CHAPTER V

PREPARATION OF SILVER NANOPARTICLES IN SURFACTANT SOLUTION

The physicochemical properties of Ag nanoparticles have been determined by the nature of the used chemical reductors. The reported procedures describe the reduction of silver ions using N-Phenylbenzohydroxamic acid (PBHA) and ascorbic acid individually. The influencing factors including cationic, anionic, zwitterionic and non-ionic surfactants have been studied. Effect of pH and reducing agent concentration have also been investigated in detail.

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5.0 INTRODUCTION

Nanoparticles have been the focus of intense research activities not only because of its unusual behavior compared to the bulk materials but also for its innumerable applications in the practical world\textsuperscript{1-10}. Nanoparticle research has become the subject of novel interest in science and technology. Nanoparticles have important technological applications, such as in catalysis\textsuperscript{11-13}, microelectronic devices\textsuperscript{14}, high-performance ceramic materials\textsuperscript{15}, and more recently they have been used in cancer treatment\textsuperscript{16-18}. Now a days there has been an increasing attention of researchers throughout the world to improve the detoxification using nanocatalysts for chemical and biological warfare agents\textsuperscript{19-22}.

The synthesis of metal nanoparticles of desired size and shape has enormous importance in nanotechnology because of their characteristic size and shape dependent optical, electronic and chemical properties\textsuperscript{23-44}. The nanoscale particles possess a very large surface-to-volume ratio and consequently the properties are mostly governed by the surface states. Surfactant plays an extra role over particle stabilization\textsuperscript{45-50}. Although some very effective methods are available for the synthesis of metal nanoparticles, the simplest and the most commonly used bulk-solution synthetic method for metal nanoparticles is the chemical reduction of the metal salts. The particle synthesis usually make use of a soluble metal salts, reducing agent and a stabilizing agent\textsuperscript{51-52}. Surfactants have been employed as stabilizers or capping agents. They decrease the surface energy, control the growth
and shape of the particles and to prevent aggregation. Reducing agents such as sodium borohydride, sodium citrate, ascorbic acid and alcohol are commonly used for the preparation of metal nanoparticles.

Silver (Ag) nanoparticles have received much more attention in recent years due to their unique physical and chemical properties and their important roles in different areas viz., photography\(^5\), catalysis\(^{54-55}\), electronics\(^5\), surface-enhanced Raman scattering (SERS)\(^{57-58}\), chemical analysis\(^5\), bioanalysis\(^{60}\), anti-microbial activities\(^{61-62}\), etc. It is the most frequently studied cheapest noble metal in this field. Therefore, due to their promising potentials and already realized applications, the efforts to develop synthetic methods, which permit to obtain ultrafine particles, have been increased\(^{63-82}\).

5.1 REVIEW OF THE EARLIER WORK

Nanostructure science and technology is a broad and interdisciplinary area of research and development activity that has been growing explosively worldwide in the past few years\(^{83-88}\). Canamares and co-workers\(^9\) prepared two different silver colloids by chemical reduction of silver nitrate with trisodium citrate and hydroxylamine hydrochloride to compare their characteristics in relation to their possible use in surface-enhanced Raman scattering (SERS) spectroscopy.

Xu et al.\(^9\) synthesized Silver nanowires by the hydrothermal route in aqueous solution of gemini surfactant 1,3-bis(cetyldimethylammonium) propane dibromide (16-3-16) at a relatively low temperature. The obtained silver nanowires are of high aspect ratios with an average diameter of \(~30\) nm and length ranging from several to tens of micrometers.
Husein and his group\textsuperscript{91} prepared AgBr nanoparticles from their bulk AgBr powder as a precursor using CTAB microemulsions. This approach is aimed at minimizing the impact of the surfactant surface layer opening, and the limits on ionic reactant solubilization capacities. The formation of the nanoparticles is based on a reaction between the surfactant counterion and the solid powder, which results in the solubilization of the solid, followed by reprecipitation of the soluble species in the water pools as nanoparticles. The same method was previously applied by their group for the preparation of AgCl nanoparticles starting from bulk AgCl powder\textsuperscript{92}.

Mirkin \textit{et al.}\textsuperscript{93} developed a method for synthesizing stable DNA-functionalized silver nanoparticles that exhibit distance-dependent optical properties and highly cooperative binding properties, as demonstrated by sharp melting transitions. This method takes advantage of the strong affinity of multiple cyclic disulfide-anchoring moieties for the silver nanoparticle surface.

Recently, Franchini \textit{et al.}\textsuperscript{94} synthesized highly monodisperse and stable cobalt ferrite (CoFe\textsubscript{2}O\textsubscript{4}) nanoparticles coated with mono- and bifunctional phosphonic and hydroxamic acids in diethylene glycol (DEG) without any surfactants. They showed that these coated cobalt ferrites are promising nanomaterials for hyperthermic applications since, due to their different magnetic properties, smaller particles, compared to magnetite, can be used.

\textbf{5.2 PRESENT INVESTIGATION}

In the present work, we have used \textit{N}-substituted hydroxamic acid i.e. \textit{N}-Phenylbenzohydroxamic acid (PBHA) (I) and L-ascorbic acid for the preparation of
Ag nanoparticles. The particles were characterized by UV-visible spectroscopy and Transmission electron microscopic (TEM) studies. TEM image of the particles generated by this procedure gives a conclusive idea about their size and shape in solution. This is the first report where PBHA has been exploited. The results open up interesting perspectives on new routes to nanostructured silver material using hydroxamic acids.

\[ \text{N-Pheny}1\text{lbenzohydroxamic acid (PBHA)} \]

(I)

5.3 EXPERIMENTAL

5.3.1 Instrumentation

UV-Vis Spectroscopy. The UV absorption spectra were recorded using Cary-50 Varian UV-vis Spectrophotometer.

Transmission Electron Microscopy. Transmission electron Microscope (TEM) images were taken using an instrument H-9000 NAR, Hitachi, with an accelerating voltage of 300 kV. A drop of particle suspension was placed on a carbon-coated copper grid and dried under vacuum. This study has been carried at IIT Kharagpur.
5.3.2 Chemicals

Silver nitrate (AgNO₃) was purchased from SRL, India. L-ascorbic acid was obtained from Hi-media and N-Phenylbenzohydroxamic acid (PBHA) was procured from Aldrich. Cetyltrimethylammonium bromide (CTAB), teradecyltrimethylammonium bromide (TTAB), dodecyltrimethylammonium bromide (DTAB), sodium dodecyl sulfate (SDS), cetyltrimethylammonium chloride (CTACl), cetyltrimethyl p-toluene sulfonate (CTPTS), cetylpyridinium bromide (CPB), N-dodecyl-N,N dimethyl-3 ammino-1 propane sulfonate (SB3-12), N-hexadecyl -N,N dimethyl-3 ammino-1 propane sulfonate (SB3-16), and TX-100 were purchased from Sigma. For the preparation of all the samples, triple distilled water was used.

5.3.3 Procedure

*Synthesis of Ag nanoparticles using PBHA.* 10 ml aqueous solution containing 1.0 x 10⁻⁴ M AgNO₃ and 50 µl of 0.1M NaOH was heated at 60°C - 70°C. Then, 20 µl of 0.01M PBHA was added into the solution at once while stirring vigorously. The colour of the solution immediately changed to light yellow. As soon as the yellow colour appeared, the solution is cooled to room temperature.

*Synthesis of Ag nanoparticles using Ascorbic acid.* 1 ml of 10⁻³ M AgNO₃ was added to 9 ml of triple distilled water. 50 µl of 0.1M ascorbic acid was then added to AgNO₃ solution. To this solution, 50 µl of 0.1M NaOH was added, resulting in a yellow colloidal silver solution.
Synthesis of Silver Nanoparticles in Surfactant Solution

Procedure for varying pH. To study the effect of pH, varied amount of 0.1M NaOH was added during the synthesis.

Procedure for varying surfactant. Different kinds of surfactants like cationic, anionic, non-ionic, and zwitterionic have been added at 1.0 mM concentration to the silver particle solution before and after the preparation of nanoparticles.

5.4 RESULTS AND DISCUSSION

Stable silver nanoparticles are formed by the reduction of AgNO₃ with PBHA and ascorbic acid. The silver particles prepared by hydroxamic acid reduction method produce relatively large sized particles. Because of the wide dispersity of the particle size and shape, we observe broad surface plasmon absorption band around 400-430nm. When ascorbic acid is used as reducing agent the particles are relatively smaller in size with sharp plasmon absorption band. Particle size of silver nanoparticles prepared using two different chemical reductants points out the unusual role of hydroxamate ions controlling the size and morphology of silver particles.

5.4.1 Characterization by UV-vis spectra

UV-vis spectra provide some information on the particle size and their distribution. Half-peak breadth indicates the particle distribution. The characterized wavelength will indicate particle size. The red shift of the wavelength indicates the increased particle size, while the blue shift indicates the decreased particle size. The well defined surface plasmon band with a maximum absorbance at 400nm implicates monodisperse Ag nanoparticles.
5.4.2 Influence of surfactants

In order to investigate the effect of alkyl chain length, cetyltrimethylammonium bromide (CTAB), tetradecyltrimethylammonium bromide (TTAB), and dodecyltrimethylammonium bromide (DTAB) were used. Figures 5.1 and 5.2 show the UV-vis spectra of the product obtained using these surfactants for ascorbic acid and PBHA respectively. When the alkyl chain length decreases there is decrease in absorbance and the wavelength absorption band is red shifted. To study the effect of counterions, CTAB (cetyltrimethylammonium bromide) and CTACI (cetyltrimethylammonium chloride) were used (Figures 5.1 & 5.2). The counterion CI showed sharp absorption band as compared to Br and the band is blue shifted. In terms of stability non-ionic surfactant was found to be most stable.

When two surfactants with different head groups were used i.e. CTAB and CPB, the spectra of CTAB was found to be sharper than CPB and is little blue shifted and the absorbance is also high. Tables 5.1 and 5.2 shows the summary of the results for the Ag nanoparticles corresponding to Figures 5.1 and 5.2.

The effects of anionic and non-ionic surfactant have no effect on the particle morphology after they are produced in ascorbic acid. However, CTAB caused aggregate effect on the evolved particles. This may be due to preferential capping selected crystal planes of the particles. Cationic surfactants helps particle aggregation. This is concluded from the red shift of $\lambda_{\text{max}}$ values from 401nm to 419nm. Spectral change in CTAB is further authenticated by conductometric studies. CTAB being a good capping agent leaves the counter ion ($X^-$) free which becomes responsible for increasing the conductance value. This explanation does not hold good at all in case of TX-100 but SDS gives intermediate result.
TABLE 5.1(a)

Effect of different cationic surfactants on Ag-nanoparticles preparation by Ascorbic acid reduction.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>[Surfactant] mM</th>
<th>λ\text{max}</th>
<th>Absorbance</th>
<th>pH</th>
<th>Conductance (mho)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Blank</td>
<td>402</td>
<td>1.37</td>
<td>7.8</td>
<td>60 x 10^{-6}</td>
</tr>
<tr>
<td>2.</td>
<td>CTAB</td>
<td>412</td>
<td>1.43</td>
<td>7.2</td>
<td>134 x 10^{-6}</td>
</tr>
<tr>
<td>3.</td>
<td>SDS</td>
<td>401</td>
<td>1.33</td>
<td>7.6</td>
<td>126 x 10^{-6}</td>
</tr>
<tr>
<td>4.</td>
<td>Tx-100</td>
<td>404</td>
<td>1.36</td>
<td>7.2</td>
<td>61 x 10^{-6}</td>
</tr>
<tr>
<td>5.</td>
<td>DDAPS</td>
<td>401</td>
<td>1.37</td>
<td>7.6</td>
<td>58 x 10^{-6}</td>
</tr>
<tr>
<td>6.</td>
<td>HDAPS</td>
<td>403</td>
<td>1.47</td>
<td>7.9</td>
<td>64 x 10^{-6}</td>
</tr>
</tbody>
</table>

Conditions: [Surfactant] = 1x10^{-3}, [AgNO\textsubscript{3}] = 1x10^{-3}M, [Ascorbic acid] = 5x10^{-4}M, [NaOH] = 5x10^{-4}M.
### Table 5.1(b)

Effect of different cationic surfactants on Ag-nanoparticles formation in the presence of Ascorbic acid

<table>
<thead>
<tr>
<th>S.No.</th>
<th>[Surfactant]</th>
<th>λ&lt;sub&gt;max&lt;/sub&gt;</th>
<th>Absorbance</th>
<th>pH</th>
<th>Conductance (mho)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>CTAB</td>
<td>412</td>
<td>1.43</td>
<td>7.2</td>
<td>134 x 10&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>2.</td>
<td>TTAB</td>
<td>433</td>
<td>0.99</td>
<td>7.8</td>
<td>172 x 10&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>3.</td>
<td>DTAB</td>
<td>414</td>
<td>1.20</td>
<td>7.9</td>
<td>163 x 10&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>4.</td>
<td>CTACl</td>
<td>408</td>
<td>1.45</td>
<td>7.3</td>
<td>144 x 10&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>5.</td>
<td>CTPTES</td>
<td>413</td>
<td>1.40</td>
<td>7.7</td>
<td>72 x 10&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>6.</td>
<td>CPB</td>
<td>419</td>
<td>1.35</td>
<td>7.5</td>
<td>95 x 10&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>7.</td>
<td>Blank</td>
<td>401</td>
<td>1.38</td>
<td>7.8</td>
<td>60 x 10&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Conditions: [Surfactant] = 1x10<sup>-1</sup>, [AgNO<sub>3</sub>] = 1x10<sup>-4</sup>M, [Ascorbic acid] = 5x10<sup>-4</sup>M, [NaOH] = 5x10<sup>-4</sup>M.
Figure 5.1(a): UV-vis spectra of Ag-nanoparticles formation in the presence of different cationic surfactants for Ascorbic acid reduction. (1) Blank, (2) CTAB, (3) SDS, (4) TX-100, (5) SB3-12, (6) SB3-16

Figure 5.1(b): UV-vis spectra of Ag-nanoparticles formation in presence of cationic surfactants for Ascorbic acid reduction. (1) CTAB, (2) TTAB, (3) DTA, (4) CTACl, (5) CTPTS, (6) CPB, (7) Blank
### TABLE 5.2(a)

Effect of different surfactants on Ag nanoparticles using PBHA

<table>
<thead>
<tr>
<th>S.No.</th>
<th>[Surfactant] mM</th>
<th>λ&lt;sub&gt;max&lt;/sub&gt;</th>
<th>Absorbance</th>
<th>pH</th>
<th>Conductance (mho)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Blank</td>
<td>411</td>
<td>0.79</td>
<td>9.1</td>
<td>70 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>Blank</td>
<td>410</td>
<td>0.55</td>
<td>9.2</td>
<td>64 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>CTAB</td>
<td>418</td>
<td>0.72</td>
<td>8.4</td>
<td>88 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>SDS</td>
<td>410</td>
<td>0.54</td>
<td>8.9</td>
<td>104 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>1x10&lt;sup&gt;-5&lt;/sup&gt;</td>
<td>410</td>
<td>0.54</td>
<td>8.9</td>
<td>52 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Conditions: [Surfactant] = 1x10<sup>-3</sup>, [AgNO<sub>3</sub>] = 1x10<sup>-4</sup>M, [PBHA]<sup>-</sup> = 5x10<sup>-4</sup>M, [PBHA] = 5x10<sup>-4</sup>M, [NaOH] = 5x10<sup>-4</sup>M.

### TABLE 5.2(b)

Effect of different surfactants on Ag-nanoparticles using PBHA

<table>
<thead>
<tr>
<th>S.No.</th>
<th>[Surfactant] mM</th>
<th>λ&lt;sub&gt;max&lt;/sub&gt;</th>
<th>Absorbance</th>
<th>pH</th>
<th>Conductance (mho)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CTAB</td>
<td>420</td>
<td>0.77</td>
<td>8.4</td>
<td>88 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
<tr>
<td>2</td>
<td>TTAB</td>
<td>425</td>
<td>0.59</td>
<td>8.8</td>
<td>143 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
<tr>
<td>3</td>
<td>CTACl</td>
<td>412</td>
<td>0.62</td>
<td>8.5</td>
<td>180 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
<tr>
<td>4</td>
<td>CIPTS</td>
<td>419</td>
<td>0.46</td>
<td>9.0</td>
<td>88 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
<tr>
<td>5</td>
<td>CPB</td>
<td>425</td>
<td>0.59</td>
<td>9.0</td>
<td>101 x 10&lt;sup&gt;-6&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Conditions: [Surfactant] = 1x10<sup>-3</sup>, [AgNO<sub>3</sub>] = 1x10<sup>-4</sup>M, [PBHA] = 5x10<sup>-4</sup>M, [NaOH] = 5x10<sup>-4</sup>M.
**Figure 5.2(a):** UV-vis spectra of Ag-nanoparticles stability as a function of effect of surfactant for PBHA. (1) Blank, 5 x 10^{-5} M PBHA, (2) Blank, 2 x 10^{-5} M PBHA, (3) CTAB, (4) SDS, (5) TX-100

**Figure 5.2(b):** UV-vis spectra of Ag-nanoparticles stability as a function of effect of surfactants for PBHA. (1) CTAB, (2) TTAB, (3) CTACl, (4) CTPTS, (5) CPB
5.4.3 Influence of pH

The morphology of silver nanoparticles strongly depended on the pH of the reaction medium. Figure 5.3 & 5.4 compares the UV-vis spectra obtained from solutions sampled at different pH for ascorbic acid and PBHA respectively. The UV-vis spectroscopic method can be used to track the morphological evolution because silver nanostructures having different shapes exhibit surface plasmon resonance bands at different frequencies. The reaction temperature was maintained. The pH was varied from 5.5-9.5 pH (Table 5.3) for ascorbic acid and 6.3-9.4 pH for PBHA (Table 5.4). As the pH increases the spectrum of the nanoparticles shows increase in absorbance.

When the pH of the solution was increased the reducing power of PBHA and ascorbic acid were also increased. Silver ions are not reduced at low pH in the case of ascorbic acid (Figure 5.3).

5.4.3 Effect of reducing agent concentration

The concentration of reducing agent also plays a vital role in the synthesis and size distribution of nanoparticles during synthesis. We have used PBHA as reducing as well as capping agent to obtain the Ag nanoparticles. Figures 5.2(a) - (1) & (2) represent the UV-vis spectra of the solutions with the ratio of 1:0.5 and 1:0.2 respectively when PBHA was used as reducing agent. The silver plasmon band shifts to a higher wavelength with increasing reducing agent concentration. The band shift to a higher wavelength can be attributed to the difference in the size and distribution of the particles. Higher of PBHA evolves Ag(0) in a faster space but it helps in aggregation of particles. This is because...
Synthesis of Silver Nanoparticles in Surfactant Solution

**TABLE 5.3**
Effect of pH on the synthesis of Ag-nanoparticles by Ascorbic acid

<table>
<thead>
<tr>
<th>S.No.</th>
<th>pH</th>
<th>λ_max</th>
<th>Absorbance</th>
<th>Conductance (mho)</th>
</tr>
</thead>
<tbody>
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<td>1.</td>
<td>5.4</td>
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<td>0.26</td>
<td>4.0 x 10⁻⁶</td>
</tr>
<tr>
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<td>6.4</td>
<td>402</td>
<td>0.30</td>
<td>4.4 x 10⁻⁶</td>
</tr>
<tr>
<td>3.</td>
<td>7.0</td>
<td>403</td>
<td>0.56</td>
<td>5.3 x 10⁻⁶</td>
</tr>
<tr>
<td>4.</td>
<td>7.6</td>
<td>403</td>
<td>0.98</td>
<td>6.5 x 10⁻⁶</td>
</tr>
<tr>
<td>5.</td>
<td>8.6</td>
<td>400</td>
<td>1.27</td>
<td>8.4 x 10⁻⁶</td>
</tr>
<tr>
<td>6.</td>
<td>9.5</td>
<td>400</td>
<td>1.33</td>
<td>1.1 x 10⁻⁵</td>
</tr>
</tbody>
</table>

**Conditions:** [AgNO₃] = 1x10⁻⁴M, [Ascorbic acid] = 5x10⁻⁴M

**TABLE 5.4**
Effect of pH on the synthesis of Ag-nanoparticles by PBHA

<table>
<thead>
<tr>
<th>S.No.</th>
<th>pH</th>
<th>λ_max</th>
<th>Absorbance</th>
<th>Conductance (mho)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<td>424</td>
<td>0.11</td>
<td>4.0 x 10⁻⁵</td>
</tr>
<tr>
<td>2.</td>
<td>7.6</td>
<td>426</td>
<td>0.32</td>
<td>5.2 x 10⁻⁶</td>
</tr>
<tr>
<td>3.</td>
<td>8.8</td>
<td>414</td>
<td>0.49</td>
<td>6.2 x 10⁻⁶</td>
</tr>
<tr>
<td>4.</td>
<td>9.4</td>
<td>425</td>
<td>0.56</td>
<td>9.0 x 10⁻⁶</td>
</tr>
</tbody>
</table>

**Conditions:** [AgNO₃] = 1x10⁻⁴M, [PBHA] = 5x10⁻⁴M
Figure 5.3: UV-vis spectra of Ag-nanoparticles stability as a function of pH for Ascorbic acid. (1) pH 5.4, (2) pH 6.4, (3) pH 6.9, (4) pH 7.6, (5) pH 8.6, (6) pH 9.5

Figure 5.4: UV-vis spectra of Ag-nanoparticles stability as a function of pH for PBHA. (1) pH 6.3, (2) pH 7.6, (3) pH 8.8, (4) pH 9.4
of higher PBHA, larger nucleation of particles and aggregation takes place. Surfactants like CTAB help the particle stabilization through capping and help to produce tight particle size distribution. This is obvious from the FWHM (Figure 5.2a curve 5.3).

In this study we fail to observe any effect of SDS and Tx-100 to have any control on this tight particle size distribution. Hence CTAB acts as better capping agent.

5.4.3 Transmission Electron Micrographs

The morphology of silver nanoparticles was established by recording transmission electron micrographs (TEM). TEM images of the silver particles (Figure-5.5) showed that the particles are spherical and small-sized of diameter 30-50 nm approximately in the case of PBHA.

Figure 5.5: Transmission electron micrograph of Ag nanoparticles using PBHA.
5.5 CONCLUSION

Colloidal silver nanoparticles were synthesized from AgNO₃ using PBHA and ascorbic acid as reducing agents. The investigation on the formation of silver nanoparticles using UV-vis spectroscopy shows that the silver colloids formed are nanosized, uniformly distributed and stable at least for 2 weeks. The rate of the formation of silver nanoparticles was greatly accelerated on increasing the pH value. Addition of surfactants may control particle growth and stabilize intermediates.
REFERENCES

Synthesis of Silver Nanoparticles in Surfactant Solution


Synthesis of Silver Nanoparticles in Surfactant Solution


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