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Original article

Preparation of capped silver nanoparticles using sunlight and cationic surfactants and their biological activity

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ABSTRACT

Silver nanoparticles were prepared *in situ* using sunlight and cationic surfactants. Silver nano-particles were confirmed using UV–vis spectrophotometry, transmission electron microscopy (TEM), electron diffraction, dynamic light scattering (DLS) and FTIR. Increasing the hydrophobic chain length of surfactants increase the amount of silver nano-particles formed in addition to increasing their stability. The results showed formed, uniform, well arranged hexagonal and spherical shapes. The prepared silver nanoparticles exhibit enhanced biological activity against Gram-positive, Gram-negative bacteria and sulfate reducing bacteria (SRB).

1. Introduction

In recent years, nanoparticle synthesis and applications attracted the attention of scientists from all parts of the world due to the catalytic, thermal, optical and electrical properties of the nano-sized colloids. Nanoparticles can be used in various applications such as conductors, chemical sensors, catalysts, conducting ink, biosensor, antibacterial activity, *etc.* [1–8]. With the increasing resistance of microbial organisms to multiple antibiotics and the pressure on the health care costs, much research was initiated to overcome such problems; which led to a resurgence in the use of silver-based antibiotics to overcome the microbial resistance to antibiotics. Silver nanoparticles (AgNPs) are used to control bacterial growth in a many applications, like dental work, catheters, and burn wounds [9]. Silver ions and Ag-based compounds are highly toxic to microorganisms, showing strong biocidal effects on bacteria [10]. Recently, for instance, Mecking and co-workers showed that hybrids of Ag nanoparticles with amphiphilic, hyper-branched macromolecules exhibited effective antimicrobial surface coating agents [11].

Several methods were developed for nano-colloidal preparations, some of them are biological [12], electrochemical [13], photochemistry [14–16], microemulsion [17] and microwave techniques [18]. In wet chemical synthesis, using an aqueous system provides the condition for large scale and lowest cost-effective synthesis of metal nanoparticles. Some reducing agents, such as citrate, sodium borohydrate, ammonia, and hydrogen, were used in an aqueous system for AgNP synthesis using surfactants for controlling the growth of the formed nanoparticles [19].

Our work focused on developing a simple and an effective green approach toward the synthesis and stabilization of AgNPs. Sunlight is used as the reducing agent with prepared cationic surfactants. The utilized surfactants act as a stabilizing agent for the synthesized AgNPs and assist in the reduction process. The prepared silver nanoparticles were confirmed using transmission electron microscopy, dynamic light scattering, and UV–vis spectroscopy. The prepared silver nanoparticle encapsulated with the cationic surfactant (antibiotic), were tested against Gram positive and Gram-negative bacteria and also sulfate reducing bacteria.

2. Experimental

2.1. Chemicals

Silver nitrate ($AgNo_3$, 99%) used in the preparation of the silver nanoparticles was provided by Sigma–Aldrich/Germany. The

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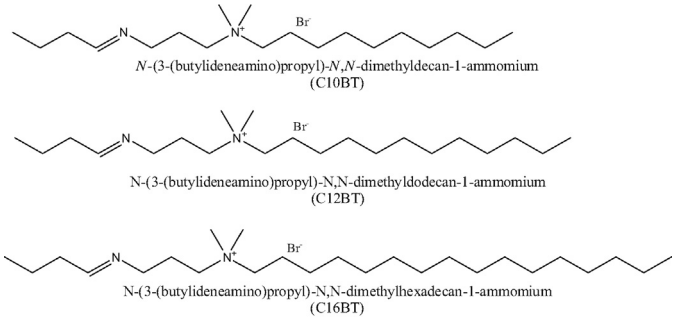
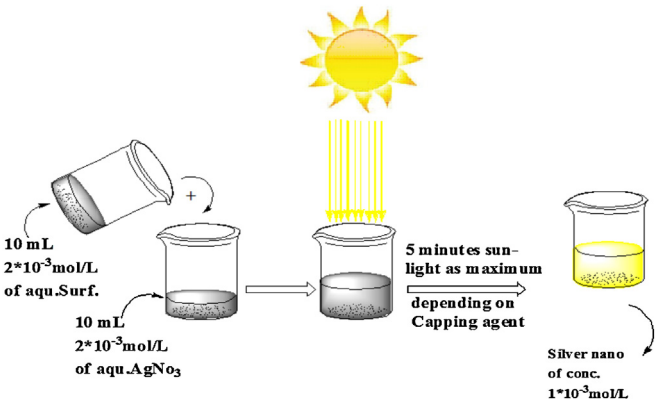


Scheme 1. The chemical structure of prepared cationic capping agents.



Scheme 2. *In situ* photo preparation of silver nanoparticles.

chemicals used in the preparation of capping agents were dimethylaminopropylamie (DMAPA), butyraldeyde, decyl bromide, dodecyl bromide and hexadecyl bromide and were purchased from Aldrich Chemicals Co., Ltd.

2.2. Synthesis

2.2.1. Preparation of cationic capping agents

The utilized cationic capping agents were previously reported [20]. The chemical structures of prepared capping agents are shown in Scheme 1.

2.2.2. Preparation of silver nanoparticles (AgNPs)

Sunlight was used in the preparation of silver nanoparticles from an aqueous solution of silver nitrate. The reducing agent was sunlight with the assistance of the prepared cationic surfactants [14]. A 20 mL aliquot of a 2 mmol/L aqueous solution of $AgNO_3$was mixed with 20 mL of a 2 mmol/L cationic surfactant aqueous solution, then the mixed solution was exposed to direct sunlight (Scheme 2). After a short time, over 5 min at maximum, the color of the solution changed from colorless to yellow within different ranges, depending on the used capping agents as shown in Fig. 1.

2.3. Silver nanoparticles confirmation

The following instrumentations have been used for silver nanoparticle confirmation:

Transmission electron microscope (TEM): A convenient way to produce good TEM samples is to use copper grids, specifically a copper grid pre-covered with a very thin amorphous carbon film. To investigate the prepared AgNPs using TEM, small droplets of the liquid were placed on the carbon-coated grid [21]. A photographic plate of the transmission electron microscopy is employed in the present work to investigate the microstructure of the prepared samples using TEM model "JeolJeM–2100 (Japan)" (Egyptian Petroleum Research Institute "EPRI").

UV–visible spectroscopy: The formation of silver nanoparticles was confirmed using UV–visible spectrophotometer (Shimadzu, UV-2550, Japan) [22].

Dynamic light scattering (DLS): The hydrodynamic diameter and zeta potential of the prepared AgNPs capped with the prepared cationic surfactant were characterized by dynamic light scattering (DLS) using a Malvern Zetasizer Nano (Malvern Instruments Ltd, Worcestershire, UK). Each DLS measurement was run in triplicate using automated, optimal measurement time and laser attenuation settings. The recorded correlation functions and measured mobilities of particles were converted into size distributions and zeta potentials, respectively, using the Malvern Dispersion Software (V5.10, http://www.zetasizer.com/).

Fourier transform infrared spectrometer (FTIR): FT-IR spectra were recorded using the obtained solid cationic surfactants capped AgNPs after centrifugation and washing to remove the unassociated organic molecules [23]. Spectra were recorded on an ATI Mattson Infinity Series^{TM}, Bench Top 961 instrument controlled by Win First^{TM} V2.01 software (Egyptian Petroleum Research Institute "EPRI").

2.4. Biological activity

Biological activity against a wide range of bacteria and fungi: Different species of tested organisms were obtained from the Operation Development Center, Egyptian Petroleum Research Institute. The bacteria species were grown on nutrient agar, while fungi mold on Czapek's Dox agar. Nutrient agar consists of beef extract (3.0 g/L), peptone (5.0 g/L), sodium chloride (3.0 g/L) andagar (20.0 g/L), then, diluted the volume to one liter, heated the mixture to the boiling, and sterilize the media by autoclave. Czapek's Dox agar consists of sucrose (20.0 g/L), sodium nitrate

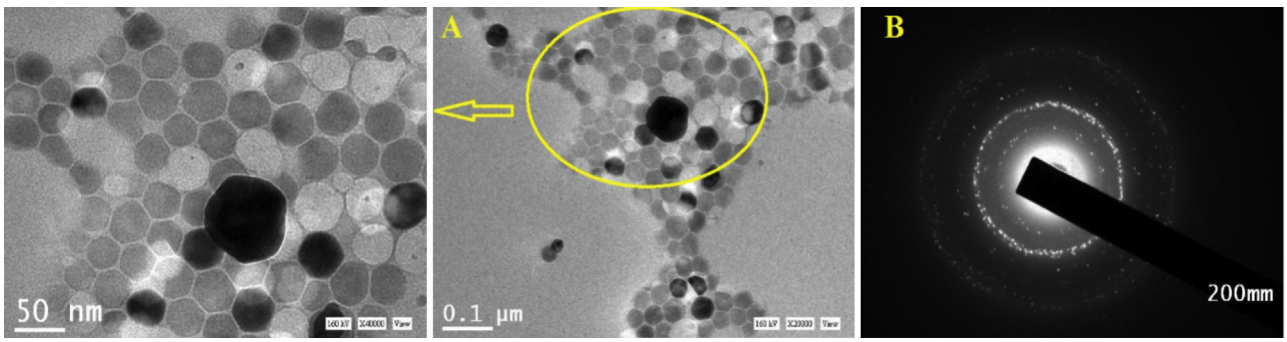


Fig. 1. (A) TEM image of prepared silver nanoparticle capped by (C_{10}BT), (B) is SAED image of prepared silver nanoparticles capped by (C_{10}BT).