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Optical study of *Desmodium elegan* mediated silver nanoparticles using Tauc's equation

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ABSTRACT

Green synthesis of metallic nanoparticles is more eco-friendly, simpler, and nontoxic as compared to chemical synthesis. Due to their thermal stability and good electrical conduction silver nanoparticles have significant importance these days. In the present work, the stable silver nanoparticles were prepared from the aqueous solution of $AgNO_3$ *by green synthesis technique in which the Desmodium elegan plant extract was used as a reducing and capping agent to convert* Ag^+ *to* Ag^0*. A UV-visible spectrometer is used in the range of 200 nm to 800 nm with a scanning speed of 200 nm per minute, the absorption band is found at a 450 nm peak that indicates the synthesis of silver nanoparticles. The particle size of the nanoparticles was in the range of 11 nm to 70 nm with an average of 45 nm and a spherical shape. Further confirmation of nano size, scanning electron microscopy (SEM) was also utilized for the size distribution and shape of the synthesized nanoparticles. The synthesized nanoparticles SEM studies show irregular spherical morphology with polydispersed trend and the average particle size was found at 45 nm. The absorption band for the synthesized sample was found at 450 nm peak. The bandgap energy was* $2.84\ eV$ *estimated by Tauc's equation. This indicates that the synthesized nanoparticles electrically lie in the range of semiconductors and can be used as a biosensor. This synthesis technique is a nontoxic technique so these particles may be used for water treatment.*

Keywords: Green synthesis, plant mediated nanoparticle, silver nanoparticle.

1. INTRODUCTION

Silver nanoparticles have gained the attention of researchers due to their unique physical and chemical properties. These properties include high thermal and electrical conductivity and chemical stability. Silver nanoparticles have also good antimicrobial and antibacterial activities. These nanoparticles have better physiochemical properties as compared to other noble metal nanoparticles. Chemical stability and an absorption band at a visible range increase their importance in practical applications. During surface-plasmon resonance, silver nanoparticles have a minimum loss that increases their efficiency [1-7]. Silver nanoparticles are also used as catalysts due to no toxicity as compared to other metal nanoparticles. It is also economically low cost as compared to other noble metallic particles like Gold and Platinum. Silver nanoparticles have also attracted the attention of many bio-medical researchers due to their use in a wide range as strong

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antimicrobial and anti-bacterial agents. Due to these properties silver nanoparticles are used in the health sector and food industries. In recent days these have been used to successfully remove dirt and control the microbe in sports kits like socks. These are also used in wound dressing, boards, and surgical instruments, biomedical devices and masks. [8-13].
A product marketed by Samsung Company called Silver Nano used to remove dust and dirt from households, is also made of silver nanoparticles. Such application increases the demand for research in silver nanoparticles and their devices [14-18].
There are many methods for the synthesis of silver nanoparticles. Chemical reduction is one the most commonly used synthesis techniques in which silver ions are reduced by a reducing agent to form a stable independent unit as nanoparticles [19-23].
The size and other physical parameters of the silver nanoparticles are controlled by changing the concentration of the reducing agent and capping agents. [24-27]. Generally, in silver nanoparticles synthesis, sodium borohydride is used as a reducing agent in chemical synthesis. Chemical synthesis is not a good option for biological applications due to chemical hazards and toxicity. Therefore, biological methods are used for the synthesis of silver nanoparticles. In biological techniques, biological components like yeast, fungus, or bacteria are used as reducing and capping agents [28-33]. Out of all the biological techniques, green synthesis is considered to be the most eco-friendly. In this technique, plant extractions are used as capping and reducing agents [34-38]. Different literature survey indicates that various plant extracts are used for the synthesis of silver nanoparticles such as *Withania somnifera* and *Acalypha indica*. Earlier research has shown that *Acalypha indica*, *Helianthus annus*, *Mentha piperita*, *Oryza sativa*, and *Gliricidia sepium* can be extracted successfully through green synthesis, which eliminates particle toxicity compared to chemical routes. [39-42].

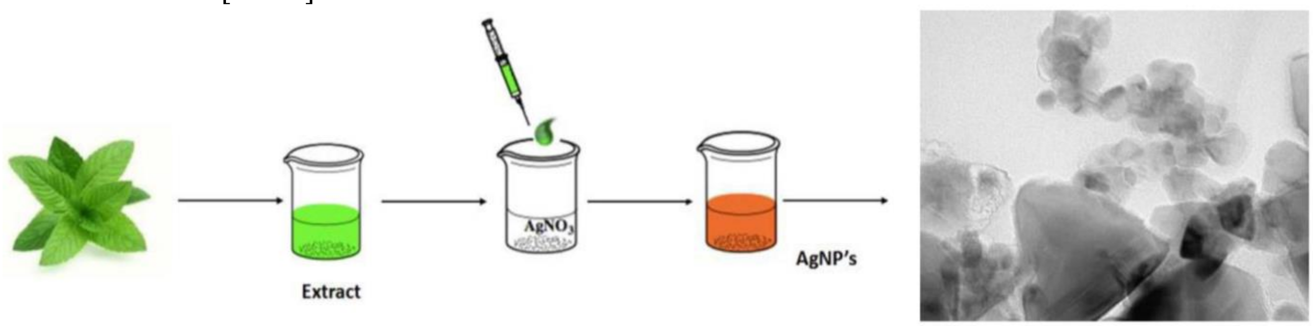

Figure 1. A pictorial illustration of green synthesis of Silver nanoparticles by using *Desmodium elegan* broth as reductant.

In the present work, the silver nanoparticles were synthesized using extraction of the plant *Desmodium elegan* (from the family Fabaceae) usually recognized as *elegant tick clover* and it is found in the Asian region. Due to the containing significant phytochemical compounds *Desmodium elegan* plays an essential role in the synthesis process. The compounds like flavonoids, sterols, and reducing sugar are used for the capping of silver nanoparticles and also as reduction agents [34, 43-46].

2. EXPERIMENTAL DETAILS

Initially, *Demodium elegen* leaves were sequentially washed through tap water and then distilled to properly clean and remove the impurities. The leaves were stored at room temperature until dried and cut down into small pieces. Then, 200 ml of distilled water was added to 20 g of the chopped leaves and heated for about 1 hour at 60 °C. The Whatmann No. 1 filter paper was used to separate *the Demodium elegen* extract at room temperature.

In the present work, 0.1 mM aqueous solution of $AgNO_3$ was prepared to obtain Ag+ ions. 5 ml of *Demodium elegen* solution was mixed drop by drop with 50 ml of $AgNO_3$ solution and stirred for two hours at 2500 rpm at room temperature. The color of the solution changed after two hours of constant stirring at 2500 rpm at room temperature. First, the solution color changed from yellowish green to light brown and later became dark reddish. This color change was an indication of the formation of nanoparticles. The formation of nanostructure is further confirmed by the UV-visible spectroscopy technique. For this purpose, the Shimadzu-UV 1800 UV-Visible spectrophotometer was employed in the range of 200-800 nm wavelength with ±1 nm resolution.

The plant mediated silver nanoparticles were studied by the AFM characterization for revealing size and shape. For AFM studies the (Agilent 5500, USA AFM) model is used under normal atmospheric environment with taping mode. The SEM examination was done with the JEOL JSM 6480 LV SEM machine and was run at 20 kV for the determination of the size and morphology of silver nanoparticles synthesized with *Desmodium elegan* extract.

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Figure 2. Visually inspection of colors of solutions before and after the final sample.

3. RESULTS AND DISCUSSION

3.1 Characterization

3.1.1 Study of UV-Visible Spectroscopy

The UV-visible spectroscopy was carried out for characterization and confirmation of silver nanoparticles. The absorption spectrum of the colloidal solution of silver nanoparticles was recorded and corrected by comparing it with reference spectra. A sharp absorption peak at 415 nm reveals the formation of silver nanoparticles. This displayed absorption peak is related to the Surface Plasmon Resonance band of silver nanoparticles. Figure 3 shows the broadening of the absorption peak which indicates that the silver nanoparticles were polydispersed.

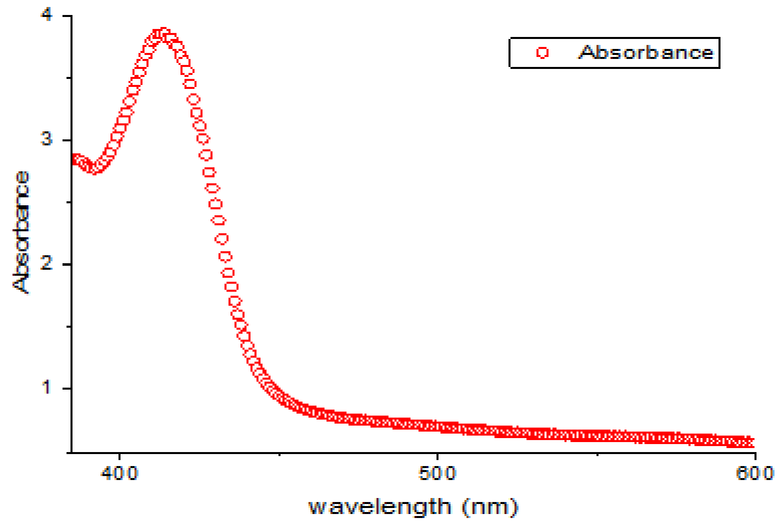

Figure 3. UV-Visible absorption spectrum of the *Desmodium elegan* mediated silver nanoparticles

3.1.2 Study of Atomic Force Microscopy

The AFM was carried out for size determination of silver nanoparticles. A 100 µl of solution sample thin layer was dried on a freshly cleaved mica slide for about five minutes at normal room temperature. The dried sample was scanned by a Silicon cantilever of length 125 micrometers with resonance frequency of 330 KHz. The force constant was 42 N/ m and the obtained micro images were studied with the Agilent's Pico view data processing software. As we can see the micro image depicted in Figure. 4 shows the polydispersed and the mostly spherical shape. The size of silver nanoparticles using *Desmodium elegan extract is found in* the range of 11-70 nm and the average size was measured at 45 nm from AFM measurements.

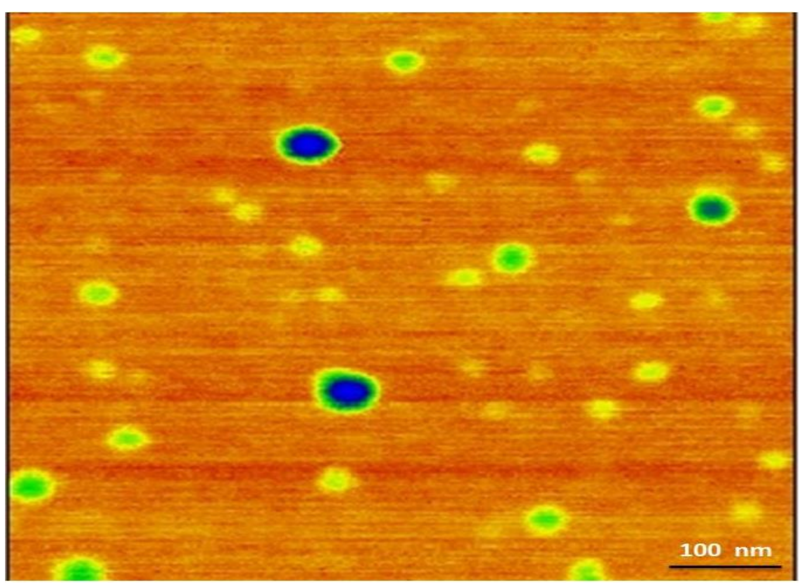

Figure 4. AFM analysis of *Desmodium elegan* mediated silver nanoparticles.

3.1.3 Scanning Electron Microscopy:

The SEM was also carried out for size determination of *Desmodium elegan* mediated silver nanoparticles. The SEM analysis showed the irregular spherical morphology with polydispersed as depicted in Figure 5. The sample was placed under the mercury lamp for 10 minutes to dry clearly before examination. A small amount of the sample was lyophilized by spreading on a SEM grid. In the SEM analysis particle size was found between 11-80 nm and the average size was 45 nm as same as observed in the AFM analysis. There is a slight difference found in the AFM and SEM data about particle sizes. AFM size is between 11 -70 nm while the SEM is between 11-80 nm and the average was the same in both analyzed sizes. The shape of SEM images are irregular spherical patterns with different sizes and in AFM are generally found in spherical form. These size and shape variations may be due to the difference in analysis processes of each characterization technique and their impacts.

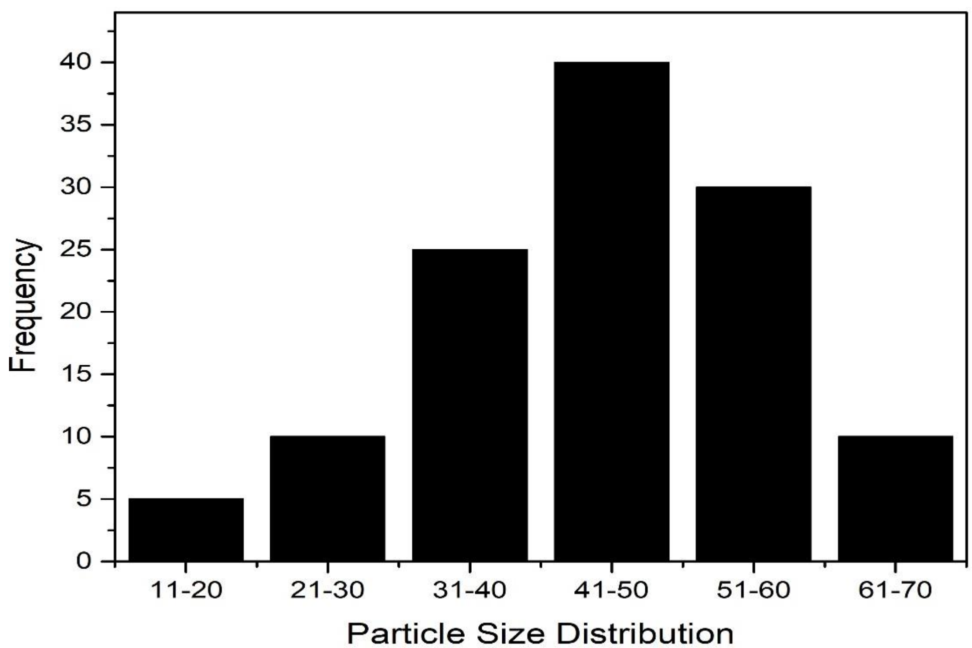

Figure 5. Particle size distribution from AFM *Desmodium elegan* mediated silver nanoparticles

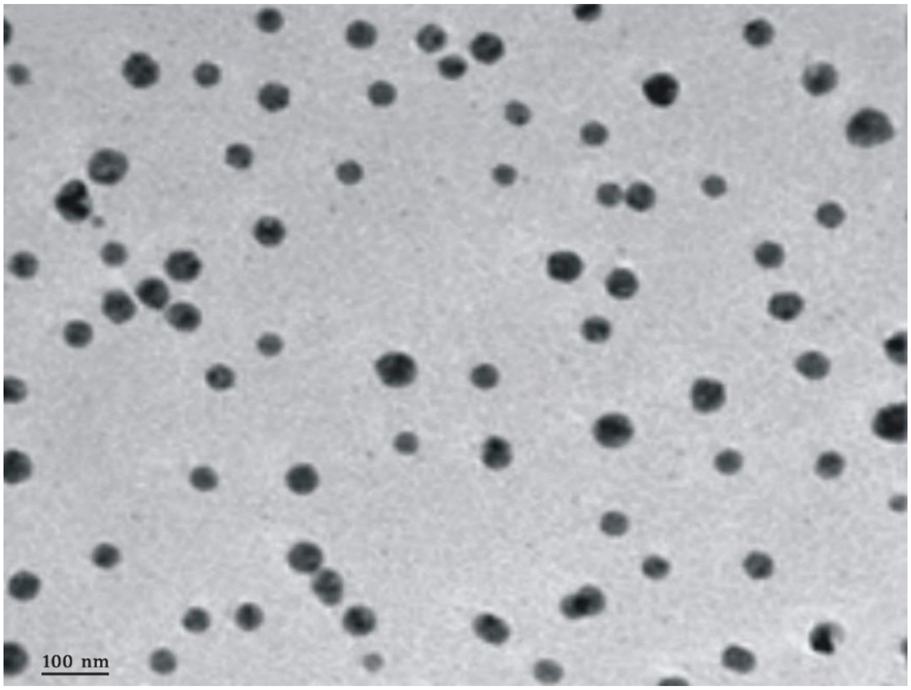

Figure 6. SEM analysis of *Desmodium elegan* mediated silver nanoparticles

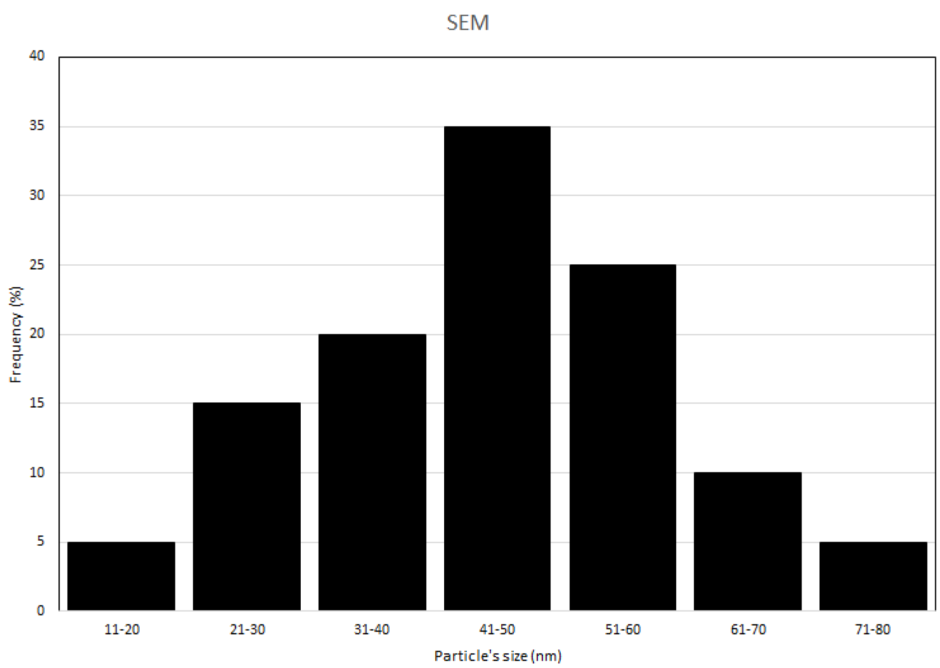

Figure 7. Particle size distribution from SEM of *Desmodium elegan* mediated silver nanoparticles

3.2 Determination of Bandgap Energy

For the determination of the bandgap energy of *Desmodium elegan* mediated silver nanoparticles, Tauc's method is incorporated. For this purpose, data obtained from the UV-visible spectrometer is utilized and analyzed using Origin. Tauc's equation is as,

$$\alpha h\nu = A(h\nu - E_g)^n$$

where A and (n) are constant and the nature of optical transition respectively. The values of (n = 2) determined the direct bandgap materials and (n = 1/2) indirect bandgap materials. The above equation can be modified as,

$$\alpha h\nu = A(h\nu - E_g)^{1/2}$$

Here, the hv represents the energy of the incident photon for the silver nanoparticles and Eg is bandgap energy. In Tauc's method, the graph known as Tauc's plot is used to determine the bandgap energy by plotting between incident photon energy (hv) and $(\alpha h\nu)^2$. Finally, bandgap energy is extracted from the tangent drawn on the plot, then it is extrapolated to the value of $(\alpha h\nu)^2$ at 0 as illustrated in Figure 8. According to the above statement, Tauc's equation will be:

$$h\nu = E_g$$

The bandgap is found with the value 2.84 eV as we can see in Figure 8 the tangent line hit the X-axis at 2.84 eV energy value with direct transition.

$$Eg = 2.84\ eV$$

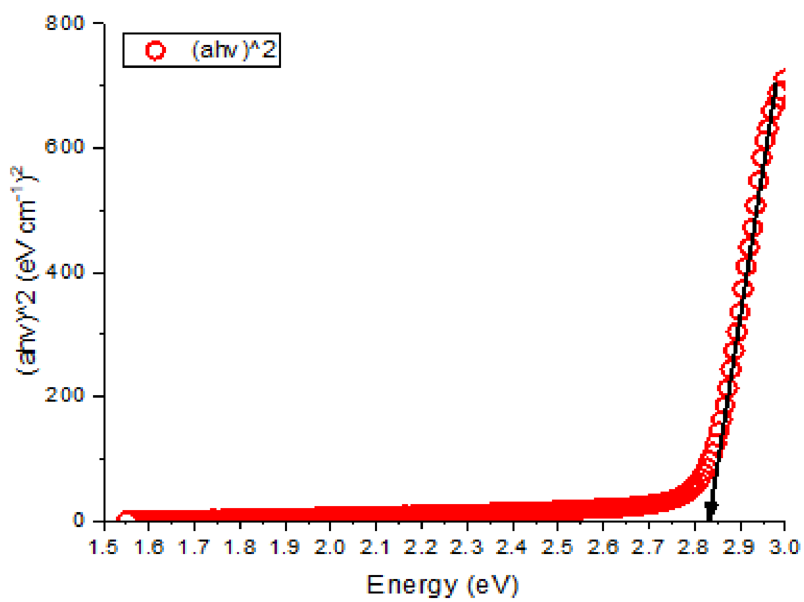

Figure 8. Tauc's plot of *Desmodium elegan* mediated silver nanoparticles

4. CONCLUSIONS

The *Desmodium elegan* plant extract is successfully used in the green synthesis of Silver nanoparticles and the plant extract effectively plays the role of deducted agent to eliminate Ag^+ ions as well as and capping agent for silver nanoparticles. The SEM and the AFM characterization revealed the morphology and particle size majority of particles were found in spherical shape while some were observed with irregular angular morphology. The average size of *Desmodium elegan* broth capping silver nanoparticles was found in the range of 45 nm and the overall size was measured 11 nm to 70 nm. The SEM and AFM characterizations revealed nearly the same size measurements. Tauc's analysis shows the bandgap energy of the *Desmodium elegan* broth capping silver nanoparticle is 2.84 eV and the UV-visible spectrum of absorption peak (SPR) accrued at 415 nm. It can be concluded the Desmodium elegan broth has a significant reducing capacity and capping capability for silver nanoparticles as compared to the chemical synthesis. The toxicity of nanomaterial also be eliminated by this technique. The prepared sample by the current synthesis technique may be used in water treatment to remove the other harmful pollutants. The degradation of water by these particles will free from any harmfully toxic effect of the reductant particles as normally other chemically synthesized particles.

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