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Application of silver nanoparticles: Synthesis, Characterization, and Evaluation

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Abstract: Nanoparticles are of great scientific interest as they are effectively a bridge between bulk materials and atomic or molecular structures. Silver is currently used to control bacterial growth in a variety of applications, including dental work and burn wounds. Particles were synthesized by the chemical reduction method. In this work, we studied the synthesis and characterization of Silver nanospheres, nanotriangle, nanorods in solution phase. Silver nanocrystals have received considerable attention in recent years owing to their unique properties and applications. For example, optical properties known as localized surface plasmon resonance (LSPR), silver nanocrystals posses a wide range of applications for use as optical labels, substrates for surface-enhanced Raman scattering (SERS) and in biosening. The Silver nanoparticles formed was shown to be a good surface-enhanced Raman scattering (SERS) substrate as it gave an enormous Raman enhancement for Rhodamine 6G (R6G).

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1.Introduction

Nanoparticles have recently become important because of their unique optical, catalytic and electronic properties which are strongly dependent on their size and shape. This makes them attractive for many applications such as optical and electronic devices, surface enhanced Raman scattering (SERS) active substrates and in biosensors. Here we report chemical reduction methods for preparation of different silver morphology like nanosphere, nanotriangles and nanorods. In order to investigate the relationship between size, stability and color of silver colloids, we obtained silver nanoparticles in aqueous solutions using different stabilizing agents. The formation of Silver nanotriangle was obtained by the reduction of silver ion to silver from silver nitrate by a sodium borohydride as a reducing agent. The shape formation was controlled by tri-sodium citrate dihydrate and hydrogen peroxide. The most popular theory at the early stages of research was the “face-blocking theory”, in which a capping agent citrate selectively bind to {111} facets and thus slows the growth rate of that facet relative to the others and H_2O_2 act as a etching agent. UV-VIS spectrum for silver colloids contains a strong plasmon band near 400 nm, which confirms silver ions reduction to Ag° in the aqueous phase. Silver nanospheres average size obtained in the range of 10 nm. The formation of Silver nanotriangles was observed by colour change when sodium borohydride was injected into solution which contained silver nitrate, tri sodium citrate, and hydrogen peroxide. The solution colour change to light yellow as soon as we put sodium borohydrate. After 2-3 minutes the colour change in blue colour after that remain same. In case of silver nanodisc the shape formation was controlled by trisodium citrate dehydrate, poly vinyl pyrrolidone(PVP) and hydrogen peroxide(H_2O_2). The formation of Silver nanodiscs was observed by colour change. The solution colour change to yellow as soon as we put sodium borohydrate. After 15-20 minutes the colour change in dark blue colour. Silver nanorods have been synthesized by seed-mediated growth utilize 10nm silver nanospheres and reduction of silver precursor with a weak reducing agent (ascorbic acid) along with a directing surfactant. Structure, morphology, composition and optical response were investigated through X-ray diffraction analysis, transmission electron microscopy, DLS and by UV-Vis. XRD demonstrate that silver nanorods are crystallized in face centered cubic symmetry. Absorbance spectra confirm the nanorods formation with two SPR bands, one at lower wavelength side and another at higher wavelength side.

In this work we have demonstrated two application of silver one in surface enhancement raman spectroscopy substrate and another one in glucose sensing. For SERS measurement of Rhodamine6G (R6G) the silver nanocrystal with R6G in certain amount is taken in capiliary and then SERS spectrum of Rhodamine 6G was recorded. For glucose sensing silver nanoparticles in solution phase add with *Poly Vinyl Alcohol (PVA) and then solution was transferred to a syringe and* electrospinning was carried out and making fiber and after that interact selectively with glucose, giving rise to shift in the LSPR.

2. Nucleation

Nucleation represents the very first stage of any crystallization process. Nucleation is the process whereby nuclei (seeds) act as templates for crystal growth. Homogeneous nucleation occurs when nuclei form uniformly throughout the parent phase.

Mechanism of Nucleation

In a synthesis of metal nanocrystals, a precursor compound is either decomposed or reduced to generate zero-valent atoms the building blocks of a metal nanocrystal. Once the concentration of atoms reaches a point of supersaturation, the atoms start to aggregate into small clusters (i.e.nuclei) by self or homogeneous nucleation.

The process of homogeneous nucleation can be considered thermodynamically. the total free energy of a nanoparticle defined as the sum of the surface free energy and the bulk free energy. For a spherical particle of radius r, the surface energy γ and the free energy of the bulk crystal ΔG_v, giving a total free energy ΔG, eq. below.

$$\Delta G = 4\pi r^2\gamma + \frac{4}{3}\pi r^3 \Delta G_v$$

Due to the surface free energy always being positive and the crystal free energy always being negative, it is possible to find a maximum free energy which a nucleus will pass through to form a stable nucleus by differentiating ΔG with respect to r and setting it to zero, dΔG/dr = 0, which gives a critical free energy and the critical radius given in below equation.

$$\Delta G_{crit} = \frac{4}{3}\pi\gamma r_{crit}^{\ 2} = \Delta G_{crit}^{homo}$$

$$r_{crit} = \frac{-2\gamma}{\Delta G_v} = \frac{2\gamma v}{k_B T \ln S}$$

This critical radius corresponds to the minimum size at which a particle can survive in solution without being re dissolved.

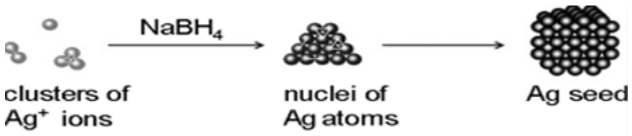


Figure 1: Nucleation of silver nanoparticle[41]

Chemical Reaction

The Chemical Reaction involved in this synthesis process are given as,

$AgNO_3 \rightarrow Ag^+ + NO_3^-$

$NaBH_4 \rightarrow Na^+ + BH_4^-$

$Ag^+ + BH_4^- + 3\ H_2O \rightarrow Ag^0 + B(OH)_3 + 3.5\ H_2$

$4Ag^+ + C_6H_5O_7Na_3 + 2H_2O \rightarrow 4Ag(0) + C_6H_5O_7H_3 + 3Na^+ + H^+ + O_2\uparrow$

Research in synthetic control of noble metal nanoparticles has proven to be a powerful and versatile approach for tailoring the properties of the metal nanostructures for various applications [1,2]. Silver nanoparticles have been prepared with various techniques to modify their optical, electrical, and catalytic properties, which are strongly dependent on the shape and size of the silver nanoparticles. Much effort from many research groups has examined the synthesis of silver colloidal solutions with suspensions of various shapes and sizes including silver nanospheres , nanowires , nanoplates , nanocubes , and nanorods [3-10]. Among these nanostructures, silver nanoplates have attracted considerable attention because they could potentially generate maximum electromagnetic field enhancement due to their highly anisotropic structure [11]. As a result, these particles are ideal for implementation in sensing applications including localized surface plasmon resonance (LSPR), and surface-enhanced Raman scattering (SERS) [12-15], which are possibly the most attractive applications.

Recently,one-dimensional 1D structures having diameter in nanoscale range such as nanorod and nanotube, have become the focus of research.[16],[17]. Which results in unique applications in mesoscopic physics and fabrication of nanoscale devices [18]. Compared with micrometer-diameter whiskers, they are expected to exhibit remarkable mechanical properties, including electrical, optical and magnetic properties. Nanosized particles of noble metals have attracted immense interest in various fields of physics and chemistry due to their conspicuous physicochemical catalytic properties and their potential applications in microelectronics, optical, electronic, magnetic devices [19]. These properties are strongly dependent on the size and shape of the particles [20] and therefore it could be critical to develop an effective preparation method through which we can attain control over the morphology of the nanomaterials. In particular, optical properties of metallic nanoparticles depend on the shape [21]. In case of spherical ones, only one absorption band can be observed. Where as, in nanorods the absorption of visible light is along the length of the nanorod (longitudinal plasmon band) and also along the width of the nanorod (transverse plasmon band). The larger aspect ratio causes the more red-shifted in the longitudinal plasmon band [22],[23]. Spheres comprise an aspect ratio of 1. Usually, capping agents usage in synthesis process leads to spheres formation, but occasionally results in shapes other than spheres. The mechanism of such shape control has recently been studied by El-Sayed and coworkers and Reetz and coworkers [24], [25]. Among all metals, silver nanorods and nanowires should be particularly interesting to fabricate and study because bulk silver exhibits the highest electrical and thermal conductivies. Silver has also been used in a rich variety of commercial applications, and the performance of silver in these applications could be potentially enhanced by processing silver into 1D nanostructures with well-controlled dimensions and aspect ratios [26], [27]. However preparation of silver nanoparticles by chemical reduction methods generally yields a wide range of sizes and morphologies. In general, the solution phase chemical method is preffered one for fabricating nanomaterials. In preparing silver nanorods using surfactants, three different approaches are available: the electro-chemical [28], seed-mediated , [29], [30] and ultraviolet irradiation–photoreduction [31] methods. We used the seed-mediated growth approach to make metallic nanorods in homogeneous solution.In seed mediated growth methods, first small metal particles are prepared and later used as seeds for the growth of nanorods. The particle size can be varied simply by altering the ratio of seed to metal salt, providing a controlled number of preformed seeds and a growth condition which avoids the secondary nucleation. However, the difficulty in finding a suitable growth condition that inhibits additional nucleation during the growth stage limits the application of such methods. In general, these conditions include using a reducing agent too weak to reduce the metal salt without the presence of seeds. Initial addition of preformed seeds has two advantages;first, it increased the overall reduction rate, and hence the growth rate: second, the particles size is controlled by varying the ratio of metal salt to seed, thus restricting the particle size to nanometer regime. In this paper, we used synthesized silver particles of 10 nm size to prepare silver nanorods of the high aspect ratios that are relatively uniform as seed material. The silver spheres were prepared through reduction of silver nitrate with sodium borohydride. Secondary nucleation during the growth stage was inhibited by carefully controlling the growth conditions using a weak reducing agent (ascorbic acid) and CTAB in aqueous solution. Here, the synthesis temperature was varied to control the aspect ratio and uniformity of the rods formation.

Surface-enhanced Raman scattering (SERS) technique has proved to be a very effective analytical tool due to its high sensitivity, high selectivity properties [32-34], which is a nondestructive technique that provides rich molecular information about molecules and molecular structures in the close vicinity of noble metal surfaces such as silver [35]. With down to single molecule sensitivity with intrinsic molecular signature, it has become a promising technique for characterization and detection of a variety of molecules [36].Noble metal NPs aggregation structure in aqueous solution is a better SERS substrate for reliable and convenient detection for any analytes compared to solid nanostructures. In general, Ag-NPs aggregation are induced by using aggregation agents such as citrate-reduced silver colloids can give very large SERS enhancement. However, the existence of the aggregation agents may have an adverse effect on the analytes. In the present study, Ag nanoparticles were aggregated by the treatment of two cycles of centrifugation, removing the supernatantand and ultra sonication and one time of water washing. The procedure of centrifugation and water washing is used for eliminating the excess surface charge provided by citrate anions. Such an aggregation is most likely due to the nonuniform distribution of capping agents on the Ag-NP crystal surfaces caused from the ultrasonicationand preferred interactions of the uncapped nanoparticle regions. Importantly, on the basis of strong aggregation of Ag-NPs in aqueous solution we have developed a simple SERS detection method for Rhodamine6G molecular.

3.1 Surface plasmon

Noble metal nanoparticles display unique optical properties that differentiate them from their bulk counterparts. Metal nanoparticles often exhibit strong extinction bands in the visible Spectrum, which are not present in the spectrum of the bulk metal. Metal nanoparticles also scatter light with high efficiency and their extinction spectra are really a combination of both absorption and scattering. The interaction of the oscillating electromagnetic field of the light with metal nanoparticles, results in the collective coherent oscillation of the metal conduction electrons with respect to the nanoparticle positive lattice. At a particular frequency of the light this process is resonant, receiving the name of Localized Surface Plasmon Resonance, LSPR (Figure 2), and is the responsible of the strong extinction band exhibited by the nanoparticle. Additionally to the extremely high molar extinction coefficients and resonant Rayleigh scattering, LSPR also results in enhanced local electromagnetic fields near the surface of the nanoparticle.

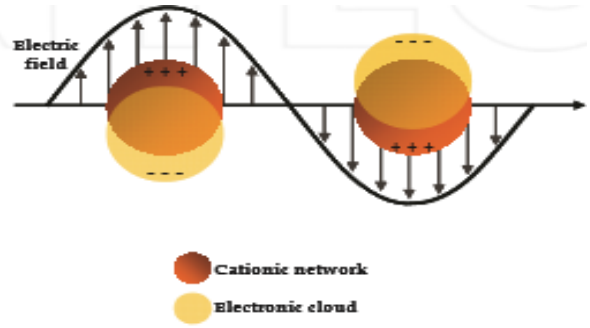


Figure: 2 Schematic representation of surface plasmon (electronic cloud) oscillation under the effect of an electromagnetic field[40]

The first theoretical approach for modelling the optical properties of nanoparticles proposed by Mie. According to the Mie theory, the resonance condition is achieved when the real part of the dielectric function of the metal equals the dielectric function of the surrounding medium (Mie, 1908). Therefore, the LSPR frequency depends both on the nanoparticle itself and on the medium where it is dispersed. Two important consequences arise from this dependency, on the one hand, the LSPR is tunable, i.e., its frequency can be modified through changes in the nanoparticle composition, size and shape (Kelly et al., 2003). On the other hand, metal nanoparticles are sensitive to their local environment, i.e., changes in the dielectric properties of their surroundings results in LSPR shifts that can be measured. Both tunability and sensitivity of LSPR convert metal nanoparticles in materials of choice for optical sensing and imaging applications. The most suitable metals are silver since the localized plasmon resonance condition mentioned above is satisfied at visible light frequencies. Additional advantages of these metal nanoparticles include simple preparation methods for a wide range of sizes and shapes.

Several types of sensors have been developed on the basis of the plasmonic properties of noble metal nanoparticles like extremely high molar extinction coefficients and resonant Rayleigh scattering and enhanced local electromagnetic fields near the surface of the nanoparticle.Sensors are classified in two main groups depending on the type of interaction involved between the metal nanoparticle and the analyte molecule. The first group sensors involving LSPR frequency shift, due to the interaction between nanoparticle and target molecule. This group is further classified in two different sensors depending on the origin of LSPR changes as aggregation sensors and refractive index sensors. In aggregation sensors the LSPR shift is due to the plasmon coupling of nanoparticles in close proximity, in refractive index sensors the LSPR shift is due to changes in the local refractive index of the medium. The second main group of sensors is based on the electromagnetic field enhancement in the vicinity of noble metal nanoparticles, which results in the surface enhanced spectroscopy, such as Surface Enhanced Raman Spectroscopy (SERS).

Experimental

Required Chemicals

The chemicals used to prepare the different silver morphology include Sodium borohydride (Sigma Aldrich), Silver nitrate (Sigma Aldrich, 99.99%), Tri-Sodium citrate di hydrate (SDFCL, 99.0-100.5%), Hydrogen peroxide 30% (Merck), Cetyl Trimethy Ammonium Bromide (SDFCL,98.0%), Ascorbicacid (Merck>=99.0%), Sodium hydraoxide (NaOH), Polyvinylpyrrolidone (Alfa Aesar) and Poly Vinyl Alcohol (PVA) and for SERS we use Rhodamine 6G (R6G) and for glucose sensing we use glucose.

Experimental Section

One of the most popular methods to synthesize different silver nanocrystals is chemical reduction method. In this method we use ice-cold sodium borohydride to reduce silver nitrate. Ice bath is used to slow down the reaction and give better control over final particle size/shape. In a synthesis process of Ag seeds, We take Mili Q Water solution in a vial add a magnetic stir bar in vial and place

on a magnetic stir plate for stiring, then put AgNO3, tri-sodium citrate and NaBH4 drop wise in a vial solution . Stir the solution for about 20 minutes after that obtained yellow silver nanoparticle. we repeat such process again for PVP and PVA at the place of tri-sodium citrate and obtained silver nanoparticle in different colour.

4.1 Synthesis of Silver nanospheres:

Silver nanospheres of different morphology were prepared in aqueous solutions using chemical reduction methods. Application of various stabilizing agents led to colloids with different color, schematically represented in Figure 2.

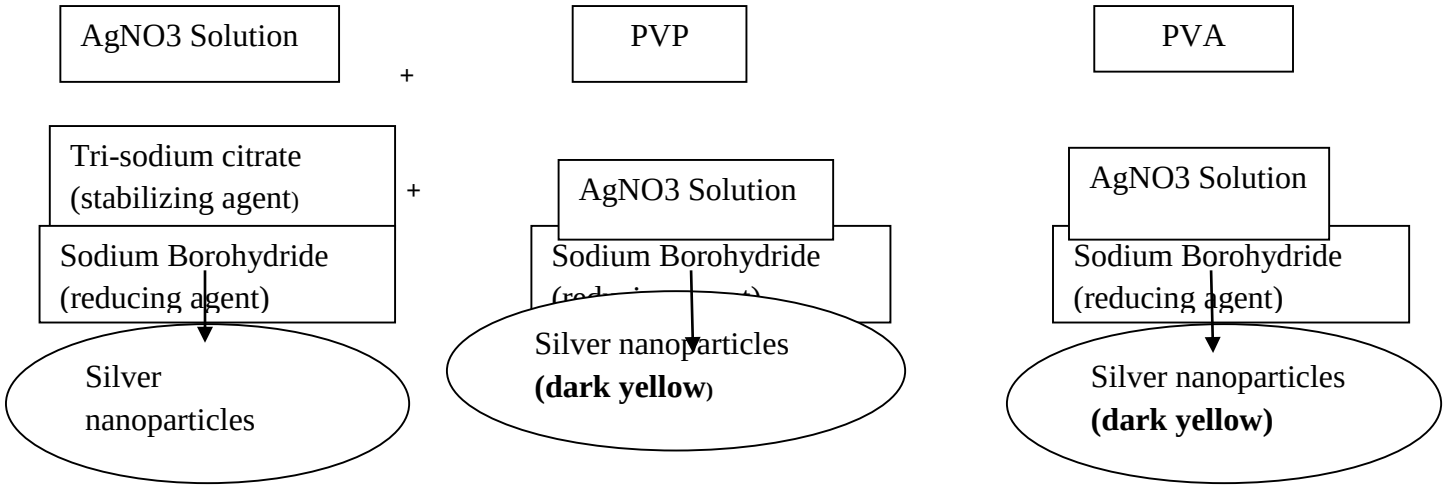


Figure 3: Preparation of silver particles using $NaBH_4$ as reducing agent and stabilizing agent as (a) tri-sodium citrate , (b)PVP poly(vinyl pyrrolidone), (c)PVA

4.2 Synthesis of Silver nanotriangles:

The triangular silver nanoplate solution was prepared by a chemical reduction method at room temperature. Synthesis process is describe as: First we take 20ml Mili Q Water solution in a vial add a magnetic stir bar in vial and place on a magnetic stir plate for stiring then put 75µl of 0.05M Silver nitrate ($AgNO_3$), 500µl of 0.05M Tri Sodium Citrate di hydrate, 150µl of Hydrogen peroxide (H_2O_2) and at the end 250µl,100mM Sodium borohydrate ($NaBH_4$) dropwise one by one. The solution was stirred by a magnetic stirrer at 1000 rpm. As soon as we put sodium borohydrate slight yellow colour appear and after 2-3 mint stirring b blue colour appear which indicate the formation of silver nanotriangles in solution. To determine the morphology shape and size of the triangular Silver nanoplates we use transmission electron microscopy (TEM), dynamic light scattering (DLS).The SERS measurement was done using a Raman spectrometer with a 532nm excitation laser wavelength with 10 seconds integration time.

4.3 Synthesis of Silver nanorods:

For the silver nanorods synthesis we use seed mediated growth method. In this method, First 80mM CTAB solution was prepare in a glass flask then seed solution was prepared by chemical reduction method as First we take 20 ml mili Q water. Then put 100µl of 50mM **Silver nitrate**, 500µl of 10mM **Tri sodium citrate di hydrate**, 1.3ml of 10mM **Sodium borohydrate** dropwise one by one.

The growth solution contained 20ml of 80mM CTAB solution, 100ul of 0.05M silver nitrate, 1ml of 100mM Ascorbic acid, 250µl seed solution and 200ul of 40m M sodium hydroxide. The solvent we use for preparing all samples was Mili Q water .

5. Characterization Techniques

Silver nanocrystal were characterized by various instrumental analyses.Crystal Structure of silver was examined by XRD. The morphology and particle size was observed by using Transmission electron

microscope(TEM) measurements.UV-Vis Spectroscopy is used to confirm sample formation by showing the plasmon resonance. Elemental composition study was investigated by Energy dispersive spectroscopy (EDS) coupled with TEM.

5.1 Ultraviolet-visible spectroscopy

Ultraviolet–visible spectroscopy or ultraviolet-visible spectrophotometry refers to absorption spectroscopy or reflectance spectroscopy in the ultraviolet-visible spectral region. This means it uses light in the visible and adjacent ranges. The absorption or reflectance in the visible range directly affects the perceived color of the chemicals involved. In this region of the electromagnetic spectrum, molecules undergo electronic transitions. This technique is complementary to fluorescence spectroscopy, in that fluorescence deals with transitions from the excited state to the ground state, while absorption measures transitions from the ground state to the excited state.

Figure 4: Setup of UV-Vis Measurement

5.2 Transmission Electron Microscope

The transmission electron microscope (TEM) operates on the same basic principles as the light microscope but uses electrons instead of light. TEMs use electrons as "light source" and their much lower wavelength makes it possible to get a resolution a thousand times better than with a light microscope. we can see objects to the order of a few angstrom (10^{-10} m). TEM instrument used for our characterization is Transmission Electron Microscope (Make: Philips, Model CM 200, Operating voltages : 20-200kv Resolution : 2.4 A^{o}) as shown in figure 4.

Figure: 5 Setup of TEM CM 200kV

5.3 X-ray diffraction

X-RAY diffractometer is used for determining the crystal structures. The diffractometer is an apparatus used to determine the angles at which diffraction occurs for powdered specimens as shown in figure. A specimen S in the form of a flat plate is supported so that rotations about the axis labeled O are possible. The monochromatic X-ray beam is generated at point T (X-ray Source) and the intensities of diffracted beams are detected with a counter labeled C in the figure. The specimen, X-ray source, and counter are all coplanar.

The counter is mounted on a movable carriage that may also be rotated about the O axis; its angular position in terms of 2Θ is marked on a graduated scale. Carriage and specimen are mechanically coupled such that a rotation of the specimen through Θ is accompanied by a 2Θ rotation of the counter; this ensures that the incident and reflection angles are maintained equal to one another as shown in figure. Collimators are incorporated with in the beam path to produce a well-defined and focused beam. Utilization of a filter provides a near-monochromatic beam. As the counter moves at constant angular velocity, a recorder automatically plots the diffracted beam intensity as a function of 2Θ; 2Θ is termed the diffraction angle, which is measured experimentally.

One of the primary uses of X-ray diffractometry is for the determination of crystal structure. The unit cell size and geometry may be resolved from the angular positions of the diffraction peaks, whereas arrangement of atoms with in the unit cell is associated with the relative intensities of these peaks.

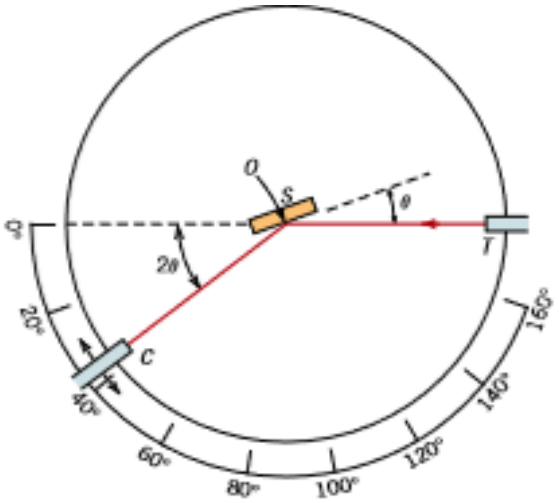


Figure 6: Diagram of an X-ray Diffractormeter

5.4 Raman Spectroscopy

Raman Effect is based on light interacting with the chemical bonds of a sample. Due to vibrations in the chemical bonds the interaction with photons causes specific energy shifts in the back scattered light that appear in a Raman spectrum. The Raman spectrum is unique for each chemical composition and can provide qualitative and quantitative information of the material. Raman spectroscopy provides a chemical "fingerprint" of the investigated compounds, it is non-invasive, non-destructive technique. it is insensitive to water and can be used for imaging.

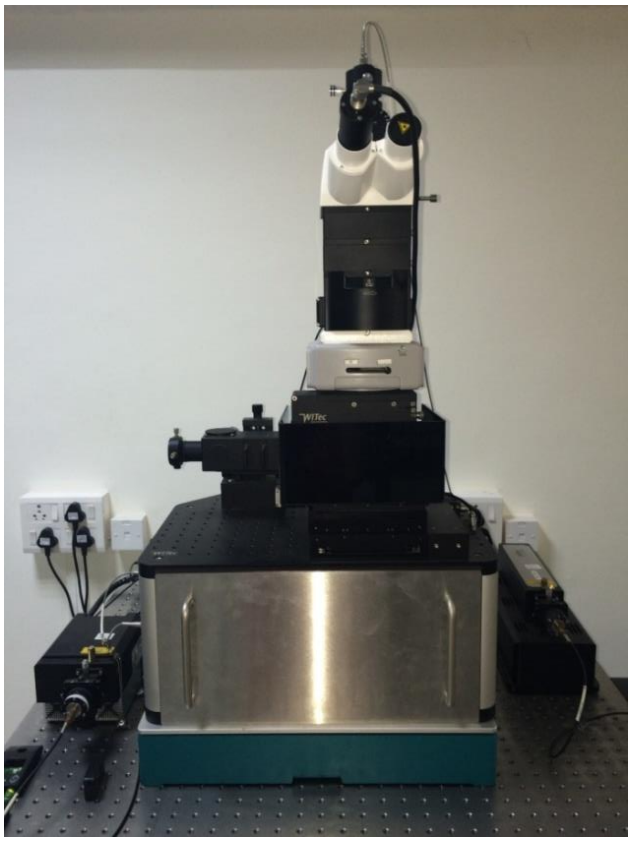


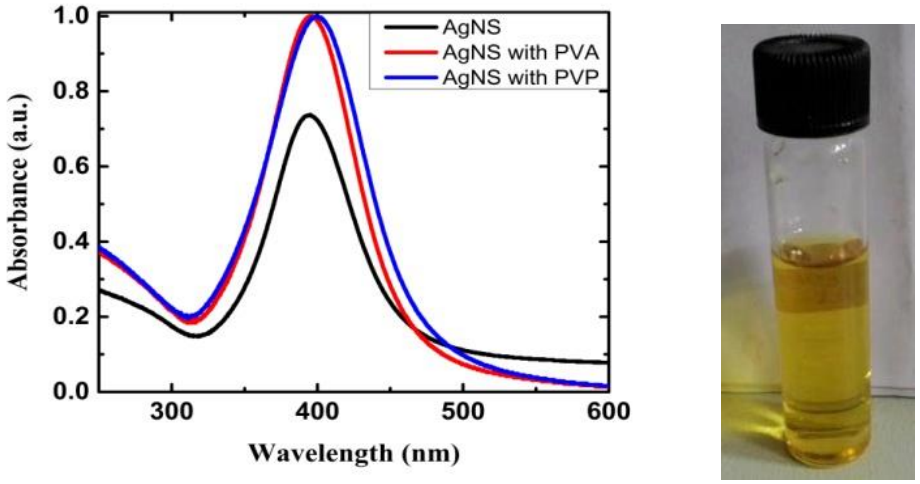
Figure: 7 Setup of Raman Spectroscopy

6. Result and discussion

6.1 UV-Vis spectroscopy

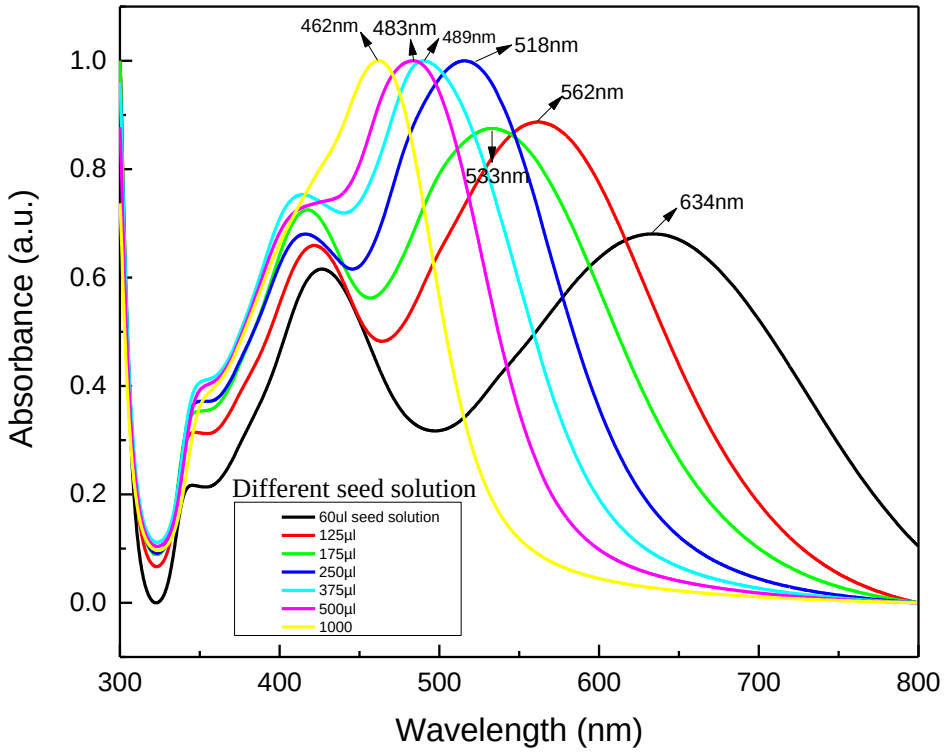
UV-Vis spectroscopic study is useful technique for morphological and optical properties evolutions because silver nanostructures exhibits SPR which depend on various shapes and sizes of silver nanostructures at different frequencies. Figure show the UV-Vis spectra of different silver morphology. Spherical nanoparticles will exhibit only one typical surface plasmon resonance (SPR) in the visible region. Spherical silver particles obtained in 3 different condition by injection of $NaBH_4$ solution to an aqueous solution of $AgNO_3$ in the presence of trisodium citrate, poly(vinyl pyrrolidone) and PVA(polyvinyl alcohol)**.** surface plasmon band in the UV-vis spectroscopy for the spherical particles is obtained approx at

λmax = 400 nm as shown in below figure(8-a) and Yellow color for spherical silver particles was reported. Silver nanorods exhibit complex absorption pattern due to absorption of visible light along both the width of the nanorods (transverse plasmon band) and along the length of the nanorods (longitudinal plasmon band).As shown in Figure (8-c) with varying the amount of seed solution different pick was observe.



(a) (b)

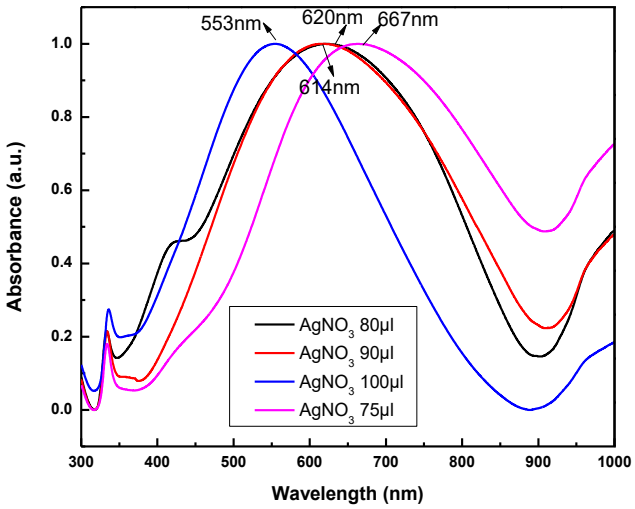
Figure 8: (a) UV-Vis absorption spectrum of silver nanosphere, (b) Silver nanosphere prepared by $NaBH_4$ as a reducing agent and TSC di hydrate as a stabilizing

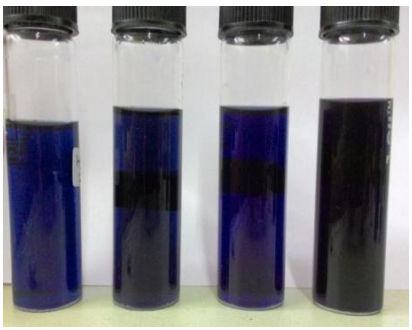


(c)

(d)

Figure 8 (c) UV-Vis absorption spectrum of silver nanorods at different seed concentration,(d) Silver nanorods coloured solutions





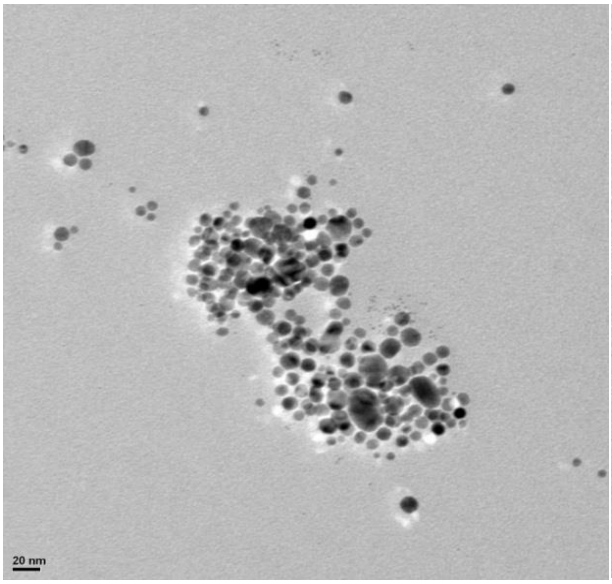
(e) (f)

Figure 8: (e) UV-Vis absorption spectrum of silver nanotriangles at different value of $AgNO_3$ concentration ,(f) Silver nanortriangles coloured solution

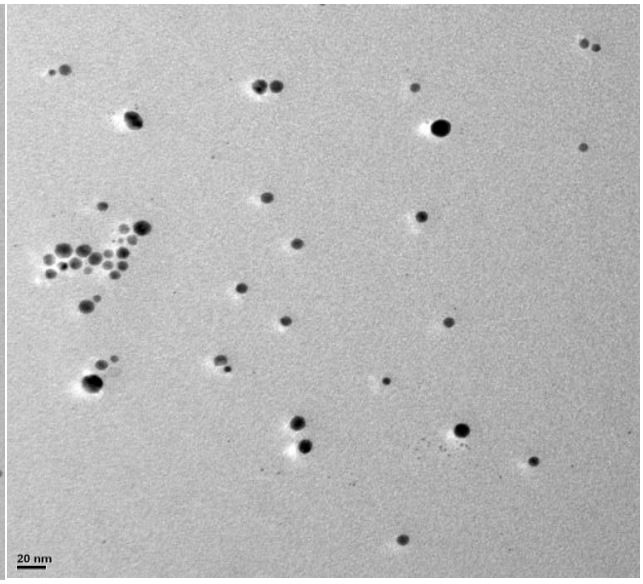
6.2 Transmission Electron Microscopy

The TEM images of the Different Silver morphology is shown in figure below. For TEM characterization, First of all Solution of different silver morphology was centrifuge at 10000rpm for 15 minute and washed the solution again for 2 to 3 times and then washed solution was dropped on a grid surface. The solution was first dried for 1 hour in oven and then put 15 minute in front of IR lamp and after that TEM characterization is taken. Figure 9 show the TEM image of different silver morphology that was captured with 200Kv TEM. It was found that the size of silver spheres in the range from 8nm to 10nm was obtained. The Average edge length of triangular nanoplates is 26 ± 1 nm as shown

in figure. Figure shows the formation of silver nanorods through TEM analysis at reaction temperature of 50°C. The Aspect Ratio of Silver nanorods from TEM micrograph is found to be 2.5.



(a)



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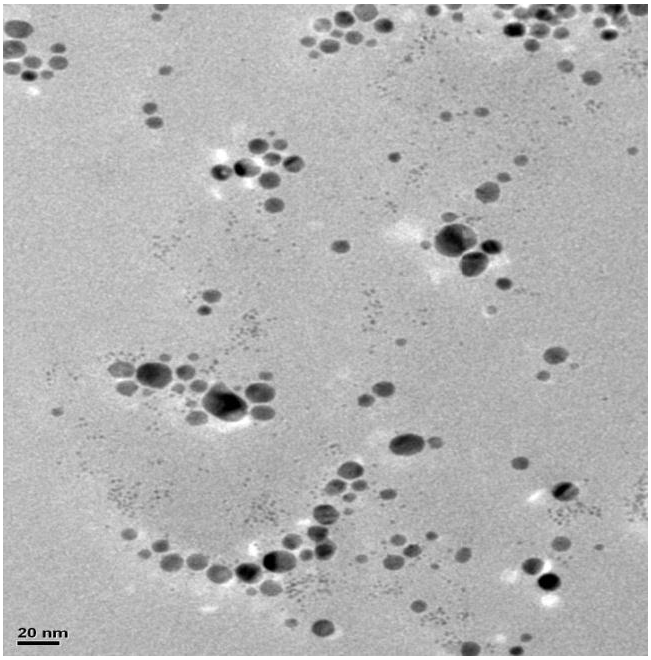
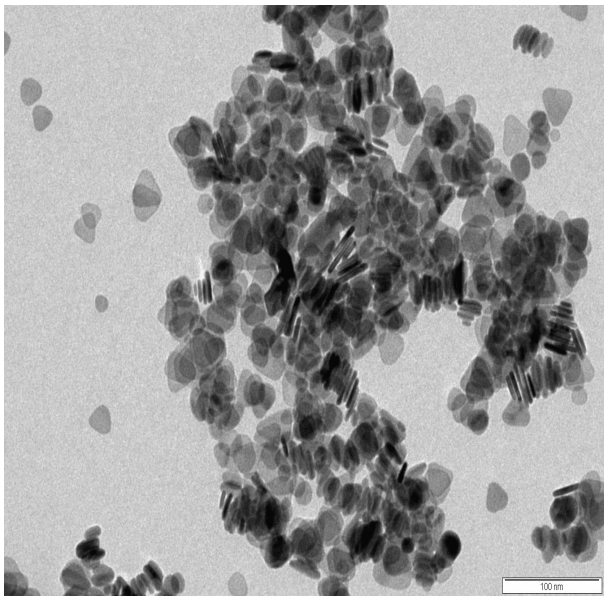
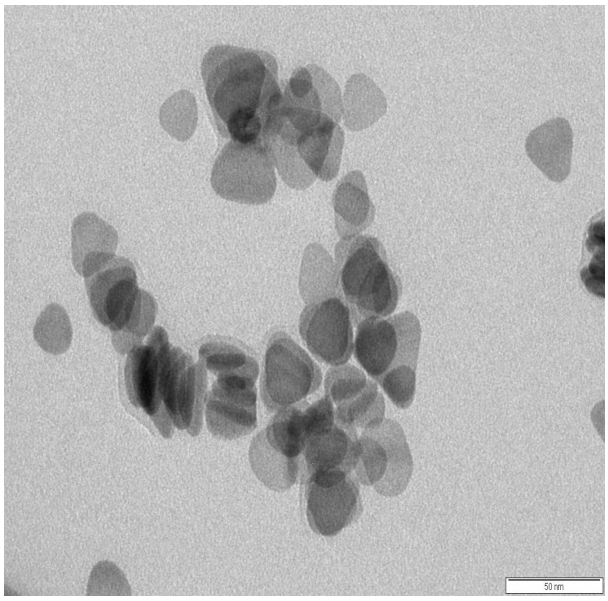


(c)

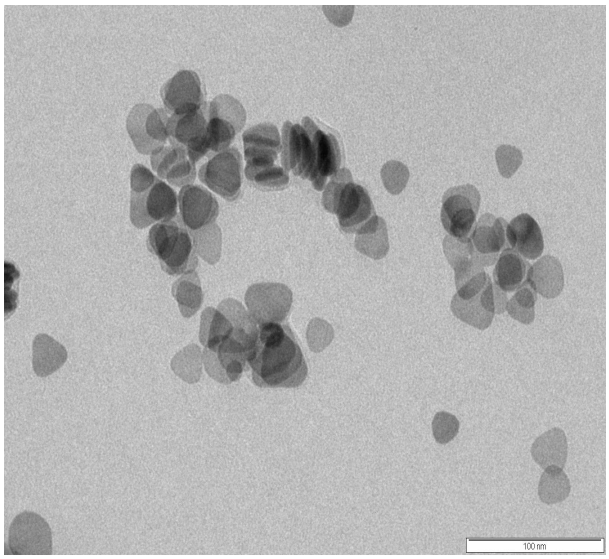
Figure 9 (a,b,c) TEM image of Silver Nanosphere



(d)

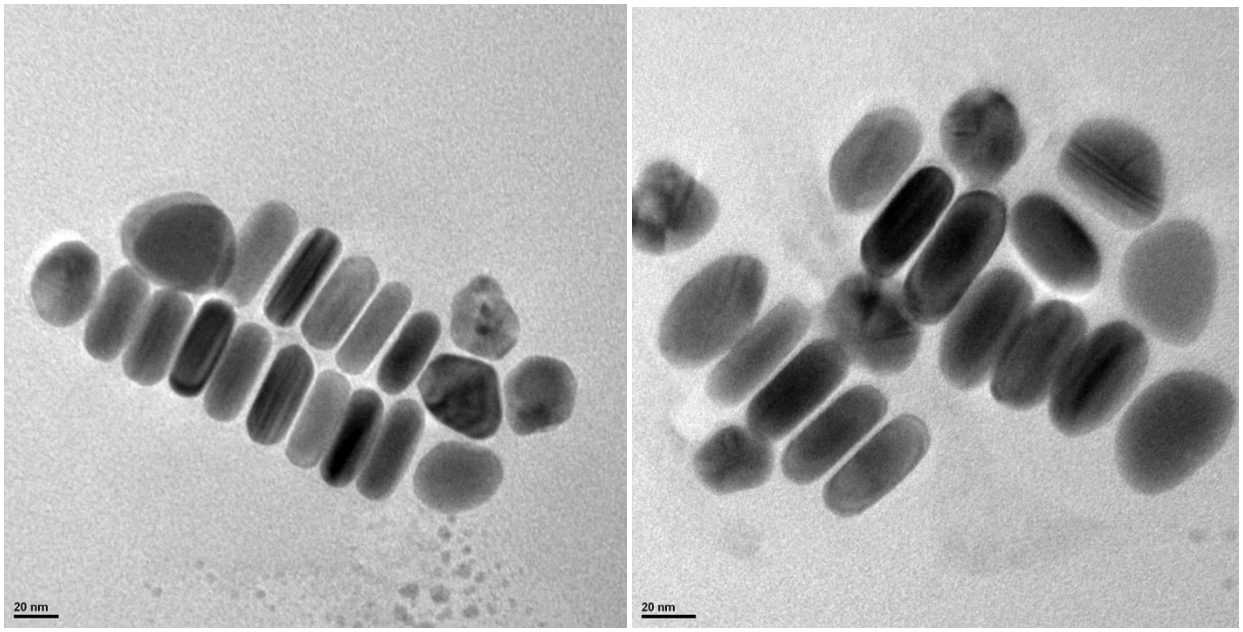


(e)

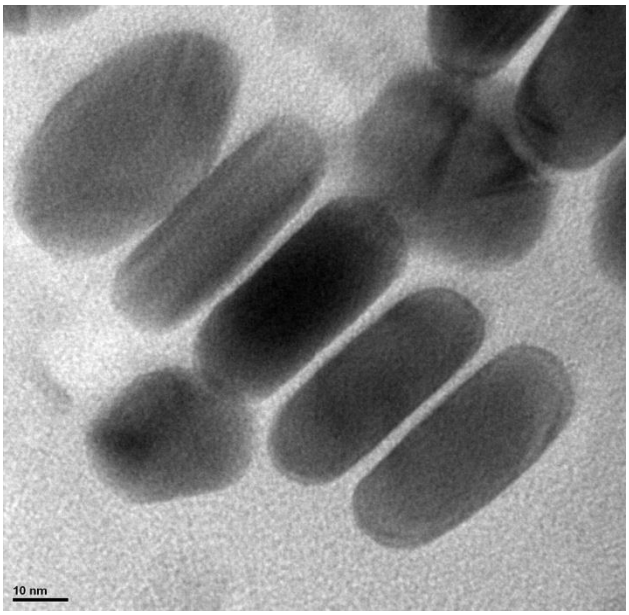


(f)

Figure 9 (d,e,f) TEM image of silver nanotriangles



(g) (h)



(i)

Figure: 9 (g,h,i) TEM of silver nanorods at synthesis temperature of 50°C.

6.3 Energy Dispersive X-ray Spectroscopy (EDS)

Energy Dispersive X-ray Spectroscopy sometimes called energy dispersive X-ray analysis (EDXA) or energy dispersive X-ray microanalysis (EDXMA), is an analytical technique.This technique is used for elemental analysis or chemical characterization of the sample.

Principle of Operation

When the electron beam interacts with the sample, it generates X-ray fluorescence as shown in figure. The energy of each photon is the representative of the elements present in the sample. The Energy Dispersive spectrometer collects the X-rays and plots them as counts versus energy curve. It indentifies and labels the

elements responsible for the peaks in this energy distribution. Figure shows the EDS spectrum of Silver nanoparticles . The spectrum shows the elemental peaks of Ag. Emission peak for silver was appeared at 2.5-3.5 keV.

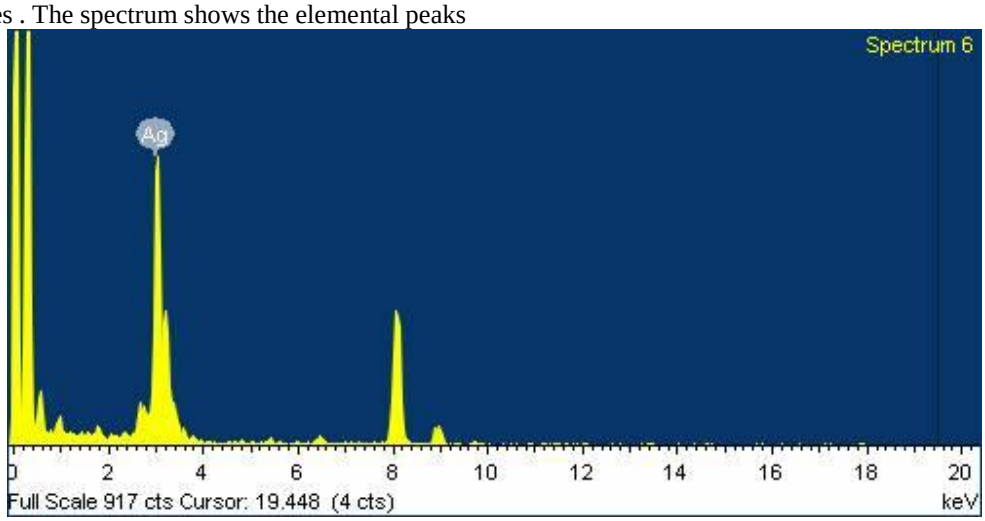


Figure : 10 EDS spectrum of silver nanoparticles

6.4 X-ray diffraction

X-ray diffraction pattern of silver nanorods is shown in Figure 11. The diffraction peaks corresponds to (111), (200) planes show face centered cubic (FCC) structure (JCPDS No: 04-0783).

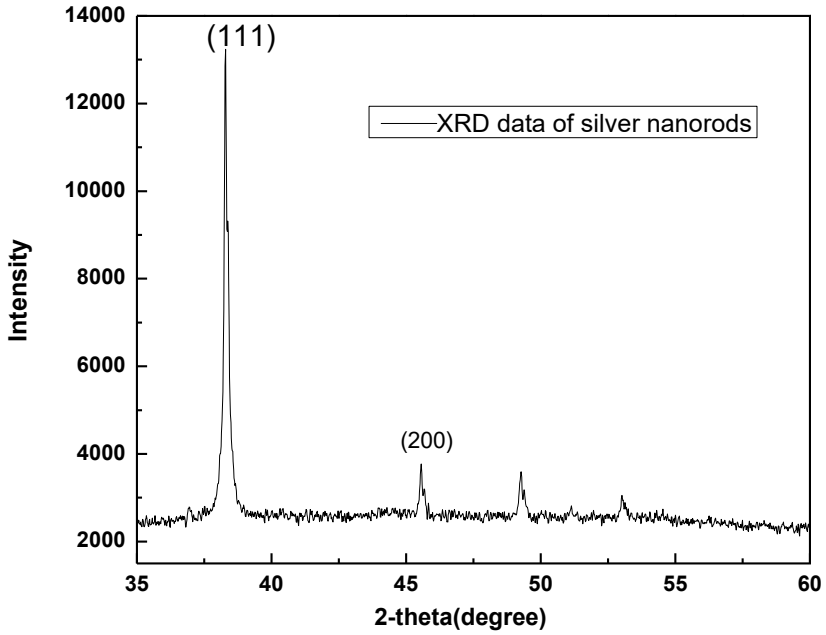


Figure 11: XRD profile of silver nanorods synthesized at 50°C

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6.5 Dynamic Light Scattering

DLS is used for size distribution measurements. The average size of different silver morphology was also confirmed using dynamic light scattering (DLS) as plotted in Figure 12. As shown in figure the average size for silver nanotriangles and nanorods is 25.6nm and 48.7nm respectively.

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Delsa™ Nano

Overlay Graph (Normalized Intensity Distribution) Common

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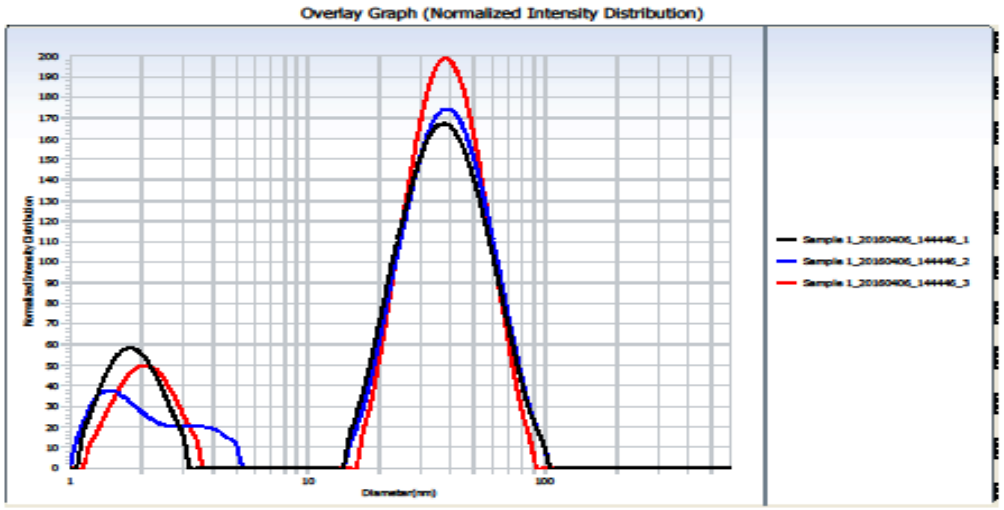
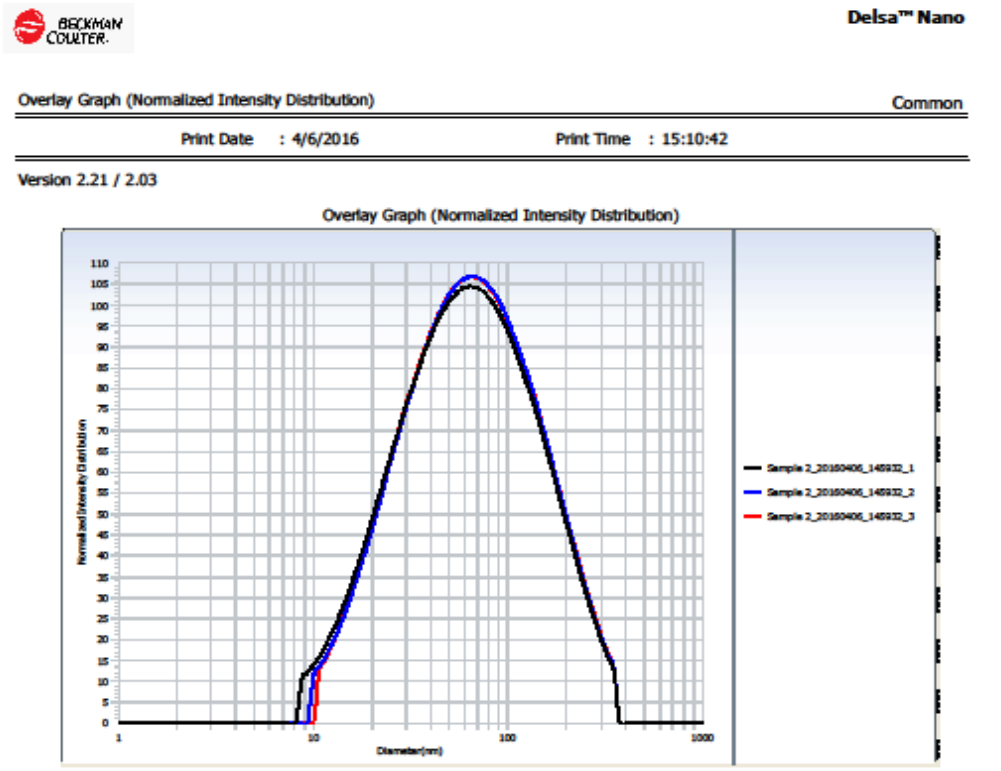


No	Data	Repet. No	pH	Ave. Diameter(nm)	Polydispersity Index	D (10%) (nm)	D (50%) (nm)	D (90%) (nm)
1	Sample 1_20160406_144446_1	1	NA	24.7	0.359	1.8	32.0	60.0
2	Sample 1_20160406_144446_2	2	NA	25.8	0.347	2.2	33.3	60.9
3	Sample 1_20160406_144446_3	3	NA	26.3	0.338	2.2	33.6	57.2

Average : 25.6

(a)



No	Data	Repet. No	pH	Ave. Diameter(nm)	Polydispersity Index	D (10%) (nm)	D (50%) (nm)	D (90%) (nm)
1	Sample 2_20160406_145932_1	1	NA	47.0	0.321	19.7	59.7	170.3
2	Sample 2_20160406_145932_2	2	NA	48.9	0.315	21.2	61.7	172.5
3	Sample 2_20160406_145932_3	3	NA	50.2	0.303	21.4	61.8	173.1

Average : 48.7

(b)

Figure 12: DLS data for (a) Silver nanoplate, (b) Silver nanorods

7.Applications

There are two main application of silver nanocrystals one as Surface-enhanced Raman Scattering (SERS) substrate and another in Glucose Sensing.

7.1 Surface-enhanced Raman Scattering (SERS)

The silver nanoparticles was shown to be a good surface-enhanced Raman scattering (SERS) substrate as it gave an Raman enhancement for Rhodamine 6G.
We use Raman spectrometer with 532 nm excitation wavelength and a maximum output power 35mW. In our experiment we Study thing that:

- The Concentration dependent SERS Spectra of Rhodamine 6G, as shown in Figure 14 (a,b,c) It has been observed that SERS signal intensity increase sharply as we moved from Rhodamine concentration level $2x10^{-8}$M to $2x10^{-6}$M. It is shown in Table 1 which indicate variation of intensity (counts/sec) with R6G concentration of different peaks. it is due to that Number of SERS-active particles increase with concentration of R6G which is responsible for high intensities.

Table1: Table indicating variation of intensity (counts/sec) with R6G concentration of different peaks.

Concentration of R6G	**620**	**780**	**1180**	**1316**	**1368**	**1514**	**1655**
$2x10^{-8}$	509	180	90	110	209	160	160
$2x10^{-7}$	1148	520	250	370	890	698	820
$2x10^{-6}$	1250	1037	741	1000	1625	1130	2039

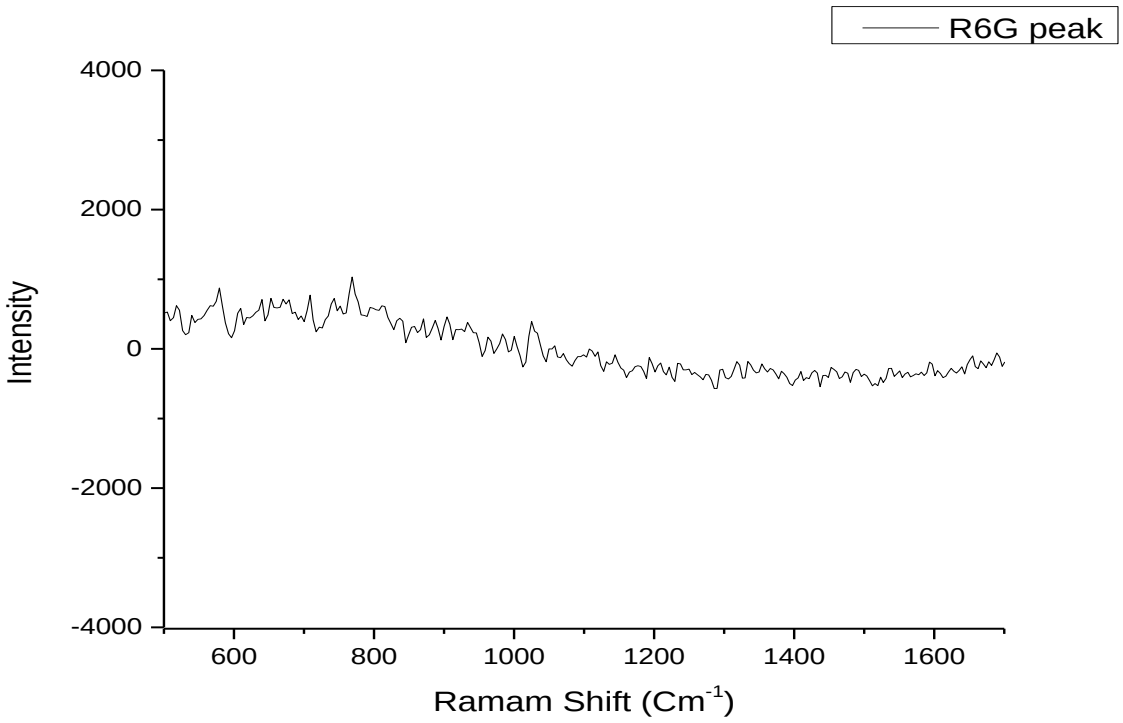
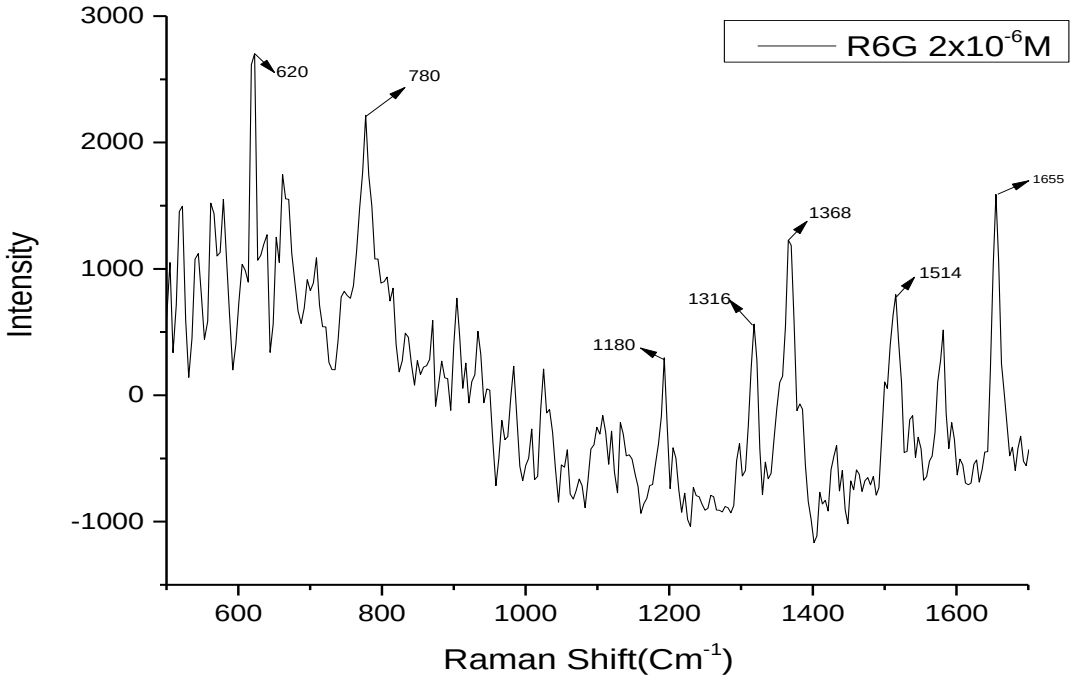
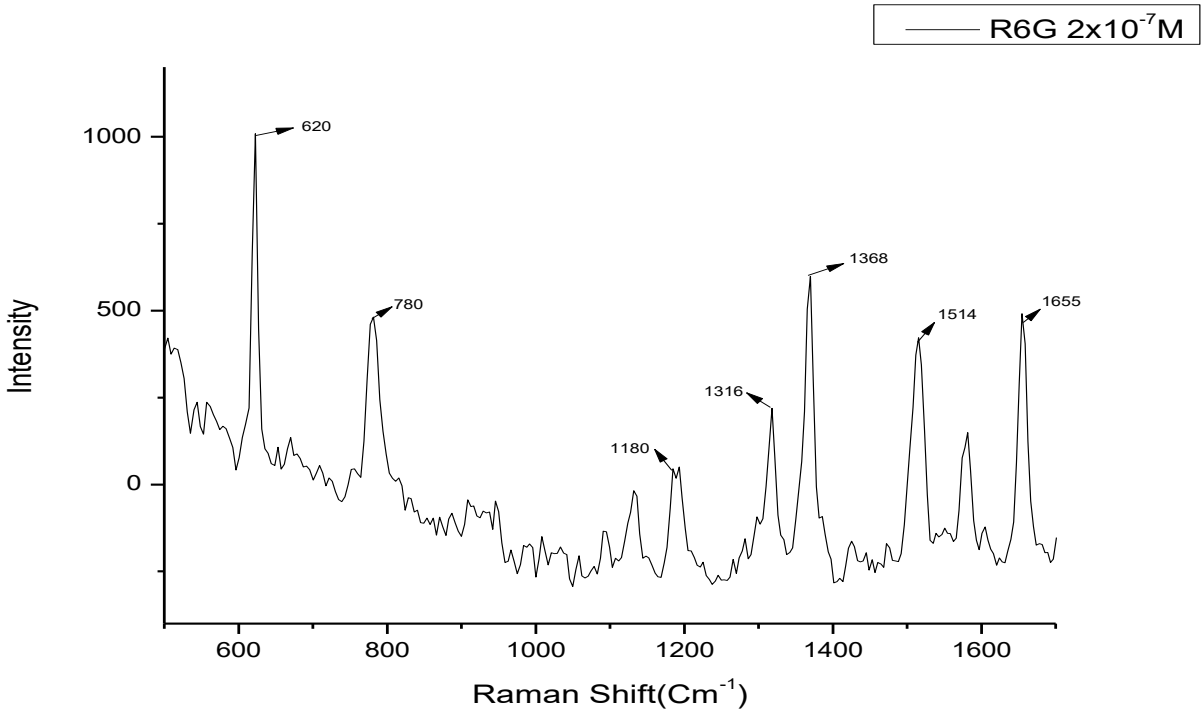


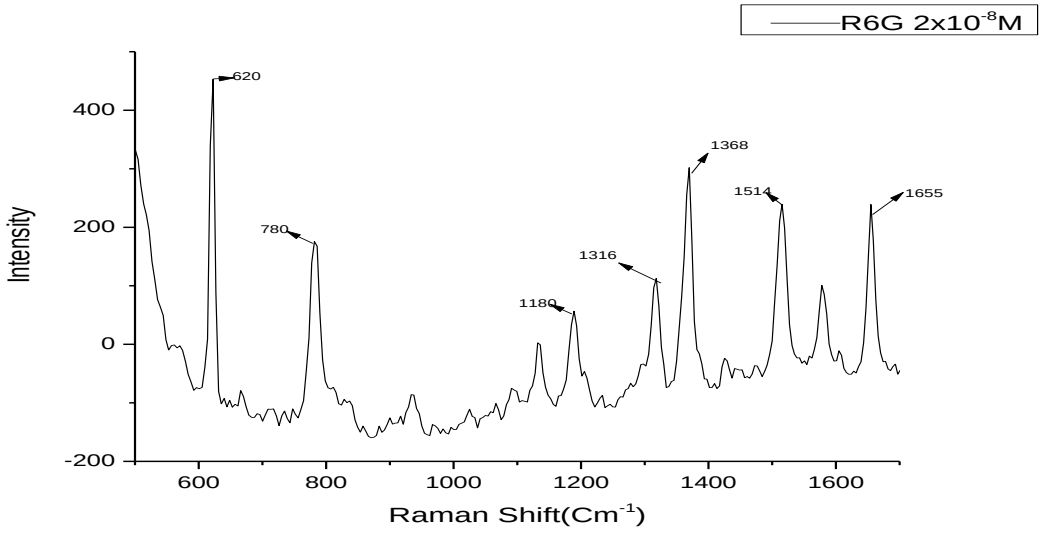
Figure 13: SERS spectra of R6G


R6G 2x10-6M
Intensity
Raman Shift(Cm-1)
620
780
1180
1316
1368
1514
1655
3000
2000
1000
0
-1000
600
800
1000
1200
1400
1600

(a)


R6G 2x10-7M
Intensity
Raman Shift(Cm-1)
620
780
1180
1316
1368
1514
1655
1000
500
0
600
800
1000
1200
1400
1600

(b)



(c)

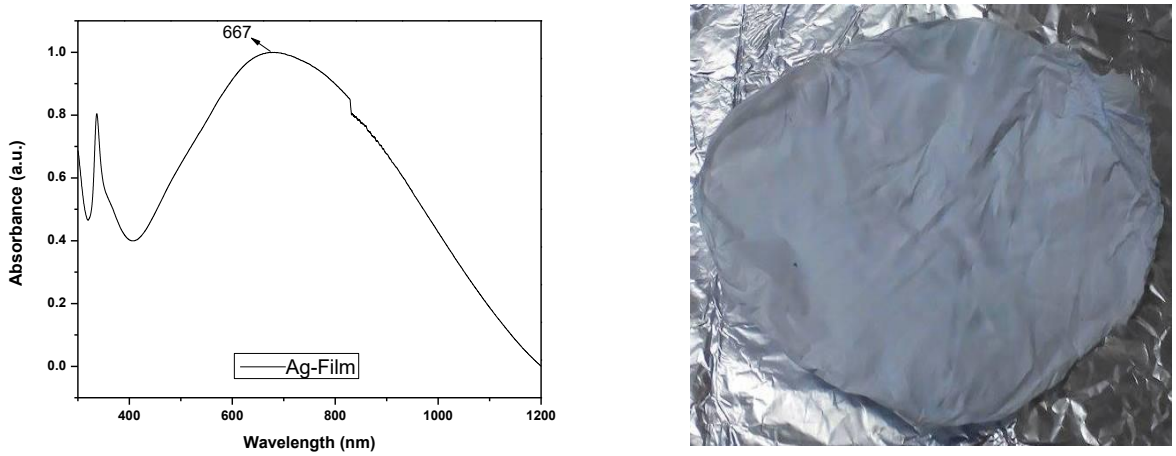
Figure 14: SERS spectra of R6G adsorbed on silver nanosphere at different R6G concentrations (a) $2x10^{-6}$M, (b)$2x10^{-7}$M, (c)$2x10^{-8}$

7.2 Glucose sensor

Electrospinning-Experimental

For electrospining first of all, silver nanotriangle solution was centrifuge at 9000rpm for 15mintue and wash it properly 2-3 times. After that measure the solution weight and after that add PVA (9% weight of solution) and stir the solution for 7-8 hour until proper mixing is done. Then solution was transferred to a 5ml syringe and electrospining was carried out. Electrospun for 4 hour@10kV

.



(a) (b)

Figure 15: Electrospining of siliver nanoplate solution in large volume (a) UV-Vis spectra of silver solution (b) Silver nanotriangle Film

Glucose sensing on siliver nanoplate fibre using methanol and Mili Q water as a solvent

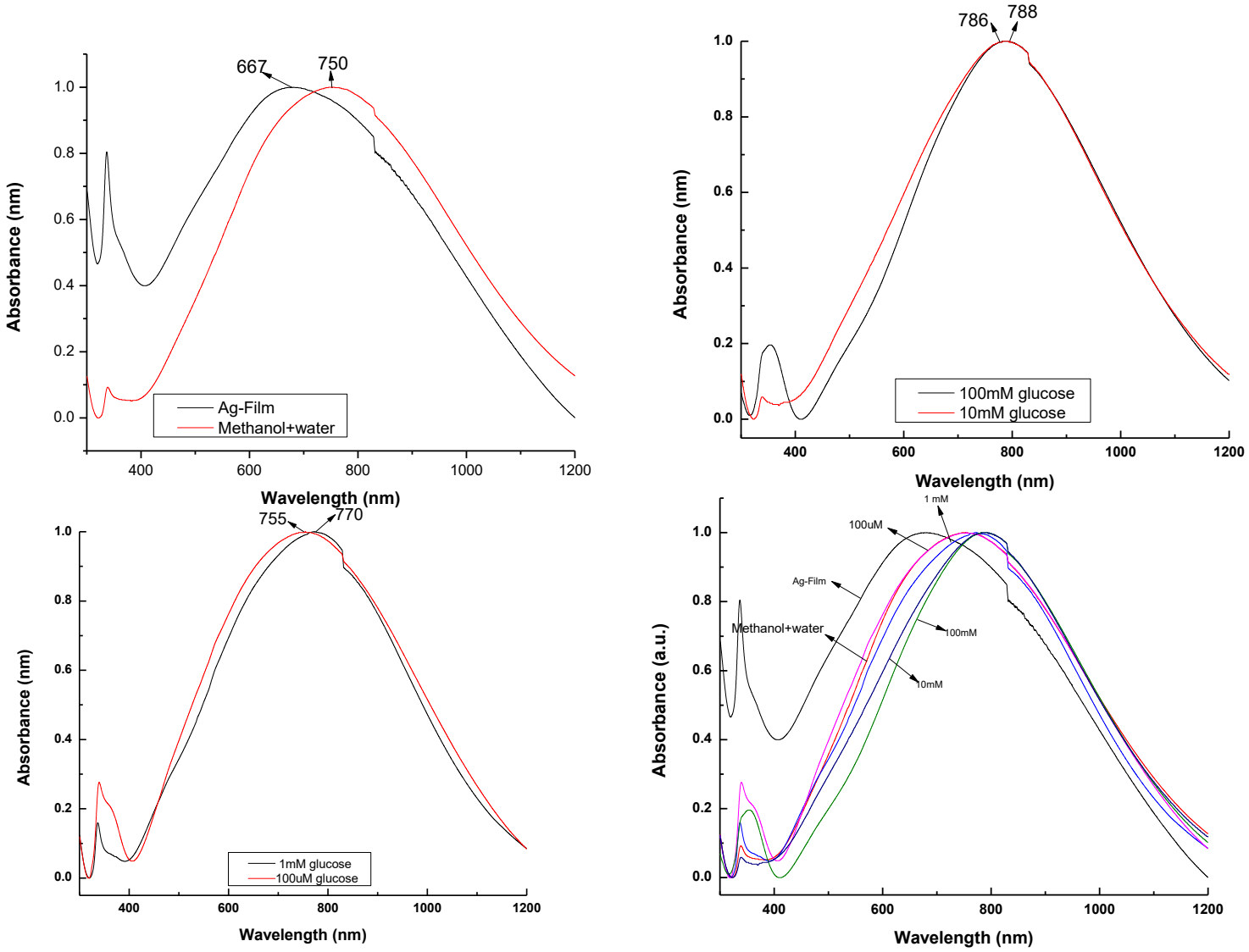


Figure 16: Glucose sensing upon silver nanotriangles Fiber

For glucose sensing measurement First of all cut the Silver fibre in to small pieces all of equal size and then put the drop of glucose different concentration (1mM to 100µM) in fibre piece.we observe the colour change of fibre which indicate the sensing.

We take the UV-Vis measurement as shown in figure 14, this also indicate the shift in plasmonic band as we go in higher Glucose concentration the shift in higher wavelength was recorded.

8. Conclusion

Nanoparticles with different shapes and sizes can be prepared by controlling the reaction conditions. The color of metal nanoparticles depends on the shape and size of the nanoparticles. In this study we investigeted the influence of parameters such as protecting agent . Silver nanoparticles prepared using different stabilizing agents had different morphologies and sizes. Synthesis of different silver nanocrystals by chemical reduction method has become possible using $NaBH_4$ as a reducing agent and using $AgNO_3$ as a reductant and tri-sodium citrate, PVP as a stabilizing agents. The resultant solution became yellowish in colour. In case of silver nanotriangles we use hydrogen perioxide as a etching agent.

Silver nanorods have been successfully synthesized by a chemical method with aspect ratio 2.5. This technique is based on the seed mediated CTAB directed growth of silver nanorods. We have studied the influence of amount of seed solution and then study the variation in optical response in UV-Vis. XRD patterns show the fcc symmetry of prepared nanorods. UV-Vis studies confirmed the nanorods formations with two SPR bands.

The Silver nanocrystal were shown to be useful as Surface Enhance Raman Spectroscopy which show Significant enhancement of the Raman signal for Rhodamine 6G dye. Silver nanoparticles in ethanol solution interact selectively with glucose, giving rise to a red shift in the LSPR.The localized surface plasmon resonances (LSPR) nanosensor developed in this study is expected to demonstrate a wide range of biomedical and environmental applications. Its simplicity and lowcost will make it accessible to the public. While the commercially available SPR biosensor has some of these capabilities, a nanoparticle based sensor could improve both medical diagnostics and biomedical research by easily diagnosing large numbers of biomolecules quickly.

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