Citrate Stabilized Silver Nanoparticles: Study of Crystallography and Surface Properties

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ABSTRACT

Citrate stabilized silver (Ag) colloidal solution were synthesized and characterized for crystallographic and surface properties by using transmission electron microscopy (TEM) and zeta potential measurement techniques. TEM investigation depicted the size of Ag\(^{\circ}\) ranges from 5 to 50 nm with smaller particles having single crystal structure while larger particles with structural defects (such as multiply twinned, high coalescence and Moire patterns). \(\zeta\)-potential measurement confirms the presence of Ag\(^+\) in nAg stock solution. The shift in \(\zeta\)-potential measurement by +25.1 mV in the filtered solution suggests the presence of Ag\(^+\) in Ag\(^\circ\) nanoparticles.

Keywords: Agglomeration, Citrate Stabilized, Coalescence, Crystallography Study, Multiply Twinned, Silver Ions, Silver Nanoparticles, Transmission Electron Microscopy (TEM), Zeta Potential

1. INTRODUCTION

The application of nanoscale materials and structures, usually ranging from 1 to 100 nanometers (nm), is an emerging area of nanoscience and nanotechnology. Nanomaterials may provide solutions to technological and environmental challenges in the areas of solar energy conversion (Atwater & Polman, 2010; Brown et al., 2011), catalysis (Bhattarai, Casillas, Ponce, DOI: 10.4018/ijnmc.2011070102
& Jose-Yacaman, 2012; Cuenya, 2010; Khanal, Casillas, Velazquez-Salazar, Ponce, & Jose-Yacaman, 2012; Raji, Chakraborty, & Parikh, 2012; Yuan, Yan, & Dyson, 2012), medicine (Conde, Doria, & Baptista, 2012; Davis et al., 2010), and water treatment (Dankovich & Gray, 2011; Kaegi et al., 2011). In recent years, noble metal nanoparticles like gold (Au), silver (Ag) etc. are of special interest due to their plasmonics properties, especially in photovoltaic (Pudasaini & Ayon, 2012; Tan, Santbergen, Smets, & Zeman, 2012), medicine (Conde et al., 2012; Davis et al., 2010; Nykypanchuk, Maye, van der Lelie, & Gang, 2008), and bio-imaging (Hutter & Maysinger, 2011; Lee et al., 2006; Y. Liu, Miyoshi, & Nakamura, 2007). Silver nanoparticles are extraordinarily efficient in absorbing and scattering light and, unlike many dyes and pigments, have a color that depends on the size and the shape of the nanostructures.

The interest in Ag nanoparticles and their applications has increased mainly due to their important antimicrobial, antifungal, antibacterial, antiviral activities (Jung et al., 2008; J. Liu, Yu, Yin, & Chao, 2012), allowing their use in several medical applications. Colloidal silver is of particular interest given its distinctive properties, such as good conductivity, chemical stability, catalytic and enhanced antibacterial activity. There is an increasing interest in understanding the relationship between the physical and chemical properties of nano silver and their potential risk to the environment and human health. The mechanism of the antimicrobial action of silver ions is closely related to their interaction with thiol (sulfhydryl) groups (Toshima et al., 1991), although other target sites remain a possibility. Amino acids, such as cysteine, and other compounds containing thiol groups, such as sodium thioglycolate, neutralized the activity of silver against bacteria (Liau, Read, Pugh, Furr, & Russell, 1997). On the other hand, disulfide bond-containing amino acids, non-sulfur-containing amino acids, and sulfur-containing compounds, such as cystathione, cysteic acid, L-methionine, taurine, sodium bisulfates, and sodium thiosulfate, were all unable to neutralize the activity of silver ions. These and other findings imply that the interaction of silver ions with thiol groups in enzymes and proteins play an essential role in its antimicrobial action, although other cellular components, like hydrogen bonding, may also be involved.

Nonetheless, colloidal Ag has been utilized for centuries but only recently it has gained notoriety; most famously as a drinkable solution marketed by alternative medicine practitioners who herald it as a “cure-all”. Despite this pseudo-science, real research is underway concerning colloidal Ag solutions because the mechanism of microbial cytotoxicity is not fully known. Moreover, the properties of specific nanostructures that will optimize microbial cytotoxicity are not, as of yet, defined because the properties of Ag nanostructures themselves are not fully understood. At present, the adverse effects of Ag NPs on wastewater treatment and the environment is not completely known. However, free silver ion (Ag\(^+\)) is highly toxic to a wide variety of organisms including bacteria. To this end, understanding the properties of silver nanoparticles and silver ions is very important to effectively control its activity. In order to control the nAg and silver ion activity, we need to understand, how the size, morphology, pH, surface coating, solution chemistry, crystalline nature of nanoparticles and surface charge affect the ion release mechanism.

The mechanism of toxic properties of Ag NPs has not been clearly elucidated. It is generally believed that the toxicity of Ag NPs is related to release of Ag\(^+\) ions from the Ag colloidal solution (Chao et al., 2011; Kennedy et al., 2012). However, the effects are not due simply the release of Ag\(^+\) into the surrounding environment, as the Ag NPs effects are distinct from those of Ag\(^+\) alone and depend on Ag NPs size and coating (G. A. Sotiriou, A. Meyer, J. T. N. Knijnenburg, S. Panke, & S. E. Pratsinis, 2012). To assess the risk of exposure and further understand the Ag NP effects, information on
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