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Preparation and characterization of silver nanoparticles homogenous thin films

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ABSTRACT

The wet chemical method by metal salt reduction has been widely used to synthesize nanoparticles. Accordingly the silver nitrate used as silver precursor and sodium borohydrate as reduction agent. The silver nanoparticles were characterized by different characterization techniques including UV–VIS spectrometry, Transmission electron microscope (TEM), and Zeta potential technique. Thin films of the colloidal solution were fabricated using direct precipitation technique on ITO glass, silicon substrate and commercial glass substrate and characterized by imaging technique. The absorption peak of the silver nanoparticles colloidal solution was around 400 nm. The TEM images indicate that the silver nanoparticles had spherical shape and their sizes were from 10 to 17 nm. The particle size of the silver nanoparticles was confirmed by Zeta potential technique. The imaging technique indicated that the homogeneous distribution of the colloidal silver solution thin film on the silicon substrate was stronger than the ITO glass and inhomogeneous film was emerged on the commercial glass.

1. Introduction

Nanostructured silver particles exhibit unique optical characteristics (Narender et al., 2013). One of the most significant current discussions in nanotechnology is the importance of Plasmonics that focuses on light manipulation at the nanoscale through exploiting surface plasmons. Recent developments in investigating the surface plasmons have heightened the need forsensing and imaging of surface binding events including photonics and chemical applications (Gao et al., 2010; Brongersma and Pieter, 2007; Stiles et al., 2008). Surface plasmons (SPs) are responsible for a variety of phenomena, including nanoscale optical focusing, negative refraction, and surface-enhanced Raman scattering (Brongersma and Pieter, 2007). (SPs) are collective charge oscillations that form when light interacts with the free conduction electrons at a metal–dielectric interface (Raether, 1988). However, the most researches in Plasmonics have normally focused on the noble metals Ag and Au owing to their absorption in the visible range. Plasmonics has attracted great attention over the last few decades due to the alluring physical mechanisms arising from the interaction of light with resonant structures at the nanometer scale (Urcan et al., 2015; Li et al., 2016). A narrow plasmonic absorption peak is suitable for surface plasmon Raman spectroscopy while, a broad one is necessary to enhance photo-absorption in solar cells (Ferry et al., 2008). Choosing of the film substrate is a very important issue in producing a high quality silver thin file for different optical applications and space technology. Using a silicon substrate was used by Tan et al. (2012) to enhance the optical trapping in silicon solar cell. On the other hand Weeber et al. (Krenn et al., 2001) used an ITO glass as a nano silver thin film. In the current study silicon, ITO glass and commercial glass substrates were used to produce a nano silver thin films. At first the silver nano particles were characterized using Uv–Vis spectroscopy and a high resolution transmission electron microscope (HRTEM) then the silver thin film was formed by direct precipitation technique. Later on the films was studied by the imaging technique to investigate the film homogeneity.

2. Experimental work

2.1. Materials

Silver nitrate ($AgNO_3$) from Alfa, Sodium borohydrate ($NaBH_4$) from Aldrish, Polyvinyl pyrrolidone (PVP) from Aldrish, were used as received and without any farther purification. Local laboratory source for deionized water was used.

2.2. Preparation

In the nanotechnology laboratory of National Reasearch Institute of Astronomy and Geophysics (NRIAG) the AgNP's was prepared (Krenn

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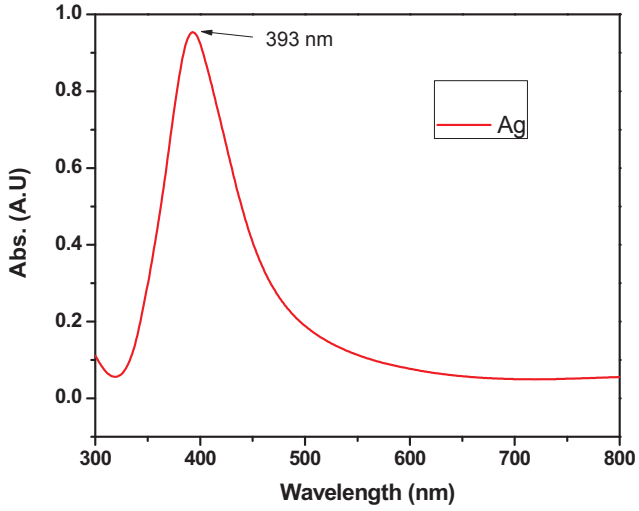

Fig. 1. The absorption spectra for the silver nanoparticles.

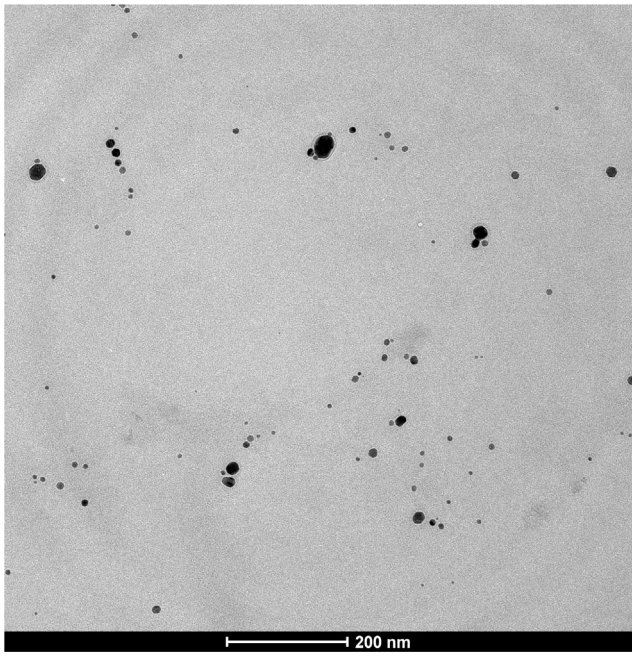

Fig. 2. The HRTEM image for the prepared PVP/Ag solution.

et al., 2001). A 5 mmol and 30 mmol of silver nitrate were dissolved in separate 50 ml flask of deionized water in ice bath. A 0.1 g of PVP was added and the solution was stirred for 30 min. A 0.0336 g of cold $NaBH_4$ solution was added dropwise onto the $AgNo_3$/PVP solution with continuous stirring. The color of the solution changed to light yellow then yellow with adding more $NaBH_4$. The color of the 30 mmol sample changed to light yellow then to dark yellow solution.

3. Characterization

A Jasco Model 730 spectrophotometer was used to carry out the absorption spectra using the sample in solution form. HR-TEM, Tecnai G20 of FEI Netherland, was used to obtain the images of the AgNP's by using a drop of the sample solution. LSD was used to measure the zeta potential.

4. Results and discussion

The prepared Ag NP's absorption spectra are illustrated in Fig. 1. The plasmonic resonance peak of the low silver precursor sample appears at 393 nm while the high silver precursor peak appears at 403 nm as explaind by Das et al.; Carlberg et al. (2016). The increases in the silver precursor increase the Ag NP's producing a red shift in the plasmonic peak. The nearly Gaussian shape of the peak indicates a good particle size distribution.

Fig. 2 shows HRTEM the image of the silver nanoparticles The HRTEM images for the AgNP's samples show the spherical shape (Huang et al., 2014) of the prepared particles in the range of 10–17 nm in addition to aggregated particles with larger size. The aggregated nanoparticles increased with the increasing the silver precursor. Fig. 3 represents the zeta LDS measurement for the PVP/Ag solution indicates and confirms the particle size distribution.

4.1. Thin film preparation

Several attempts have been made to prepare thin films using PVP/Ag colloidal solution. Hegazy et al. (2016) used thin film deposition technique to prepare Gold thin film by immersing the substrate in a solution of gold nanoparticles. Electro spining technique was successfully used by Ming to produce a PVP/Ag fibers thin film Zheng et al. (2001) showed that the spin coating technique is useful method to produce a PVP/Ag thin films. In this study direct precipitation technique was used to produce a PVP/Ag thin films on different substrate. In such method droplets of the PVP/Ag solution were applied on the surface of each substrate and left to dry in room temperature. Silicon, ITO and commercial glass substrates were used to carry out the PVP/Ag thin films. At first the substrates were cleaned by regular soap solution in an ultrasonic water bath for 30 min. followed by washing the

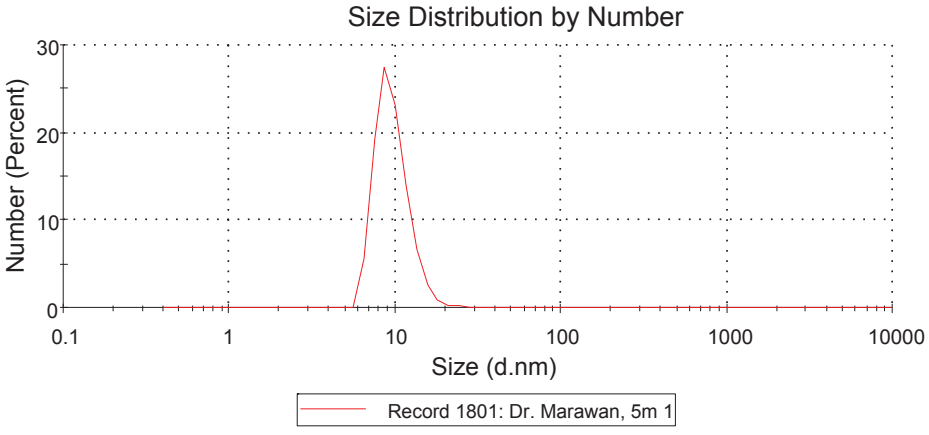

Fig. 3. The DLS measurement for the PVP/Ag solution.

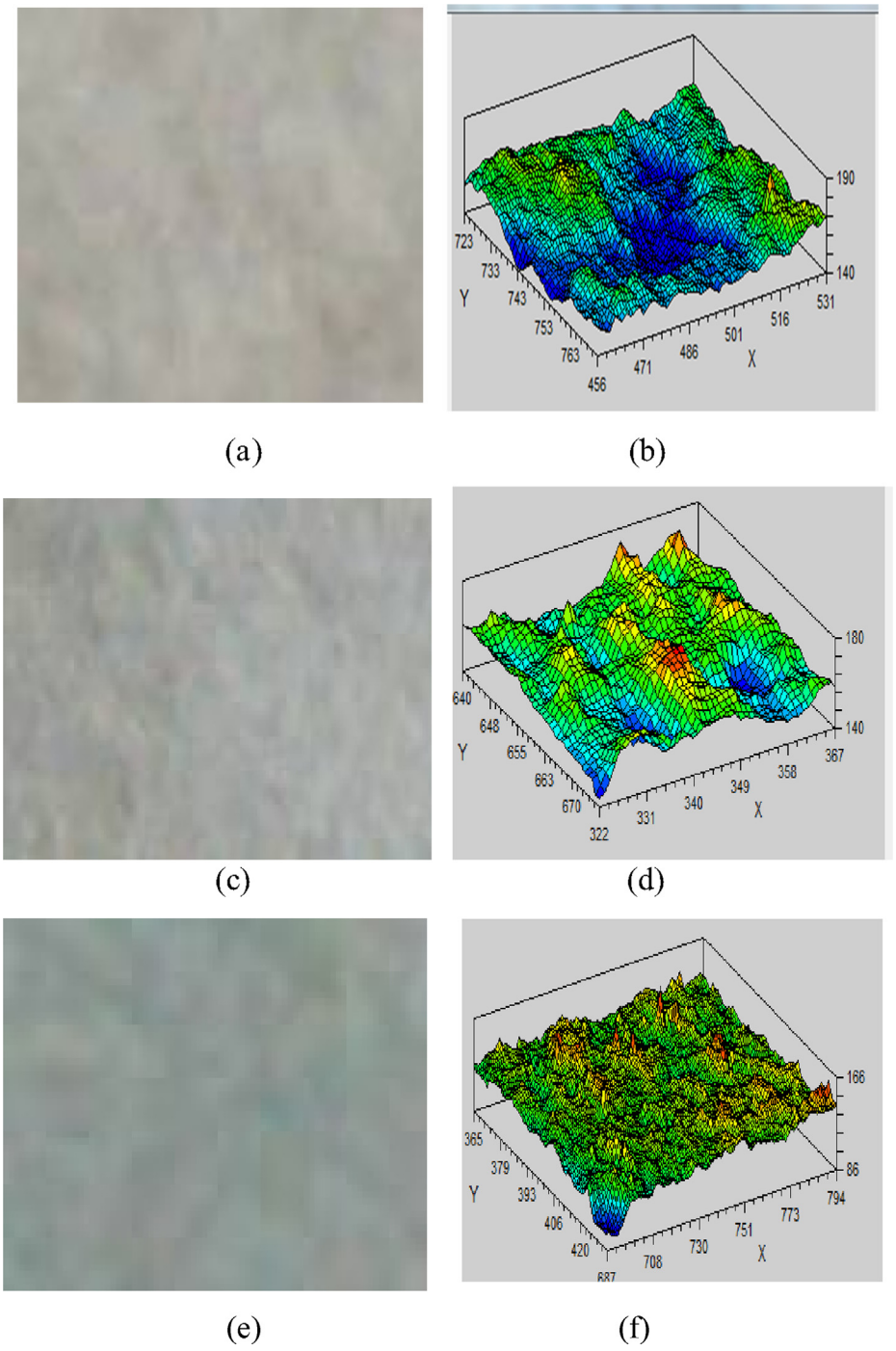

Fig.4. The image analysis for PVP/Ag thin films using optical microscope equipped with A CCD camera for Commertial Glass in (a) and (b), ITO in (c) and (d) and Silicon in (e) and (f). The figures (a), (c), and (e), are images from the CCD camera, and (b), (d), and (f), are images from the 3-D analysis.

substrates by distilled water the by ethanol. The washing process repeated many times using isopropyl alcohol instead of soap solution. Finally the substrates washed several times by distilled water. A certain volume of the PVP/Ag solution was applied onto each substrate.

4.2. Imaging of the PVP/Ag thin films

The images of the thin films were carry out using an optical microscope equipped with CCD camera (model TsVeiw 5 MP) with pixel size 2592H × 1944 V. Fig. 4a represents the image of the commercial glass substrate and Fig. 4b represents the 3-D analysis of the image using a Blue-Red scale where the blue color indicates a bottom points and the red color indicates a top points. Similarly Fig. 4c represents the image of an ITO substrate and 4d represents the 3-D analysis, and Fig. 4e represents the image for the silicon substrate and Fig. 4f presents its 3-D analysis.

In Fig. 4b, the variation of the colors indicated a poor smoothing morphology in the commercial glass substrate. In Fig. 4d the color variation indicates a medium smoothing surface morphology in the ITO substrate. On the other hand in Fig. 4f, the color variation indicates a good smoothing surface morphology in case of silicon substrate.

5. Conclusion

Thin films of PVP/Ag nanoparticles were successfully fabricated using the direct precipitation method. Commercial glass, ITO glass and silicon substrates were used. The characterization of the Ag nanoparticles indicates the size of nanoscale and the spherical shape of the produced particles. The DLS technique confirmed the size of the Ag nanoparticles. The image analysis using optical microscope equipped with a high resolution Camera indicated that the surface morphology of the silicon substrate is the best substrate for PVP/Ag thin films comparing with the commercial glass and the ITO glass. The ITO glass showed better smoothing morphology than the commercial glass but still lower smoothing than the silicon substrate.

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