Fast and Facile Synthesis of Stable and Biocompatible Silver Nanoparticles Stabilized by Polyethylene Glycol

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ABSTRACT

The role of green synthesis methods of nanoparticles is very significant in the field of nanotechnology. Herein, we report, the synthesis of stable and biocompatible silver nanoparticles by a fast and facile, one-step process involving polyethylene glycol. Silver nanoparticles show enhanced properties, when supported on a substrate and incorporated into an organic or inorganic matrix. Silver nanoparticles were prepared using silver nitrate ($AgNO_3$) as a precursor in an aqueous solution of polyethylene glycol (PEG) which acted as both a reducing and stabilizing agent. The reducing reactivity of PEG is sensitive to its molecular weight, thus a study has been made on establishing the optimum length of PEG that exhibits maximum reducing abilities. Therefore, different molecular weight PEG, ranging from 200 to 8000 daltons have been be tried. Ethylene glycol and PEG 200 were used as a reducing agent and were found to be ineffective in their role in synthesis of silver nanoparticle even at high temperatures (> 150° C). However, under the same conditions, PEG 1000 was able to reduce Ag^+ to silver nanoparticles. Further studies demonstrated that the reducing properties of PEG increased with the chain length of the polymer chain of PEG. The size of the nanoparticles depended on the reaction temperature and concentration of the precursor apart from the chain length of PEG. The properties of the synthesized silver nanoparticles were studied at different reaction times. The ultraviolet-visible spectra were in excellent agreement with the obtained nanoparticle studies performed by scanning electron microscopy (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM) and size distributions. The silver nanoparticles were characterized by using Fourier transform infrared

(FT-IR) and zeta potential measurements. The use of biocompatible reagents, such as PEG provides green and economic features to this work.

Keywords: size controlled silver nanoparticles, green synthesis, polyethylene glycol

1 INTRODUCTION

Silver nanoparticles show enhanced properties, when supported on a substrate and incorporated into an organic or inorganic matrix. Their remarkable properties are shape and size dependent. Of late, a large number of research projectes have been focused on the control of the size of the nanoparticles by trying different substrates, metals salts and reducing agents [1]. The use of PEG 400 and PEG 600 as an effective way of the controlling size and shape of copper nanoparticles has been reported [2]. There have been reports on the use of ethylene glycol as reducing agents where the substrate was PVP. The reducing properties of ethylene glycol have also been reported [3].

Ethylene glycol and its polymers are environmentally benign materials and have wider biomedical applications as compared to the other reducing agents such as hydrazine, dimethyl formamide, sodium borohydride etc. that are used in the preparation of silver nanoparticles.

In this paper the role of PEG as a reducing as well as stabilizing agent has been studied. The reducing activity of PEG is sensitive to its molecular weight. Thus a study has been made on establishing the optimum length of PEG that exhibits maximum

reducing abilities. Apart from molecular weight of PEG, weight of the metal precursor, viscosity and reaction temperature are some other variables that will establish the size of the nanoparticles. Thus, different molecular weight PEG, ranging from PEG 200 to PEG 8000 have been tried**.**

2 EXPERIMENTAL

2.1 Preparation of silver nanoparticles

Silver nitrate ($AgNO_3$) in different weight percentages ranging from 1 wt. %, 2.5 wt. %, 5.0 wt. % to PEG were refluxed and stirred constantly at 80° C for 1 hour to obtain colloidal silver nanoparticles. Accurately weighed silver nitrate was dissolved in 2 mL of water. PEG solid flakes were heated in a water bath until PEG melted into a viscous liquid in the reaction flask. This was followed by the drop wise addition of Silver nitrate solution in molten PEG. This mixture was then refluxed under constant stirring for 1 hour at 80°C. Nitrate ions were washed off the obtained colloidal dispersion by distilled water centrifugation at 12000 rpm for 15 minutes.

3 CHARACTERIZATION STUDIES

3.1 UV-Visible Spectroscopy

UV-visible spectroscopy was performed with measurements range between 300-700 nm at room temperature. The solution for UV-Visible measurements was obtained by dissolving 1 mL of the mixture of PEG-silver nanoparticles in dichloromethane (0.3 g/10 mL) by a double beam UV-Visible spectrophotometer (Cary100, Varian) at a resolution of 1nm.

3.2 Scanning electron microscopy (SEM)

SEM studies were performed by Zeiss EVO 50 variable pressure Scanning Electron Microscope (SEM) with digital imaging and EDS to study the size and shape of the silver nanoparticles synthesized.

3.3 Transmission Electron microscopy (TEM)

The morphology of the synthesized silver nanoparticles was observed by a Zeiss EM 10 Transmission Electron Microscope (TEM) operating at 50kV. TEM samples were prepared by drop-casting dispersion of silver nanoparticles on carbon-coated copper grids, which were allowed to dry at room temperature.

3.4 Fourier-Transform Infrared Spectroscopy (FT-IR):

FT-IR (Perkin-Elmer, Germany) was used to characterize the surface–structure of Ag nanoparticles and the spectra were scanned in the range of 400-4000 cm^{-1} range at a resolution of 4 cm^{-1}.

3.5 Zeta Sizer

Zetasizer Nano Z (Malvern) was used for zeta size and zeta potential analysis. Zeta size gives an average size distribution over the size range of the nanoparticles and Zeta potential provides information on the stability by analyzing agglomeration tendencies of the nanoparticles in a solution.

4. RESULTS AND DISCUSSION

The first signs of formation of silver nanoparticles were visually observed by the color change of the reaction solution. Color changes occurred due to excitation of surface plasmon resonance (SPR) in the silver nanoparticles formed during the reaction. Absorption peak at 406 nm is characteristic of SPR of silver nanoparticles. The intensity of the peak increased with increase in concentration of the metal precursor as shown in Figure 1. The spectra of the silver nanoparticle synthesized showed strong SPR near 416, 427 and 412 nm for PEG 8000, PEG 2000 and PEG 1000 respectively (Figure 2). These bands are considered to be in the ideal wavelength range for silver nanoparticle colloidal solutions. The absorbance intensity provides insight into the reduction of Ag^+ and productivity of each method.

Figure 3 and Figure 4 shows SEM and TEM images of silver nanoparticles synthesized by using PEG. The shape of the nanoparticles is predominantly spherical and size observed is in agreement with zeta size and zeta potential data (Fig 5 A and 5 B)

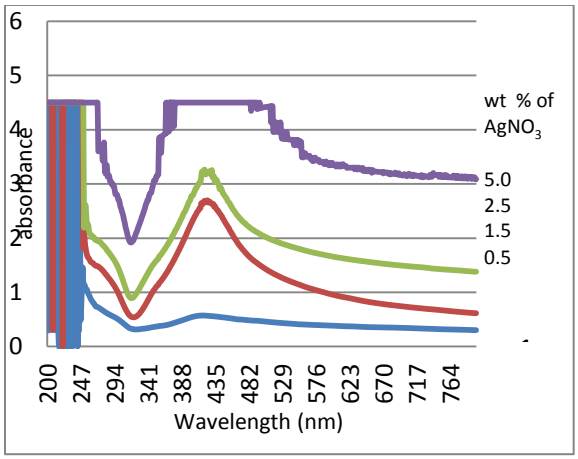

Figure 1: Absorption peak at 406 nm is characteristic of surface Plasmon resonance of silver nanoparticles. Weak Plasmon peak developed showing Ag nanoparticles developed at relatively low concentration. Shoulder developed with slight increase in concentration at 315 attributes to Plasmon resonance of bulk silver/ Ag.

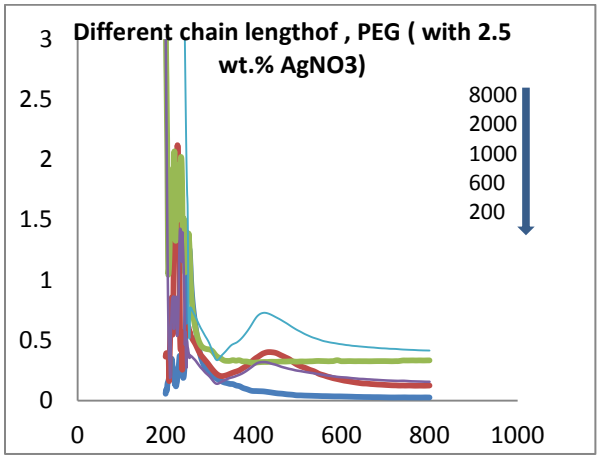

Figure 2: The effect of the chain length of PEG in the formation of silver nanoparticles.

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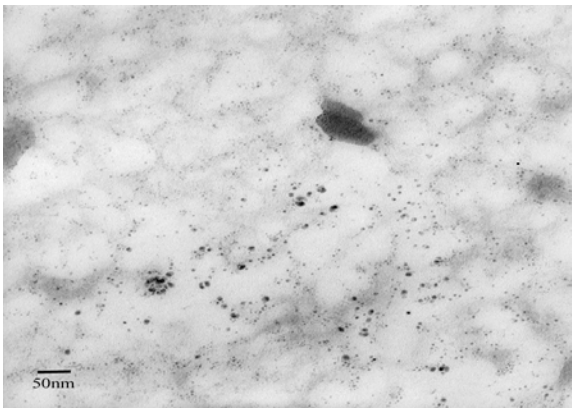


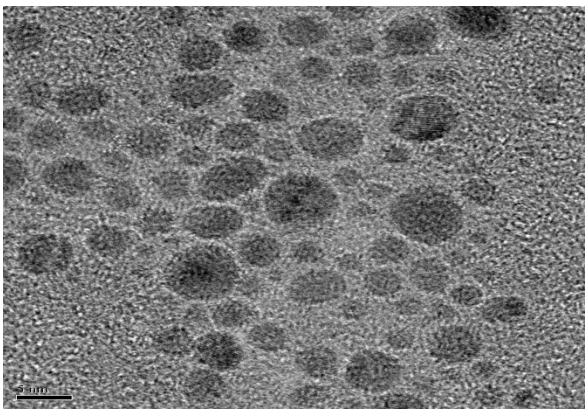
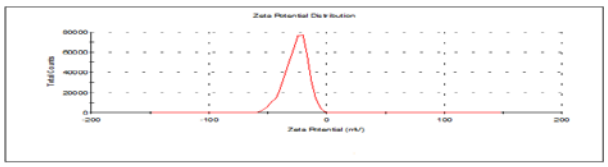


Figure 3 and 4: SEM (above) and TEM (below) micrographs of silver nanoparticles prepared in PEG 2000 at 80°C for 3 h. The average size of silver nanoparticles is < 5 nm.



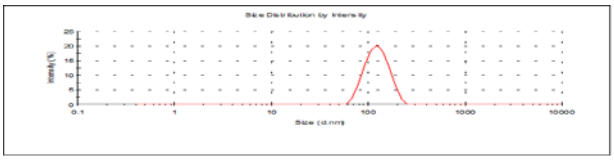


Figure 5: Zeta Size (A) and Zeta Potential (B): Zeta size data gives size distribution over the size range of the silver nanoparticles and Zeta potential results showing high stability and low agglomeration tendencies of the silver nanoparticles in a solution.

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