite or graphene) nanoparticles/nanosheets play a great role in the generation of charge carries, their transport, separation, and attachment in many light manipulating devices. Gold nanoparticles have also been utilized for centuries by artists due to their vibrant and unique optical-electronics properties in high technology applications. Recently, gold nanoparticles are advocated as additional supplements to be sandwiched or to be doped in the graphite/graphene sheets in order to make use of their local surface plasmon resonance (LSPR) properties to enhance the absorption characteristics of the system. However, present study, looks for gold-graphite coated nanoparticles towards the light absorption enhancement as a function of nanoparticles size. It is found that absorbance (a.u.) of graphite nanoparticles can be improved to a large extent along with the reduced scattering in case of graphite@gold nanoparticles (spherical) as compared to gold@graphite nanoparticles. These findings clearly indicate the importance of gold LSPR characteristics in the enhancement of light absorption and its tunability.

Keywords coated nanoparticles, absorbance, LSPR, graphene, graphite

1. Introduction

Recently, a series of carbon materials represented by carbon (graphite/grapheme) nanotube have attracted a good deal of public attention. In this trend, low dimensional graphite family with nanostructure is of great interest in various applications such as energy storage devices [1-2]. Graphene and metal nanoparticle composites possess properties which are attractive for sensing, photocatalysis, and photo-energy conversion. Preparation of graphene-Au (G-Au) nanohybrids along with other metals has been reported in literature. Recently, gold nanoparticles are advocated in the literature as good absorbers as well as additional supplements to be sandwiched or to be doped in the graphite/graphene sheets to make use of their local surface plasmon resonance (LSPR) properties to enhance the absorption characteristics of the system [3,4].

Present study looks for gold-graphite coated nanoparticles towards the light absorption enhancement as a function of nanoparticles size. It is found that absorbance can be improved to a large extent as compared to graphite nanoparticles along with the reduced scattering in case of graphite@gold nanoparticles (spherical). Whereas gold@graphite coated nanoparticles do not show much improvement on the light absorption/scattering characteristics as compared to graphite nanoparticles at lower size of gold in the core. The thickness of the coated Au shell was varied from 10-30 nm, with core of graphite from 30-120 nm and vice-versa also which is very desirable to provide an optical absorption enhancement effect by LSPR in the full visible range.

2. Methodology

In the present studies, the simulation code MieLab version 0.2.1 freely available to download from internet (http://www.scattport.org/index.php/programs-enu/mie-type-codes-menu/391-mielab) (copyright Ovidio Peña-Rodríguez, ovido@users.sourceforge.net) was used. MieLab is a free computational package for simulating the scattering of electromagnetic radiation by multilayered spheres or an ensemble of particles with normal size distribution and details on most important aspects of the scattering algorithm implemented in MieLab are given in [5].

3. Result and Discussion

The size dependent absorbance of graphite nanoparticles has been shown in figure 1. For size < 30 nm, it is almost less than 1 and lies in a low wavelength regime. As with increase in size of nanoparticles, absorbance though increases above 1 a.u. but only in low wavelength region but with further increase in size above 60 nm, the sharp decrease in absorbance has been found and it is maximum (~ 1.6 a.u.) for 110-120 nm size in the wavelength range of 300-600 nm. However, in the higher wavelength region the absorbance decreases fast. The broadening of wavelength region though can be achieved with even larger nanoparticles size but then scattering will dominate the absorbance.

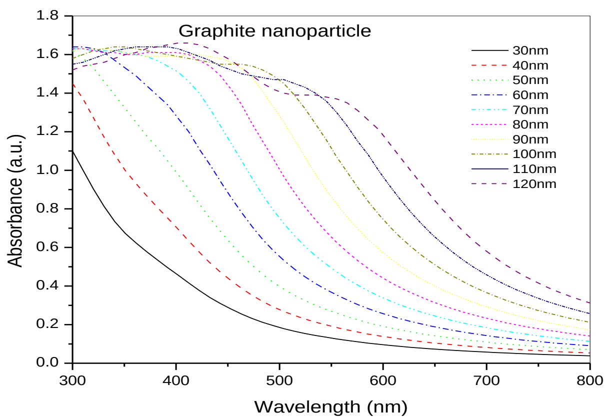

FIGURE 1. Absorbance with wavelength as a function of size of graphite nanoparticles

For small (~30 nm) monodisperse gold nanoparticles the surface plasmon resonance phenomena causes an absorption of light in the portion of the spectrum (~500 nm) with an LSPR around 500 nm while light (> 500 nm) is reflected. As particle size increases, absorbance increases and the wavelength of surface plasmon resonance related absorption shifts to longer wavelengths. Red light is then absorbed, and blue light is reflected as shown in figure 2. As particle size continues to increase towards the bulk limit, surface plasmon resonance wavelengths move into the IR portion of the spectrum and most visible wavelengths are reflected. Thus, gold nanoparticles with tunable absorbance characteristics as a function of their size can be used as a controlling tool to enhance absorption characteristics of carbon nanoparticles.

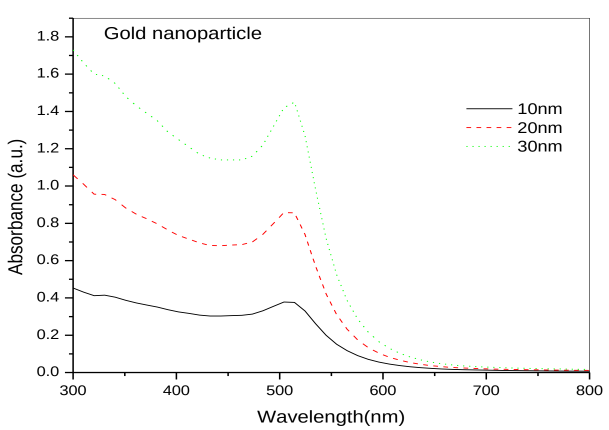

FIGURE 2. Absorbance with wavelength as a function of size of gold nanoparticles

Results from Figure 1 and 2 motivated to look for a combination of graphite and gold in terms of their coated nanoparticle to enhance absorbance characteristics of graphite tunable with LSPR properties of gold nanoparticles. It is clear from the Figure 3 that for almost every core size (30-120 nm) of graphite nanoparticle coated with gold shell of 10 nm absorbance is always higher than 1 a.u. within a large wavelength spectrum (300-650 nm to 800 nm) and the maximum absorbance can be achieved from a value of 2.5 to 3.5 with the increasing size of core. Scattering remains higher with the large size of core. Absorbance and scattering trends were obtained with the shell size of gold varied from 20-30 nm. It was also found that for shell size of 20 and 30 nm, the wavelength region of maximum absorbance is limited to 550 nm and can be shifted with core size 30-120 nm. However, lower core size is better option for maximum absorbance.

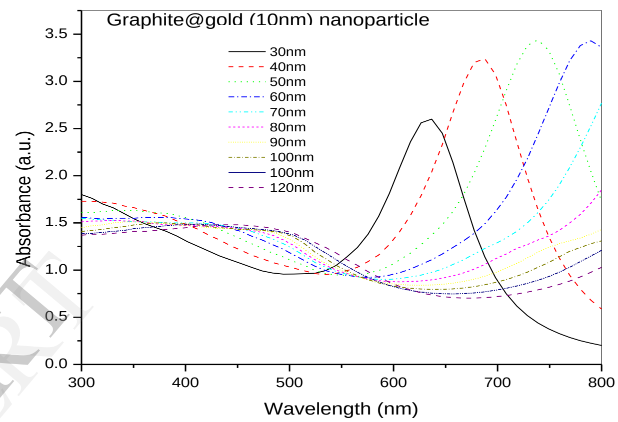

FIGURE 3. Absorbance with wavelength as a function of size of graphite@gold nanoparticles

The absorption and scattering characteristics of gold@grpahite nanoparticle with core shell (gold) 10-30 nm and shell size (graphite) varied from 30-120 nm was also studied. It was found that absorbance characteristics are almost same as they were for graphite nanoparticles (Figure 1). It means at lower core size of nobel metal, its LSPR does not contribute towards the scattering characteristics tunability of the coated nanoparticles. However, with the increasing core size, LSPR becomes important and do influence the scattering/absorption characteristics indicating its dominance on the size of the shell (graphite) as absorbance is same for 30 nm to 120 nm size only with small increase in wavelength region.

The absorbance of graphite nanoparticles can be enhanced with the help of gold. The combination as graphite@gold is better as compared to gold@graphite. The size of carbon (graphite) nanoparticles for an increased absorbance in maximum wavelength region can be controlled by considering graphite@gold nanoparticles combination with a gold particle of ~10 nm as a shell.

Conclusion

The absorption characteristics of graphite coated gold nanoparticles and vice-versa are observed by using MieLab scattering tool. The gold nanoparticles are used to enhance the absorbance properties of graphite nanoparticles due to its size dependent tunable LSPR properties. It has been found that more enhancements in absorbance can be seen in case of graphite@gold nanoparticles and it can be tuned in the large region of the EM spectrum. The absorbance can be varried from 2.5 to 3.5 a.u. with increase in the core size from 30 to 120 nm of graphite nanoparticles coated with gold shell of 10 nm. The absorbance can also be tuned with the shell size of gold varied from 20-30 nm but lower core size is better option for maximum absorbance.

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