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Original Research Paper

An investigation on the application of process control agents in the preparation and consolidation behavior of nanocrystalline silver by mechanochemical method

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ABSTRACT

In this paper, the effect of various amounts and types of process control agent (PCA), i.e., stearic acid (SA) and ethylene bis-stearamide (EBS), in the production and consolidation behavior of nanocrystalline silver prepared by mechanochemical reduction of Ag_2O by graphite was studied. The structural evolution and morphology of powders were investigated using XRD, HRSEM and particle size analyzer techniques. The results showed the nanocrystalline Ag formed after 25 h of milling and the addition of PCA prolonged the synthesis process time. Also, the effect of EBS on prevention of the excessive cold welding of ultra-fine Ag particles in the final stages of milling was more serious than SA. In fact, the presence of PCA effectively inhibited the creation of coarse Ag particles and finally decreased the crystallite size to 14 nm. Moreover, with the addition of PCAs, the Brinell hardness of sintered Ag samples was considerably increased.

1. Introduction

Due to widespread application, the commercial nanotechnology is forecasted to grow significantly to $3 trillion by 2015 [1]. It is predicted that within all the nanoparticles in user products, silver nanoparticle applications currently have the highest level of commercialization. A broad range of Ag nanoparticle applications has appeared in consumer products ranging from decontamination of medical devices and home appliances to water treatment. Furthermore, due to the unique physical and mechanical properties, Ag nanoparticles have also been used in potential catalysis, aerosol, filter, sensor, magnetic, biomedical, optoelectronic, dielectric ceramics, hygienic and healing purposes [2,3].

As reported by Zheng Min et al. [4], a wide variety of synthesis methods such as gas reduction process, precursor pyrolysis, microwave plasma synthesis, and laser ablation have been successfully employed in the preparation of silver nanoparticles. Nevertheless, there has been little research directed to the mechanochemical synthesis of silver nanoparticles yet.

Mechanochemical synthesis is a novel technique for preparation of nano-sized materials. Studies show that improved reaction rates can be achieved and dynamically maintained during the mechanical activation by different mechanisms, such as repeated fracture, welding, deformation of particles, microstructural refinement and mixing processes [5–13]. Depending upon which mechanism is dominant during the milling, the size of prepared powder may grow through agglomeration by cold welding, or become smaller through the fracture phenomenon. Mostly, to generate the balance between the fracturing and welding phenomena, a process control agent (PCA) applied in the milling process [14,15]. PCAs are generally organic materials, which invariably lowers the surface tension of deformed particles and consequently impeding the clean metal-to-metal contact essentially for cold welding [16]. Majority of PCAs decompose during milling, introducing carbon and/or oxygen into the powder particles, resulting in the formation of carbides and oxides which are uniformly dispersed in the matrix [14].

In our pervious works, the preparation of nanocrystalline silver through the mechanochemical reduction of Ag_2O with graphite according to Reaction (1) was investigated [11].

$$2Ag_2O + C \rightarrow 4Ag + CO_2 \uparrow \quad (1)$$

To the best of our knowledge, the effects of process control agents in mechanochemical reduction of Ag_2O have not been thoroughly investigated. These investigations are appreciated for the ability to control the solid-state reactions. In this paper, a novel technique for synthesis of highly spherical silver nanoparticles using mechanochemical reduction of Ag_2O in the presence of stearic acid and ethylene bis-stearamide as PSAs has been proposed.

The main advantages of the mechanochemical method in comparison with the traditional technological procedures are: decrease in the number of technological stages, excluding the operations that involve the use of solvents and stabilizing agents, simplification of the process, mass production capability and easy handling of process, environmental health and safety. These items characterize

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