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Structural, Optical and Electrical Properties of SilverNanoparticlesDeposited by Spin Coating Method

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Abstract

In this study, silver nanoparticles were synthesized by chemical reduction method at different concentrations of Ag colloid in the range of 500-16000 ppm. Nanoparticles were deposited by spin coating method on pre-etched glass and Si substrates. Structural, optical and electrical properties of the samples were studied using Scanning Electron Microscopy equipped with EDAX, UV-Vis spectrophotometry and four-point probe. Particles size was determined according SEM results and was compared for two different substrates.

1. Introduction

Nanoparticles are one of the building blocks of nanotechnology and play an important role in many fields. Among the metal nanoparticles, silver nanoparticles have a broader range of applications. Some important features of silver nanoparticles include optical, catalytic, and anti-bacterial properties [1- 6].

Different methods for synthesis of nanoparticles have been used [7-11]. Here, chemical reduction method was used, due to simplicity and inexpensively[12,13].Thereare different parameters that can be important in the spin coating method. In this experiment, concentration of Ag colloid and also substrate effect have been studied respectively [14- 16].

2. Experimental procedure

Silver nitrate salt (supplier of silver ions), sodium borohydride (reducing agent) and polyvinyl-pyrrolidone (stabilizers) with adequate

values were used to achieve the desired concentration values of 500-16000 ppm (Table 1).

$$AgNO_3 + NaBH_4 \rightarrow Ag + \tfrac{1}{2} H_2 + \tfrac{1}{2} B_2H_6 + NaNO_3$$

Silicon wafers and pre-etched glass substrates with a thickness of 1 mm (1 cm × 1 cm) were cleaned ultrasonically. For the deposition, spin-coating method was used. Initially, the device was cleaned with alcohol and substrates were located in their holder. In the coating process, 0.15 ml Ag colloid of a chosen concentration was placed on the substrate and dispersed uniformly. The samples were rotated at 3000 rpm for 30 seconds and finally were dried in the air at room temperature. This process was repeated three times per sample.

Table 1: Ag colloidal concentration, in the range of 500 – 16000 ppm.

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Concentration (ppm)	$AgNO_3$ (mol)	$NaBH_4$ (mol)	PVP (gr)	H_2O (liter)
500	0/0400	0/0081	0/093	1
1000	0/0812	0/0162	0/187	1
2000	0/1625	0/0325	0/375	1
4000	0/3250	0/0650	0/750	1
8000	0/7500	0/1300	1/500	1
16000	1/5000	0/2600	3/000	1

3. Results and discussion

In order to investigate the morphological properties of the samples, we used Scanning Electron Microscope equipped with EDAX. Particle sizes were also measured on SEM images.

For optical measurements, UV-Vis absorption spectra were used and for electrical properties Four-point probe was used.

Fig.1 shows the surface morphology of the samples at different concentrations of 2000, 4000 & 8000 ppm on glass and Si substrates. An EDAX spectrum for the sample on Si substrate and 4000 ppm is shown on Fig.2.

From SEM images, we can see at low Ag colloid concentrations, the nanoparticles are dispersed on the surface. By increasing the concentration, the nanoparticles packed to a multi-layer structure with a shiny surface.

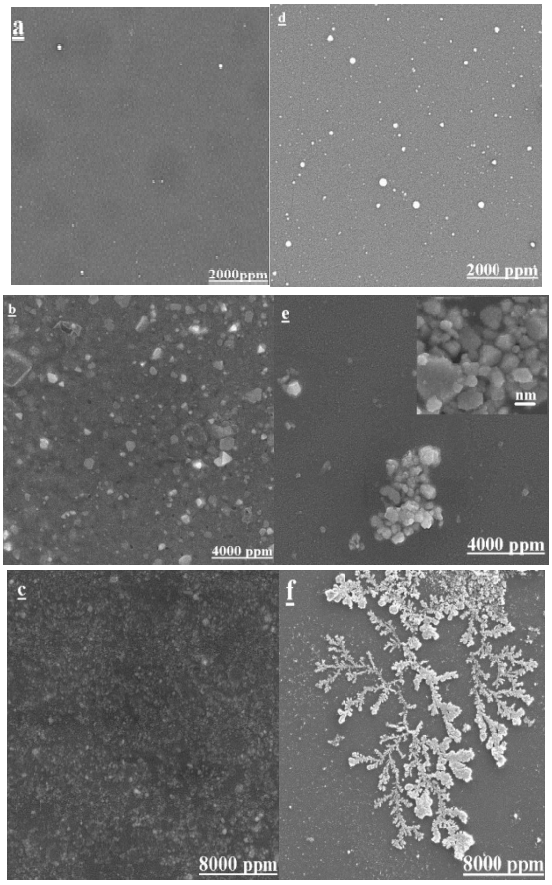


Fig.1.SEM images of Ag nanoparticles on Glass (a-c) and Si (d-f) substrates.

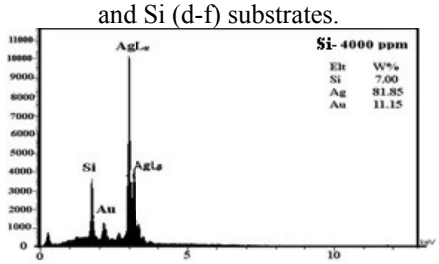


Fig.2.EDAX spectrum of Si substrate at concentration of 4000 ppm.

The average particle size was measured on Scanning Electron Microscope images. At lower concentrations, the average particle size is about 10-12 nanometers and increases to the range of micrometer at higher concentrations. The results of particles size measurement are given (on Fig.3) for

4000 ppm on glass and Si substrate. In both cases, the distribution is approximately Gaussian.

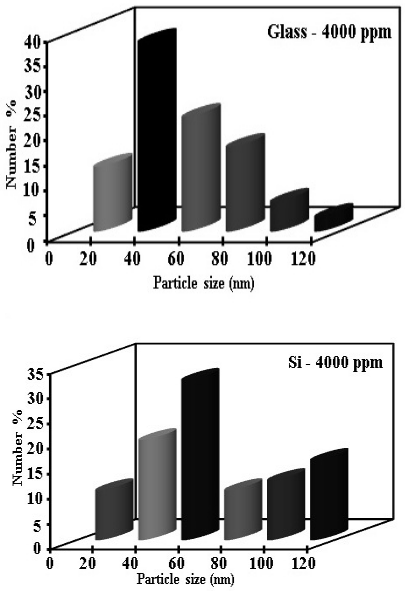


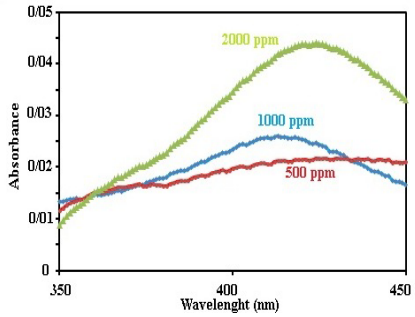
Fig.3. Particle size distribution of colloid on glass and Si substrate at concentration of 4000 ppm.

As can be seen from the Fig.3 the average particle size on glass was about 20-40 nm whereas on Si it was 40-60 nm.

The size of nanoparticles coated on Si substrate is larger than the later on glass. It can be due to Si hydrophilic properties.

Perhaps, the most important and widely used properties of the metal nanoparticles are their optical features and the dependency to the particles size. This is very important in the optical devices, sensors and diagnostic capability.

Change in particle size and locations of the absorption peaks according to the concentration of silver nanoparticles are shown in Fig.4.



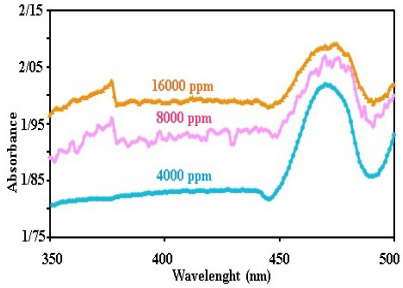


Fig.4. UV-Vis absorption spectra of silver nanoparticles at different concentrations.

We can see that by increasing the amounts of silver nitrate as a precursor, the size of particles increases and Plasmon absorption peak is displaced towardlonger wavelengths (414 nm to 474 nm) and surface to volume ratio increases accordingly.

These results are in good agreement with the results of SEM images.

The electrical resistivity of the samples was also measured by Four-Point probe. The results show that increasing the concentration leads to decreasing the electrical resistance (The electrical conductivity increases).

Electrical resistance versus concentration is plotted for two different substrates in Fig.5.

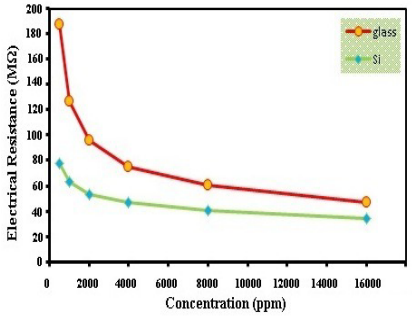


Fig.5. Electrical resistance versus concentration curve for glass and Si samples at differentconcentrations.

From the Fig.5,we can see that electrical resistance of Si samples is less than glass. Conductivity of Si is larger than glass,and this may also be dependent on particle size. We saw that the particle size on the Si substrates was larger than glass substrates.

4. Conclusion

Silver nanoparticles were synthesized at different concentrations of Ag colloid by chemical reduction method. Here,the effect of initial concentration of silver nitrate and also substrate material were studied.

At low concentrations, nanoparticles were highly dispersed and small in size.At higher concentrations, they were agglomerated on the surface. By changing the concentration, particle size increases and absorption peak shifts toward longer wavelengths and absorption intensity increases. This is due to better dispersion of nanoparticles and higher surface to volume ratio. Four point probe study of the samples show that by increasing the concentration and particle size, electrical resistance decreases.

The study of nanoparticles size on silicon and glass substrates show that the size of the particles on silicon substrate is bigger than glass substrate.It can be due to hydrophilic property of silicon which ismore than the glass. According to our study, the size of nanoparticles for a constant concentration on silicon substrate is larger than the glass, whereas the electrical resistance for silicon is less than glass.

In general it can be concluded that the properties of nanoparticles is dependent on the concentration and substrate material which requires further investigation.

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