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Simple one-step synthesis of gold nanoparticles with controlled size using cationic Gemini surfactants as ligands: Effect of the variations in concentrations and tail lengths

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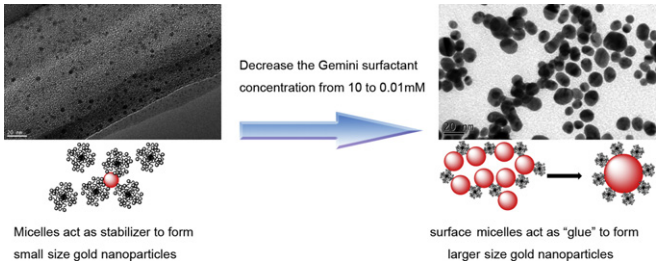
HIGHLIGHTS

- Increasing the tail length of the surfactants, the size of nanoparticles decreases.
- Increasing the surfactant concentration, gold nanoclusters are obtained.
- Low surfactant concentrations allow for the aggregation of gold nanoparticles.

GRAPHICAL ABSTRACT



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ABSTRACT

Gold nanoparticles with diameters ranging from 1.3 to 10.2 nm have been synthesized by in situ reduction of $HAuCl_4$ with $NaBH_4$ in aqueous phase using Gemini surfactants as ligands. Their properties/behaviors were characterized by UV–vis spectroscopy, transmission electron microscopy (TEM), Fourier transform infrared spectroscopy (FTIR) and zeta potential spectroscopy. FTIR and zeta potential measurements suggest that surface aggregates adsorb on the nanoparticle surface at high surfactant surface coverage. Above the CMC, micelles could serve as stabilizers that lead to the formation of ultrasmall nanoparticles. It is interesting to note that at low surfactant concentrations, surface aggregates adsorbed on gold nanoparticles might bridge small particles, which results in the formation of larger nanoparticles. However, when the surfactant concentration was further reduced to 1 μM, the AuNPs precipitated, indicating that 0.1 mM is the lowest concentration to obtain stable nanoparticles in this study. In addition, the average particle size decreases at a given surfactant concentration as the tail length of the Gemini surfactant is increased. As a result, the particle size can be controlled by the variations in concentration and/or tail length of the Gemini surfactants.

1. Introduction

Gold nanoparticles (AuNPs) with their size-dependent physical and chemical properties have generated a great interest because of potential applications in photonics, nanoscale electronics, nanodevices, and more recently in biological sensing and imaging [1–3]. In recent years, the tremendous progress has been made in preparation methods, such as using alkanethiol ligands [4], polymer ligands [5,6] and biomacromolecule ligands [7]. When the size of metal nanoparticles is further reduced to around 2 nm or less, the structure of the surface plasmon band (SPB) becomes discontinuous and is broken down into discrete energy levels, somewhat similar as the energy levels of molecules. Therefore these ultrasmall particles are said to have molecule-like properties and do not anymore exhibit plasmonic properties. In order to

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