
Silver Nanoparticle Research for Plasmonic Solar Cell

[1]Satyarth Tiwari, [2]Dr. Sanjay Kumar Sharma

Ph.D. Scholar, Department of Electronics and Communication Engineering, UIT-RGPV, Bhopal, India[1]

Head of Dept., Department of Electronics and Communication Engineering, UIT-RGPV, Bhopal, India[2]

Abstract: Environmental concerns and limitation of fossil fuels have motivated the researchers to explore green energy as the solution to the energy crisis in the modern era. Solar energy is the most widely available and potential source of green energy. Solar cells or photovoltaic cells are semiconductor transducers that convert the solar energy into useful electrical energy. Inside the solar cells, absorption of photon energy leads to electron-hole pair generation then the generated charge carriers contribute as the useful photocurrent by the solar cell. We demonstrate that how shape and size of the silver nanoparticle changes by changing their precursor concentration. We demonstrate how these findings will promise in the design of ultrathin film plasmonicsolar cell.

Keywords: *Nanoparticle, Plasmonic, Solar Cell*

I. Introduction

Advancements in nanofabrication techniques have created new opportunities for studying the behavior of sub wavelength photonic nano scale devices [1]. In addition to the nano fabrication techniques, the development of sophisticated analytical methods for optical simulations has pioneered many science and technology research fields, including nanophotonics. Nanophotonics is the study associated with nano scale photon generation, power transmission and detection. One very influential branch of nanophotonics is plasmonics, which deals with the study of surface plasmonpolaritons (SPP) in dielectricinterfaced nano metallic structures [2]. Surface plasmonpolaritons is a surface wave produced by the coupling between an electromagnetic wave of suitable frequency and collective electronic oscillations at metal-dielectric interface [3]. The metal nanostructures on a dielectric boundary interacts with the incoming light to produce localized surface plasmons (LSP) which scatter the light into guided modes of the substrate [4]. The propagating modes generated by the excitation of SPPs can be utilized in integrated plasmonics for on-chip communications whereas the local field enhancement due to LSP can be used in areas such as solar cells. While plasmonics is a future technology, in scientific and technological applications it may be of great importance, there are still several challenges to be addressed. Metals do not behave as perfect electrical conductors in optical frequency range they are rather lossy media of propagation. At optical frequencies metals exhibit complex permittivity which results as significant propagation losses. This is a major restriction that prevents plasmonics from becoming a viable technology on the practical front [5]. To curb such high frequency losses associated with metals, noble metals such as Gold (Au) and Silver (Ag) are preferred mostly [5]. Many approaches have been proposed to mitigate these losses, such as the incorporation of gain materials into the dielectric medium or uses ofthin metal films [6] etc.

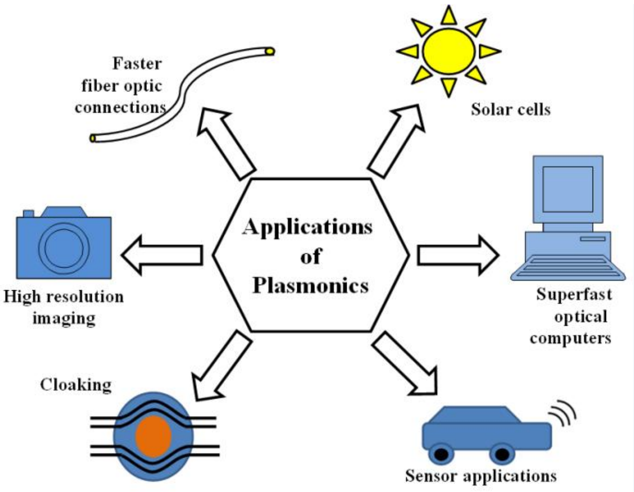

Fig. 1: Applications of plasmonics

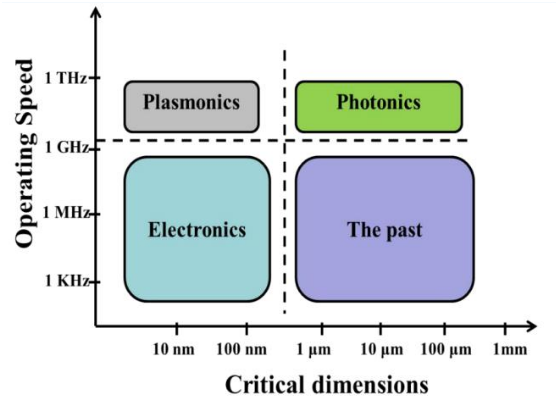

Fig.2: Critical dimensions vs. operating speed

Such loss reduction strategies, however, include some other problems such as system complexity or an increase in device size. Plasmonics is the study based on the flow of plasmons at metal-dielectric boundary. It can be seen as a merger of two technologies based on electronics and dielectrics [6]. It bridges the gap between the two by using the advantages of either side. Fig. 2 displays current technologies in comparison with plasmonics on critical part measurements vs. their speed graph [7]. In addition to their nano metric dimensions plasmonic structures offer high data rates with larger bandwidth. Plasmonics works as an interface between electronics and photonics.

Plasmonics has enormous potential for many chip scale applications due to its advanced features. It has been named as „the next chip scale technology" [8]. Some of the important applications of plasmonics are shown in Fig. 1. However, in this thesis we are focused on solar cell applications as it is a promising way to fulfill the present day energy requirement.

II. Plasmonic Solar Cell

Plasmonic solar cell is a photovoltaic device which converts the light into electricity by using the surface Plasmon. Usually it is uses in thin film solar cell because they don't absorb much light as of current solar cell.Plasmon is the quanta of plasma oscillation. Plasmon is the collective oscillation of free electron density, some particular wavelength of light scatters through these oscillation according to the mye theory of scattering [9].

Our objective is to find the ratios of the precursor of the silver nanoparticle at which shape of the silver nanoparticle have higher surface to volume ratio which is more beneficial for light trapping in photovoltaic material in comparison to any other shape.

When using the ultra-thin film in solar cell then our requirement is to increase the electron hole pair generation. For increasing the electron hole pair generation we trap the light in the ultra-thin film photovoltaic film by using the metal nanoparticle. These metal nanoparticles should have more valence shell electron for ex silver. When light interacts with the surface atom of these metal nanoparticles then it generates the surface Plasmon. These plasmonic wave of metal nanoparticle interacts with the light then it scatters the particular set of wavelength of light to the photovoltaic material after reflecting the light from the photovoltaic material it again interacts with metal nanoparticle then it again scatters to the photovoltaic material . In this way we can confine the light in the photovoltaic material. We can confine more light when number of surface Plasmon is more that can be possible when the surface to volume ratio of the silver nanoparticle is more .Here we have prepared three sample of different concentration of precursor showing different shape of the silver nanoparticle.

III. Method

3.1 Seed Mediated Growth

This method is used to form the silver metal nanoparticle. In this method first we creates the seed of silver by using the agno3 and strong reducing agent nabh4 and soft reducing agent ascorbic acid then we allow further growth over this seed . This seed decides the shape of the particle. Size of the seed depends on the concentration of reducing agent.

3.2 Precursor

$AgNO_3$, $NaBH_4$, ascorbic acid

3.3 Material used

Magnetic stirrer, weaker, funnel, distil water.

3.4 Synthesis process of silver metal nanoparticle surrounding by the air medium

Here we are going to synthesize the three sample of silver metal nanoparticle by changing the concentration, of the reducing agent , here surrounding medium is air.

- First sample: In this sample we will take $NaBH_4$ 5 times of $AgNO_3$
- Second sample: In this sample we will take $NaBH_4$ 10 times of $AgNO_3$
- Third sample: In this sample we will take $NaBH_4$ 15 times of $AgNO_3$

For making the sample 1 first we will form the seed by adding the $AgNO_3$ (5ml) in the solution of $NaBH_4$ (wt .189 gm in 300ml) by the help of burette. .This $NaBH_4$ is 5 times of the weight of the agno3 .after the formation of seed we will add ascorbic acid for stabilizing the particle .now again we will add again $AgNO_3$ till brown colour obtain . now we obtain the colloidal solution of silver nano particle sample1.

For making the silver nanoparticle we will make, the 50ml stock solution of $AgNO_3$ of molarity 3m mole . For making the sample 1 first we will form the seed by adding the $AgNO_3$(5ml) in the solution of $NaBH_4$ (molarity 10 m mole, wt =.378325 gm, 300 ml) by the help of beurrate. This $NaBH_4$ is 10 times of the weight of the agno3.after the formation of seed we will add ascorbic acid (1gm in 50ml) now after that we add again $AgNO_3$ till we obtain the brown colour. We stop the reaction when we obtain the brown colour. Now we obtain the silver nanoparticle sample 2.

For making the sample 3 first we will form the seed by adding the $AgNO_3$ (5ml) in the solution of $NaBH_4$ (molarity = 13.5 mmole, wt.= .51073875 which 15 times of the silver nano particle) by the help of buratte. This $NaBH_4$ is 15 times of the weight of the $AgNO_3$. after the formation of seed we will add ascorbic acid for stabilizing the particle . Now again we will add AgNO3 till brown colour obtain. Now we obtain the colloidal solution , of silver nano particle sample3.

IV. Characterization

Scanning electron microscopy

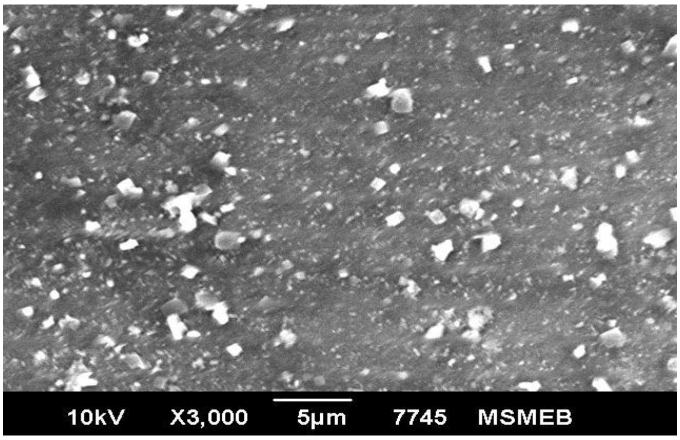

Fig. 3: Sample 1

Here we obtain the cubic shape of the silver nanoparticle in sample1 (AgNO3,NaBH4(1:5))

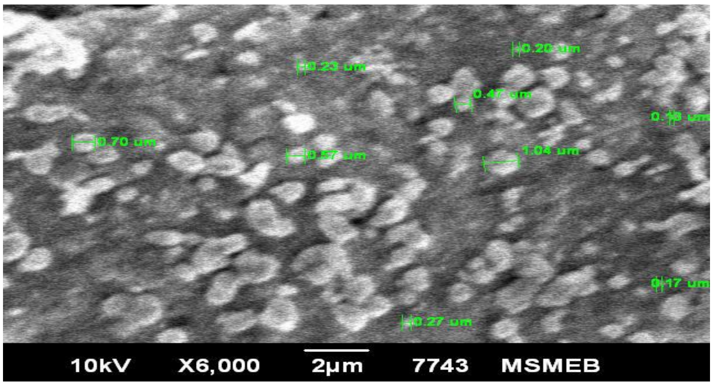

Fig. 4: Sample 2

Here we obtain the irregular spherical shape of the silver nanoparticle in sample 2(AgNO3,NaBH4(1:10))

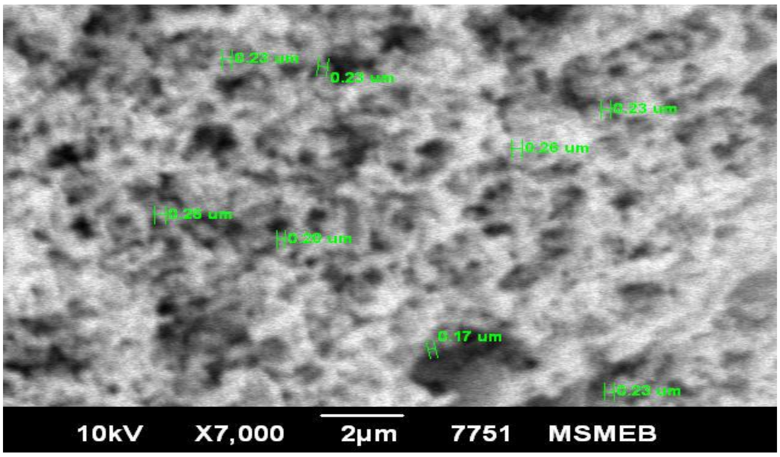

Fig. 5: Sample 3

Here we obtain the mesh nanowire of the silver nanoparticle in sample 3 (AgNO3,NaBH4(1:15))

- By performing the SEM we obtain the different shapes of silver nanoparticle.
- We found that surface to volume ratio of the particle is decreasing by increasing the amount of reducing agent.

4.1 Raman Analysis Of Silver Nanoparticle

Inraman spectroscopy we analyse the raman shift due to weak vibrational modes. And in raman spectroscopy of the Sample 2 found raman shift at 1000nm and in sample 3 raman shift obtain at the wavelength of 1500nm.

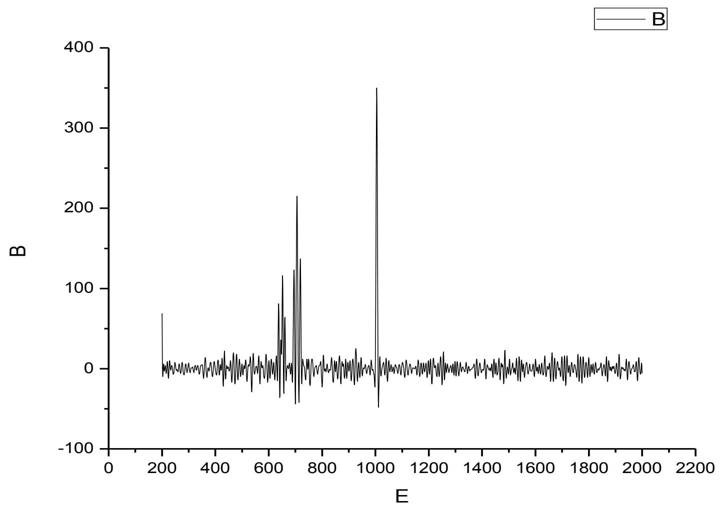

Fig. 6: Raman analysis of sample 2

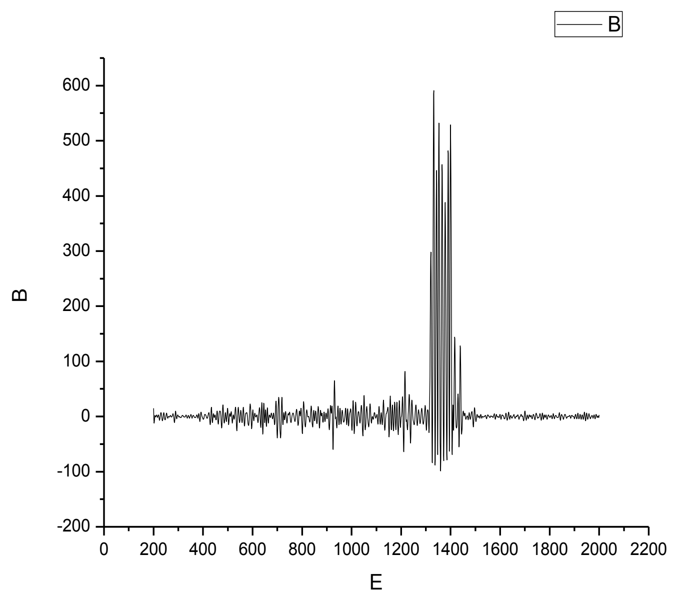

Fig. 7: Raman analysis of sample 3

When the incident light in the experiment strikes the surface, localized surface plasmons are excited. The field enhancement is greatest when the plasmon frequency, ω_p, is in resonance with the radiation. In order for scattering to occur, the plasmon oscillations must be perpendicular to the surface; if they are in-plane with the surface, no scattering will occur.

So by seeing the spectra we can see in sample 2plasmonic wave have the wavelength of 1000nm and in sample 3 have the wavelength of 1400nm .By seeing we can say by increasing the ratio of the AgNO3 to the NaBH4 plasmonic wavelength will go increase. So we can tune the trapping wavelength according to the excitation wavelength of the photovoltaic material.

4.2 Photoluminiscense analysis

Photoluminescence (abbreviated as PL) describes the phenomenon of light emission from any form of matter after the absorption of photons (electromagnetic radiation). It is one of many forms of luminescence (light emission) and is initiated by photoexcitation (excitation by photons).

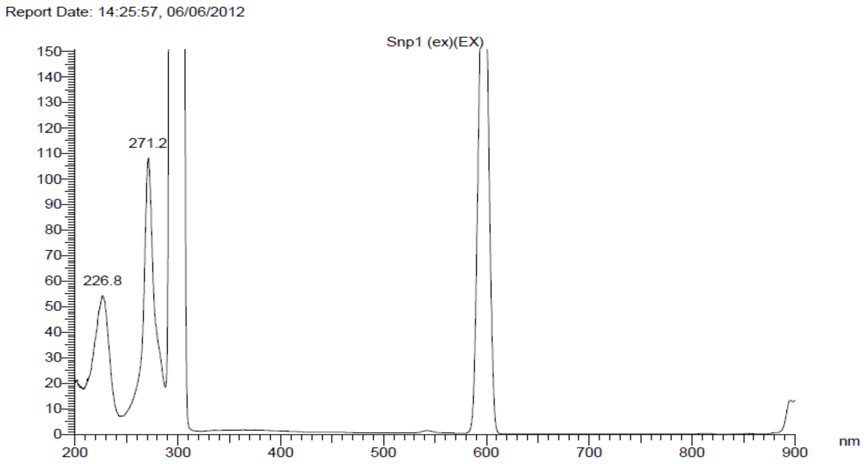

Fig. 8: Excitation of silvernanoparticle sample 1at the wavelength of 271 nm

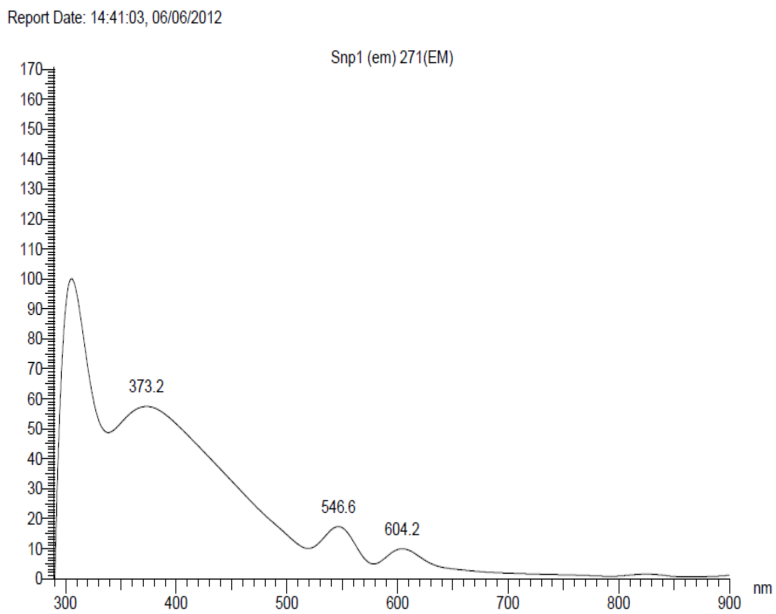

Fig. 9: Emission of snp1 at the wavelength of 373nm

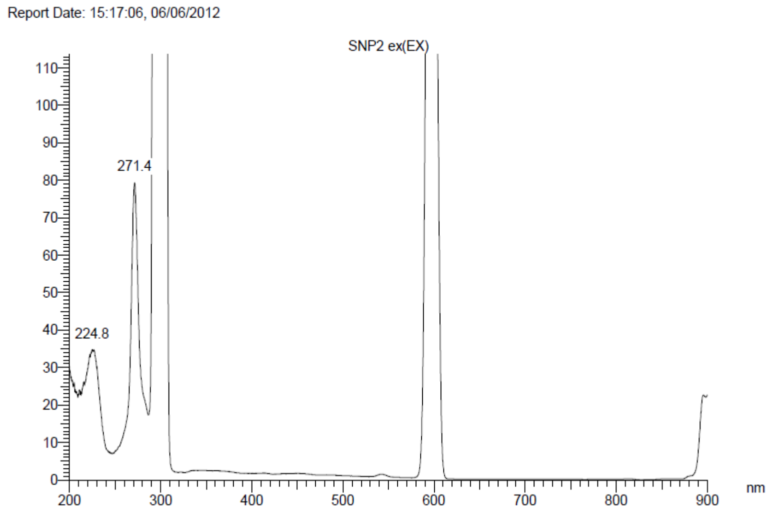

Fig. 10: Excitation of snp2 at the wavelength of 271nm

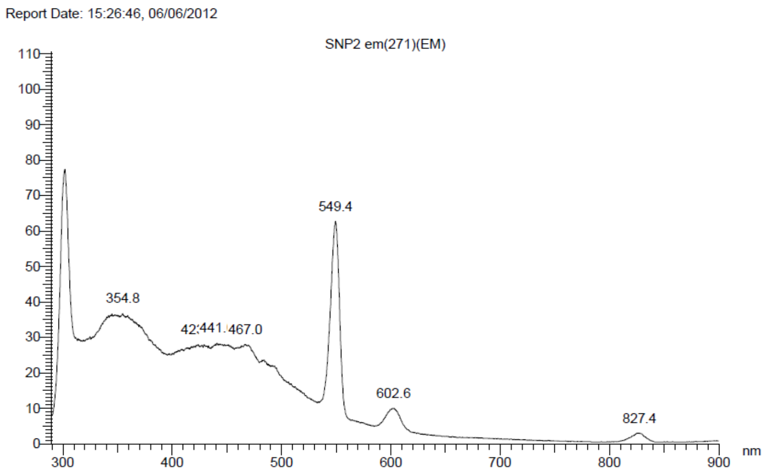

Fig. 11: Emission of snp2 at the wavelength of 354nm

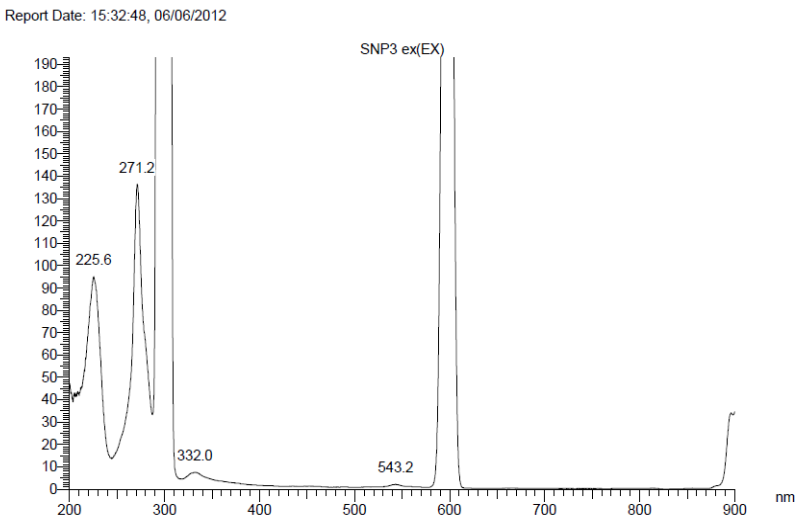

Fig. 12: Excitation of silvernanoparticle sample 3 at the wavelength of 271 nm

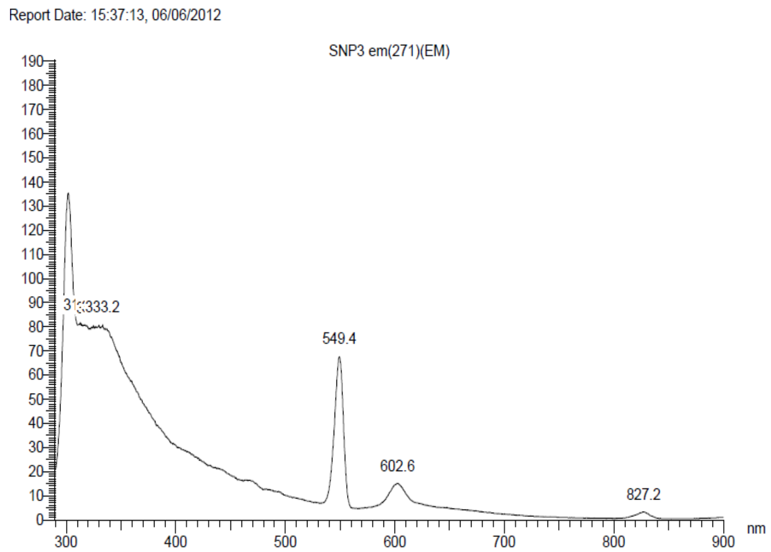

Fig. 13: Emission of snp3 at the wavelength of 333nm

V. Conclusion

Here we found different shape at different ratios of AgNO3 and reducing agent NaBH4. Also we found that surface to volume ratio of the particle is decreasing by increasing the amount of reducing agent .In all shapes cubic shape have high surface to volume ratio that's why we can use cubic shape particle for plasmonic solar cell. This cubic shape we obtained at the 5 times concentration of reducing agent NaBh4 in comparison of Agno3. After then we can coat these silver nanoparticle over the photovoltaic material on both side & these particle will capture the light in the photovoltaic material & we can achieve high efficiency. Also we found by PL analysis that by increasing the amount of reducing agent the emission wavelength of the silvernanoparticle will go decrease and by raman spectra we observed that we can increase the plasmonic wavelength by decreasing the AGNO3 to the NAbh4 ratio so we can tune emission wavelength of the silver nanoparticle according to the excitation wavelength of the photovoltaic material by changing the precursor concentration of the silver nanoparticle.

References

[1] AimalDaud Khan, Javed Iqbal, Salim urRehman, "Polarization-sensitive perfect plasmonic absorber for thin-film solar cell application", Applied Physics A, 124:610, pp 1-9, August 2018.DOI: 10.1007/s00339-018-2033-3.

[2] A. H. Fallahpour et.al., "3-D Simulation and Optimization of Organic Solar Cell With Periodic Back Contact Grating Electrode", IEEE Journal of Photovoltaics, Vol. 5, No. 2, pp. 591-596, 2015.

[3] Matthew B. Wincott et.al., "Optimized Rear-Electrode Grating Structures in Organic Solar Cells", IEEE Journal of Photovoltaics, Vol. 5, No. 4, pp. 1113-1117, 2015.

[4] Qi Xu et.al., "Enhanced Broadband Light Trapping in c-Si Solar Cells Using NanosphereEmbedded Metallic Grating Structure", IEEE Journal of Photovoltaics, Vol. 6, No. 1, pp. 61- 67, 2016.

[5] Abhishek Pahuja, Manoj. S. Parihar and V. Dinesh Kumar, "Investigation of Euler Spiral Nanoantenna and its Application in Absorption Enhancement of Thin Film Solar cell", Optical and Quantum Electronics (Springer), 50, 401, pp. 1-11, October 2018.

[6] Abhishek Pahuja, Manoj S. Parihar, Dinesh Kumar V, "Performance enhancement of thin film solar cell based on extra ordinary transmission", Superlattices and Microstructure (Elsevier), 1, pp. 81–87, February 2018.

[7] Abhishek Pahuja, Manoj Singh Parihar and Dinesh Kumar V, "Performance Enhancement of Thin Film Solar Cell Using Two Dimensional Plasmonic Grating in Rear Electrode", IEEE Transactions on Nanotechnology, vol. 18, pp. 626-634, July 2019.

[8] MohamadrezaNajiminaini, et.al.," Optical resonance transmission properties of nano-hole arrays in a gold film: effect of adhesion layer", Opt. Exp., vol.19, pp. 26186- 26197, 2011.

[9] Cui Y., He S., "Enhancing extraordinary transmission of light through a metallic nanoslit with a naocavity antenna", Opt Lett., vol. 34(1), pp. 16–18, 2009.

[10] ZhihaoJia,Qiang Cheng, Jinlin Song, Mengting Si and Zixue Luo, "Optical properties of a grating-nanorod assembly structure for solar cells", Optics Communications, vol. 376, pp.14–20, 2016.

[11] Michael Smeets, Vladimir Smirnov, Matthias Meier, KarstenBittkau, ReinhardCarius, Uwe Rau, and Ulrich W. Paetzold, "On the geometry of plasmonic reflection grating back contacts for light trapping in prototype amorphous silicon thin film solar cells", Journal of Photonics for Energy, 5, 057004(1-11), 2015.

[12] K. R. Catchpole and A. Polman, "Plasmonic solar cells," Opt. Express 16, 21793-21800, 2008.

[13] Heath, J. R.; Knobler, C. M.; Leff, D. V. *J. Phys. Chem. B*, **101**, 189-197, 1997.

[14] Timothy H. Gfroerer, john-wiley and sons ltd chichester, pp 9209-9231, 2000.

[15] M.A. Foad, M. Watt, A.P. Smart, C.M. Sotomayor Torres, C.D.W. Wilkinson, W. Kuhn, H.P. Wagner, S. Bauer, H. Leiderer, W. Gebhardt, "High-resolution Dry Etching of Zinc Telluride: Characterization of Etched Surfaces by X-ray Photoelectron Spectroscopy, Photoluminescence and Raman Scattering", *Semicond. Sci. Technol.*, **6**, A115–A122, 1991.

[16] Tom RT, Nair AS, Singh N, Aslam M, Nagendra CL, Philip R, Vijayamohanan K, Pradeep T., Freely dispersible Au@TiO2, Au@ZrO2, Ag@TiO2, and Ag@ZrO2 core– shell nanoparticles: one step synthesis, characterization,spectroscopy, and optical limiting, 2003.