Imaging of Surface Plasmon Resonance for Nano Material of Different Shapes

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Abstract: The studies of Surface Plasmon Resonance SPR have focused on novel materials (gold and silver). In this paper, four kinds of samples have been prepared also the system of plasmonic imaging with objective lens to excite the SPR our samples. The hot spot images for our different samples proved that the blue wavelength (405nm) can be excite the SPRs better than the green wavelength (532nm) for silver samples and the green wavelength can be excite the SPRs better than the blue wavelength for gold samples, also the increasing in consternation of AgNWs due to increasing in width of Gaussian hot spot.

1. Introduction

In recent years, the most important studies of surface plasmon have focused on gold and silver nanoparticles inasmuch to the favorable dielectric properties of these metals in the visible and near-infrared (NIR) spectrum region [1]. As both the wavelength and intensity of the surface plasmon resonance (SPR), for nanoparticles of noble metals such as gold and silver that are often in the visible region of the electromagnetic spectrum, which are highly sensitive to the shape, size, organization, and insulating environment of nanoparticles [1-3]. The plasmon occurs as a result of the interaction of light with free electrons in the metal and results in extremely high local electromagnetic filed[3]. In the last decade, plasmonic has received a lot of attention and widespread This is because the light can be confined to sizes limited by nanoscale and optical partial aberration [4]. Regarding nanoscale control and temperature distribution [5], drug delivery [6, 7], cancer Photothermal therapy [8, 9], optical thermal imaging [10], And many other useful applications. SPR was studied through the use of a polymer with silver nanowire (Ag NWs) [11], the SPR was imaged and data collected about the plasmonic hotspot [12]. The performance of SPR sensors in terms of instrumentation, data processing and analysis has been developed and has reached a stable stage, due to the emergence of local surface plasmon resonance (LSPR) [13], and SPR imaging assay (SPRi) [14]. These SP (surface plasma) based optical technologies provide significantly higher sensitivity and easy extension to a highly multiplexed architecture compared to conventional SPR [15,16]. In this paper, we want to clarify the method of excitation that depends on a large numerical aperture (NA) lens and coupled charge camera(CCD) for different samples. we focusing on imaging surface plasmon resonance to study its properties.
2- Experimental part:

A- Samples preparation:

samples were prepared as:

- sample 1 is 1Dimension Ag nano layer
- sample 2 is 1Dimension Au nano layer
- sample 3 is Ag NWs + PVA \ Ag NWs70%
- sample 4 is Ag NWs + PVA \ Ag NWs80%

Method for preparing samples 1 and 2

The preparation of the substrate was done by removing the outer layer of the compact disc (CD) called the label, cleaning it with detergents and alcohol, and cutting it into small pieces with dimensions of 2cm in length and 1cm in width, then put it in an ion- Coater device. The samples were prepared in the laboratory using an ion- Coater device, where films with a nano layer of silver nano layer and films with a layer of gold nano layer are prepared. Where we obtained the silver nano layer samples in one dimension and the gold nano layer samples in one dimension, and the ion- Coater device was controlled to give a value that was the current 7MA at a time of 5 minutes for silver nano layer, and and give a value that was the current 7MA at a time of 6 minutes for gold nano layer.

Method for preparing samples 3 and 4

This samples are prepared using a glass slide, cleaned well with detergent, washed with alcohol and appropriately dried, and then covered a layer of Ag NWs +PVA on it. The PVA (Poly vinyl alcohol) is as white granules and its chemical formula (C2H4O)x, is a polymer that is highly soluble in water but does not dissolve in acids and organic solvents. These polymers are supplied by (Sigma – Aldrich). The PVA polymer was prepared in the laboratory by mixing the powdered polymer in the amount of 0.2 mg PVA with distilled water (deionized water) in a volume of 20 mL. All polymer was stirred at 50°C in a magnetic stirrer for 30 minutes to obtain best homogeneity, after which the polymer was mixed with AgNWs (silver nanowires) and the mixing ratio was 70% of AgNWs, 30% of PVA polymer and the other sample contained 80% of Ag NWs and 20 % of the PVA polymer. The mixture was then deposited on a glass slide and placed in a vacuum chamber for 24 hours to dry.

![Diagram of samples 1, 2, 3, and 4]
Figure 1: samples preparation

B-Experimental setup of the surface Plasmon resonance imaging system

The system consisting of laser (where we used two lasers, the first laser is the green laser with wavelength 532 and the second laser is a tunable blue laser with wavelength 405) And two lenses (were used, the first lens 1 with focal length $f = 15cm$ and the second lens 2 with focal length $f = 5cm$) Also, a numerical aperture with $\text{NA} = 0.45$ was used. In addition to the beam splitter with $\text{B.S} = 50:50$, with CCD camera

C- Plasmonic imaging system

As shown in Figure 2 the green laser beam with a wavelength of 532 nm is divided into two symmetric parts by the beam splitter. Then, the sample is lit by an objective lens with a numerical aperture set the light reflected from the sample is received and focused by a convex lens 2 on a camera and the sample image collected by a lens 2 is located before the CCD camera. The same applies when using a blue laser with a wavelength of 405 nm.

The purpose of the digital high aperture is Check the condition of the scattering match between the light and SPR. The propagation constant of excited SPRs on the metal surface is expressed by Eq. (1) as follows

$$K_{sp}(\omega) = \frac{\omega}{c} \sqrt{\left(\varepsilon_1(\omega)\varepsilon_2(\omega)\right) \left(\varepsilon_1(\omega) + \varepsilon_2(\omega)\right)}$$  (1)

Where $\omega$ and $c$ represent the anar frequency and the light Speed in the vacuum, And also $(\varepsilon_1)$ and $(\varepsilon_2)$ are the relative permittivities of the metal and air, respectively. And the propagation constant of light propagating in the air is given as follows

$$K_{light}(\omega) = \frac{\omega}{c} \sqrt{\varepsilon_2(\omega)}$$  (2)

In typical cases, the ratio of $k_{sp}$ to $k_{light}$ is approximately $1.05–1.10$. This is what has been applied and proven in [17].
3. Results and Discussion

The hot spot images for our different samples are shown in Figure 3,4. One can see the excited SPRs by two different wavelengths, 532nm in the Figure 3 and 405nm in Figure 4. This figure proved that the blue wavelength (405nm) can be excite the SPRs better than the green wavelength (532nm) that is because we have AgNWs and this material have a good absorption in blue range. In Figure 4 In addition, increasing of Ag NWs concentration yield to enhance the hot spots width, because the increasing of SPRs. also The change in power by controlling the power supply and the capacities used were (1.10 -1.30 -1.50 -1.60) mw, where we also note that as the amount of power increases, the intensity of the emission spectrum of plasmon increases, as shown in the table 2. We can observe the behavior of the values of the peaks; It increases when the concentration of Ag NWs in our samples increases and this occurs due to the increased dispersion of the SPRs and we also find that the highest intensity is for silver at 80% AgNWs because the absorption spectrum of particles Silver nanoparticles are highest at wavelength 450 and also by the shape we find that the distribution of the plasmon emission spectrum is regular in sample 1 and 2, and irregularly in sample 3 and 4.

And The figure 3 proved that the green wavelength (532nm) can be excite the SPRs better than the blue wavelength (405 nm) that is because we have gold nanoparticles and this material have a High absorption in green range. It is noted through the figure 3 that the emission spectrum of the plasmon is highest in the case of sample 2 as it can be observed from Table 1. And that the emission spectrum of the plasmon is in the case of sample 1 and 2 the distribution of the plasmon is regular, but in the case of sample 3 and 4, the spectrum of the plasmon is irregular due to the random distribution of the nanoparticles in the samples.
From Tables 1 and 2 we are listing hotspot properties such as hotspot width at 13.5% full density and half width at 50%. According to the value of the peak. In these tables the width of the hotspot in the X-direction is not equal to or close to the Y-direction. The logic trend less than half the stain intensities in X and Y directions can also be seen by enhancing Ag NWS concentrations. We can observe the behavior of the values of the peak, in table 2 It increases when the concentration of Ag NWs in our samples increases and this occurs due to the increased dispersion of the SPRs. And in table 1 increases when use sample 2 It increases and this occurs due to the increased dispersion of the SPRs.

**Figure 3 : hot spot for four different samples, this images for green excitation**

NA=0.45, λ=532 nm

**Table1: hotspots properties for four different samples excited by λ=532nm NA=0.45**

| Samples | Width of hotspot at X direction(μm) | Width of hotspot at Y direction(μm) | Peak value % |
|---------|-----------------------------------|-----------------------------------|--------------|
|         | 50%                               | 13.5 %                            | 50%          | 13.5 %          |
| Samples 1 | 211.1                             | 419.7                             | 220.4        | 455             | 82.2%        |
| Samples 2 | 165.7                             | 440.4                             | 169.2        | 347.1           | 100%         |
| Samples 3 | 590.6                             | 686.3                             | 376.2        | 584.7           | 80%          |
| Samples 4 | 143.1                             | 457.2                             | 352.2        | 699.1           | 88.6 %       |

| Power (mw) | Samples 1 | Samples 2 | Samples 3 | Samples 4 |
|------------|-----------|-----------|-----------|-----------|
Figure 4: Hot spot for four different concentrations (from top to bottom) samples this images for blue excitation $\lambda = 405\text{nm}$.
Table 2: hotspots properties for four different samples excited by $\lambda = 405$nm

| Samples | Width of hotspot at X direction(μm) | Width of hotspot at Y direction(μm) | peak value % |
|---------|-------------------------------------|-------------------------------------|--------------|
| Samples 1 | A1 83.4 | 614.7 | 481.8 | 571.5 | 63% |
|          | A2 171.1 | 492.7 | 103.6 | 160.4 | 86.1% |
|          | A3 653.4 | 1030.7 | 137.7 | 203.9 | 87.7% |
|          | A4 738.7 | 1340.8 | 147.7 | 278.3 | 89.6% |
| Samples 2 | B1 165.5 | 291.7 | 341.1 | 106.4 | 34% |
|          | B2 1316.7 | 2673.3 | 109.9 | 738.5 | 47.4% |
|          | B3 159.7 | 388 | 147.3 | 352 | 85.4% |
|          | B4 438.4 | 875.8 | 1341.1 | 1817.2 | 87.7% |
| Samples 3 | C1 597.6 | 792.5 | 78.8 | 239.2 | 56.2% |
|          | C2 879.2 | 1323.3 | 147.4 | 463.8 | 77.1% |
|          | C3 558.4 | 1024.7 | 144.2 | 225.7 | 87.8% |
|          | C4 658.4 | 1293.8 | 153.7 | 290.7 | 90.4% |
| Samples 4 | D1 95.8 | 174.9 | 91.4 | 154.9 | 70.6% |
|          | D2 305.4 | 646 | 171.2 | 247.7 | 81.7% |
|          | D3 601 | 1095.8 | 152.3 | 271.9 | 89.5% |
|          | D4 1101.7 | 1591.1 | 184 | 341.3 | 100% |

Conclusion

In summary, we used two lasers on different samples in terms of composition, the green laser with wavelength of 532 nm and the blue laser with wavelength 402nm, and the two lasers were shed on four different samples, and the results we obtained proved that the best excitation of SPRs for gold sample is by green laser, and the best excitation SPRs Silver samples are made by blue laser. Moreover, we used two concentrations of AgNWs. It should be noted that the higher concentration of AgNWs gives a higher reflection of the summit, as well as the hot spot width is greater. Also, this increase is affected by the increase in the power of the laser using the blue tunable laser and this increase in power interacts with the increase in concentration. Also The effect of the shape of the nano materials can be observed since in samples land 2 which are 1D we notice that the distribution of the surface plasmon resonance spectrum is regular and in the case of samples 3 and 4 the distribution of the surface plasmon resonance spectrum is irregular.

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