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Effect of Ultrasonication on Properties of Sequential Layer Deposited Nanocrystalline Silver Thin Films

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Abstract. Nanocrystalline silver thin films were deposited by using sequential layer deposition (SLD) method with and without ultrasonication. Silver nitrate and hydrazine hydrate (HyH) were used as precursors. The deposited silver thin films were characterized by using X–ray diffraction (XRD), UV-visible-NIR absorption spectroscopy and scanning electron microscopy (SEM) techniques. XRD confirmed the formation of nanocrystalline silver with face centred cubic structure without any oxide presence. Absorption spectra reveal that for ultrasonication silver thin film dipole plasmon band get red shifted which can be assigned as increase in size. SEM and TEM images show particle size increases with ultrasonication due to increase in diffusion rate of particles onto the substrate.

Keywords: Silver, Surface plasmon resonance, SLD
PACS: 61.05.cp, 81.07.Bc, 68.35.bd, 78.66.Bz, 68.37.Hk.

INTRODUCTION

Recently due to the unique property of metal nanoparticles to show surface plasmon resonance they have various applications in optoelectronics and Surface Enhanced Raman Scattering (SERS). Silver nanostructures have various applications in solar cells, light emitting diodes, etc [1]. There are various methods for the formation of metal nanostructures like spray pyrolysis, Solid liquid interface reaction, spin coating, pulsed electro deposition, lithography, sputtering, etc.

Sequential layer deposition (SLD) method consists of sequential immersion of the substrate in alternately placed precursor solutions followed by rinsing between each immersion with distilled water to avoid reaction in the solution. It is well known that high intensity ultrasound affect chemical reaction primarily due to acoustic cavitations, i.e. the formation, growth, and implosive collapse bubbles in a liquid irradiated with ultrasound. Therefore ultrasonication can make differences in chemical reactions as well as in physical state of the films such as surface morphology. In this work effect of ultrasonication on properties of nanocrystalline silver thin films deposited by SLD method are extensively studied.

EXPERIMENTAL DETAILS

Silver thin films were deposited on glass substrates by using silver nitrate and hydrazine hydrate (HyH) as precursor solutions. The experimental procedure is given elsewhere [2]. The silver thin films were deposited using 0.1M $AgNO_3$ and 0.1M of HyH solutions. Silver thin films were deposited using SLD method with and without ultrasonication. To see effect of ultrasonication all beakers containing precursor solutions and rinsing water were kept in ultrasonic bath having frequency around 36KHz (300W). The deposited thin films were characterized by means of X-ray diffraction (XRD), using a Bruker D8 advance diffractometer. Optical absorption measurements were carried by JASCO UV-Vis spectrophotometer. Scanning electron microscopy (SEM) images were recorded using a JEOL JSM-6360A microscope with operating voltage 20 kV. Transmission electron microscopy (TEM) images were recorded using a TECNAI G^2 20U-Twin microscope with operating voltage 200 kV.

RESULTS AND DISCUSSION

Fig 1 shows XRD patterns of silver thin films deposited by using SLD method with and without ultrasonication. All the observed four peaks (111), (200), (220), (311) are exactly matched with the standard JCPDS data for silver, indicating that the silver thin films deposited with and without

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ultrasonication are of silver only with face centered cubic structure.

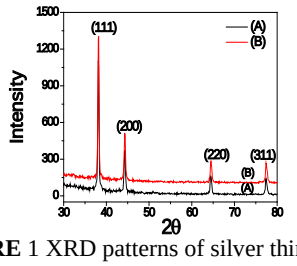

FIGURE 1 XRD patterns of silver thin films deposited using SLD method with (A) and without ultrasonication (B)

Fig. 2 (A and B) shows the optical absorption spectra of silver thin films deposited using SLD method with and without ultrasonication. Two surface plasmon peaks are apparent from the absorption spectra. The peak appeared in the region from 436 to 454 nm can be assigned to dipole plasmon band, whereas other peak in the region from 363 to 371 nm can be assigned to quadrupole plasmon band of nanocrystalline silver [1].

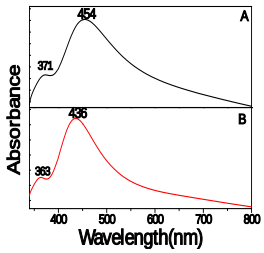

FIGURE 2 UV VIS absorption spectra of silver thin films deposited with (A) and without ultrasonication (B)

Furthermore, it is observed that the SPR peak due to dipole plasmon band gets red shifted to 454 nm from 436 nm for the films deposited with ultrasonication, indicating increase in particle size.

Fig 3(A and B) shows SEM images of silver thin films deposited using SLD method with and without ultrasonication. It is evident from the SEM images that ultrsonication significantly affect size and distribution of Ag nanoparticles.

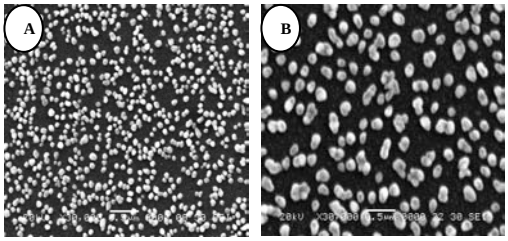

FIGURE 3 SEM images for silver thin films deposited (A) without and (B) with ultrasonication

Fig 4 shows TEM images, selected area diffraction (SAED) pattern of silver thin films deposited with and without ultrasonication. From TEM images it is observed that with ultrasonication particle size of silver nanoparticles increases. From SAED pattern it is observed that all the d values exactly match with standard JCPDS data for silver. The film of ultrasonication having bigger average particle size with wide size distribution compare with the film deposited without ultrasonication (Fig 4E and F).

The increase in size and decrease in density because of ultrasonication can be explained as follows: Because of ultrasonication faster diffusion of the Ag nanoclusters, formed after reduction of Ag^{2+} ions, on the surface of substrate resulted into bigger particles due to agglomeration. On the contrary, without ultrasonication slower diffusion of Ag nanoclusters resulted into smaller particles. As the concentrations of precursor solutions were same for both depositions, we believe the amount of Ag deposited on the substrate in both depositions should be same and therefore increase in size tend to decrease in density of Ag nanoparticles in the films deposited with ultrasonication.

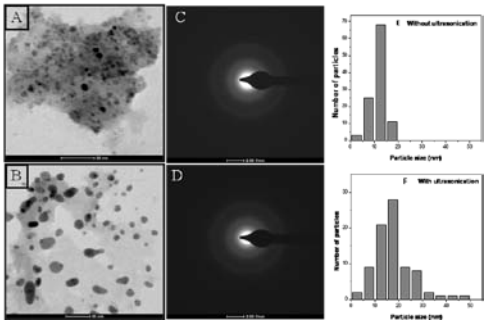

FIGURE 4 TEM images, SAED pattern and particle size distribution for silver thin films deposited without (A, C, E) and with ultrasonication (B, D, F) respectively

CONCLUSIONS

In the present work nanocrystalline silver thin films were deposited by using SLD method with and without ultrasonication. Solution of $AgNO_3$ and HyH were used as precursors. XRD confirmed the formation of nanocrystalline silver with face centred cubic structure. UV-VIS absorption, SEM and TEM measurements reveal that the films deposited with ultrasonicaton consists of bigger size of silver nanoparticles with less density. It is due to faster diffusion of particles takes place in presence of ultrasonication.

ACKNOWLEDGMENTS

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