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Preparation of silver nanoparticles by gamma Irradiation method using chitosan as stabilizer

Nguyen Tan Man, Le Hai, Le Huu Tu, Tran Thu Hong, Nguyen Duy Hang, Pham Thi Le Ha, Tran Thi Thuy,Tran Thi Tam, Nguyen Trong Hoanh Phong, Le Xuan Cuong

Nuclear Research Institute, Nguyen Tu Luc Street, Dalat, Vietnam

E-mail: nguyen_tanman@hotmail.com

Abstract: Silver nanoparticles were prepared from (Ag^+) aqueous solution by the method of γ-ray irradiation using chitosan as stabilizer. The saturated conversion dose ($Ag^+ \rightarrow Ag^o$) determined by UV-Vis spectroscopy was found to be about 16 kGy. The UV-Vis spectrum showed that an absorption peak at λ_{max} = 400 nm due to surface plasma resonance. The image of transmission electron microscopy (TEM) showed that the silver nanoparticles were mostly spherical in shape and the average diameter was of about ~ 12 nm. The prepared colloidal silver nanoparticles solution was in good stability during storage time.

Keywords: *γ-ray irradiation, silver nanoparticles, chitosan*

I. INTRODUCTION

Silver is known as a powerful disinfecting agent for killing microorganisms. In addition to silver, although heavy metals, such as copper or zinc, may exert the same action, silver has the strongest antimicrobial effects. Various inorganic materials doped with silver nanoparticles (AgNPs) and used as antimicrobial agents have been intensively developed [1-3].

Silver in an ionic state exhibits high antimicrobial activity. However, ionic silver can be disadvantageous because it is unstable due to its high reactivity and thus easily oxidized or reduced in to a metal depending on the surrounding atmosphere. Silver in form of a metal or oxide, which is stable in the environment, may be disadvantageous because it is undesirably used in a relatively increased amount due to its low antimicrobial activity [3-6].

Silver, having the above advantages and disadvantages, is presently receiving attention in the form of nanoparticles. Various methods of preparing the nanoparticles include mechanical grinding, co-precipitation, spraying, electrolysis, etc. However, these methods are disadvantageous because the size of the particles formed is difficult to control, or high cost is required to prepare fine metal particles. For example, the sizes, shapes and size distribution of the particles are impossible to control in the co-precipitation method, since the particles are prepared using an aqueous solution.

Method of preparing nanometer sized particles using gamma radiation from Co-60 source has many advantages because sizes, shapes, and size distribution of the particles

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are easily controlled, and the particles can be prepared at room temperature. Also, preparation processes are suitable and efficient [1-6]. In this paper, colloidal AgNPs solution was prepared by gamma Co-60 irradiation method using chitosan as stabilizer.

II. EXPERIMENTAL

A. Chemical

Silver nitrate and acetic acid were purchased from Merck, Germany. Chitosan with deacetylation degree of about 90% and weight average molecular weight (M_w) of about 100 kDa was prepared at Nuclear Research Institute, Dalat. Distilled water was used in all experiments.

B. Sample preparation and irradiation

Chitosan solution (1%) was prepared in acetic acid solution (0.5%). A required amount of $AgNO_3$ was dissolved in chitosan solution to obtain concentration of 5×10^{-3}M $AgNO_3$. The mixture $AgNO_3$/chitosan solution was bubbled with pure nitrogen gas for about 15 min. to remove oxygen and then irradiated on a γ-ray Co-60 source (GC-5000, BRIT, India) with dose up to 20 kGy and dose rate of 3.2 kGy/h at Nuclear Research Institute, Dalat.

C. Characterization of AgNPs

The UV-Vis spectra of the prepared AgNPs solution (diluted 100 times by distilled water) was recorded by UV/Visible Spectrophotometer, UV mini-1240, Shimadzu, Japan. Distilled water was used as reference.

The size and size distribution of AgNPs were obtained from TEM photographs by JEM 1010, JEOL, Japan.

The stability of the prepared colloidal AgNPs solution was investigated by measuring optical density (OD) and maximum absorption wavelength (λ_{max}) during storage time.

III. RESULTS AND DISCCUSION

In the radiolysis method, aqueous solutions exposed to gamma radiation creating solvated electron. These solvated electrons reduce the silver ions. The irradiation-reduction processes can be written as follows [5]:

$$H_2O \rightarrow e_{aq}^- + H^\bullet + OH^\bullet + H_3O^+ + H_2$$

$$Ag^+ + e_{aq}^- \rightarrow Ag^o$$

As in the aqueous solution hydrogen atoms formed by radiolysis process can also reduce the Ag^+ ions. The neutral atom Ag^o reacts with Ag^+ ions to form the relatively stabilized Ag clusters such as:

$$Ag^o + Ag^+ \rightarrow Ag_2^+$$

$$Ag^+ + Ag_2^+ \rightarrow Ag_3^+$$

And then such clusters are further reduced to form the AgNPs. In this study, chitosan was used as stabilizer to prevent the formulation of larger particles in the solution.

In metal nanoparticles, electrons give rise to a surface plasma resonance (SPR) absorption band, due to the collective oscillation of electrons of AgNPs in resonance with the light wave. When the frequency of the electromagnetic field becomes resonant with the coherent electron motion, a strong absorption takes place. This absorption strongly depends on the particle size, dielectric medium and chemical surroundings. The UV/Vis absorption spectrum of the AgNPs solution was shown in Fig. 1. The absorption peak was obtained at wavelength of 400 nm which is typical for AgNPs [7].

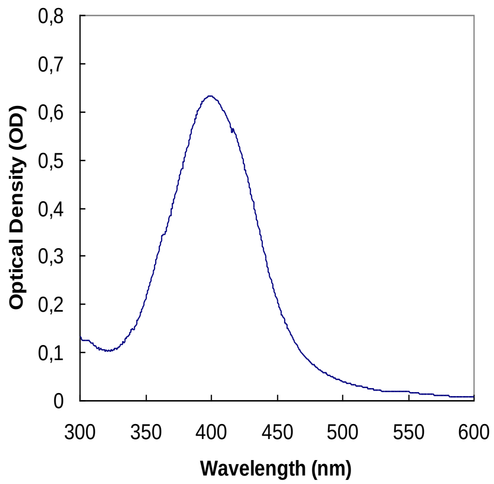

Fig. 1. The UV-Vis absorbance spectrum of AgNPs solution

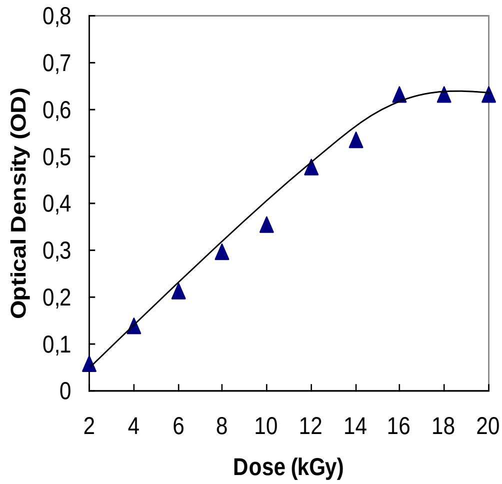

Fig. 2. The dependence of OD value of irradiated Ag^{+} 5×10^{-3}M solution on dose

The dependence of optical density (OD) of irradiated Ag^{+} solution on dose was shown in Fig. 2. It indicated that the OD increased with increasing absorbed dose and attained the saturated value at dose of 16 kGy for Ag^{+} 5×10^{-3}M concentration. In the previous study of Phu et al. on the synthesis of AgNPs in chitosan by γ-irradiation, the saturated conversion dose at 16 kGy for 5 mM of Ag^{+} concentration was also reported [8].

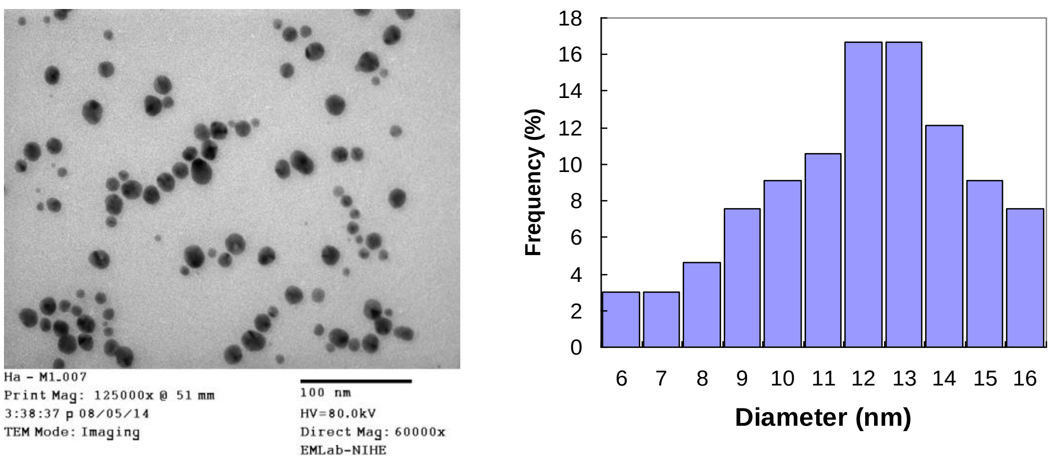

Fig. 3. TEM image and size distribution of silver nanoparticles

TEM image and size distribution of the prepared silver nanoparticles were shown in Fig. 3. The AgNPs were mostly spherical in shape. The average diameter of AgNPs was calculated to be approximately 12 nm.

The change of maximum absorption wavelength (λ_{max}) and optical density (OD) of the AgNPs solution with storage time at ambient temperature was shown in table 1. It was clear that the λ_{max} and OD values were

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almost not changed with the storage time for more than three months. This indicated that the prepared colloidal AgNPs solution was in good stability.

Table I: Change of λ_{max} and OD of the AgNPs solution with storage time

Time (days)	1	3	5	10	15	20	25	30	40	60	90	100
OD	0.633	0.631	0.632	0.633	0.630	0.629	0.632	0,630	0.640	0,638	0.641	0.642
λ_{max} (nm)	400	400	400	400	400.5	400.5	400	401	401	401.5	401	401.5

IV. CONCLUSIONS

The colloidal AgNPs solution was successfully prepared by γ-irradiation method using chitosan as stabilizer. The saturated conversion dose ($Ag^+ \rightarrow Ag^o$) determined by UV-Vis spectroscopy was about 16 kGy for Ag^+ 5×10^{-3}M. The average diameter of the AgNPs was of about 12 nm. The prepared colloidal AgNPs solution was in good stability. The γ-irradiation method has been considered as a suitable and efficient method for synthesis of metal nanoparticles particularly AgNPs.

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