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Improvement of hollow mesoporous silica nanoparticles synthesis by hard-templating method via CTAB surfactant

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ABSTRACT

In this study, hollow mesoporous silicate nanoparticles using TEOS precursors in the presence of polystyrene template were synthesized. The process was performed in an alcohol-based chemical system and the addition of CTAB surfactant. The polystyrene template was used under controlled conditions having a spherical morphology with a uniform distribution and an average size of 50 nm. The results of the FTIR analysis showed that TEOS precursor particles formed surface boundaries during the synthesis with CTAB surfactants, and also the presence of Si—O—Si bonds (in the 600 to 1320 cm^{-1} range) indicates the formation of silicate chains on Polystyrene templates. Thermal analysis studies showed that by using appropriate thermal treatment and precise control, organic compounds can be removed from the system and synthesize hollow mesoporous silicate particles with minimum structural defects at 280 °C. The BET analysis showed that the specific surface area of these particles is 1180 $m^2 g^{-1}$. X-ray diffraction results demonstrated that the resulting product was amorphous silica and unwanted phases were not formed in this system. The dynamic light scattering analysis illustrated that the synthesized particles had dimensions ranging from 1 to 10 nm, and the particle size distribution occurred within a narrow range. Scanning electron microscopy images confirm the nodularity of nanoparticles with a mean size of 25–30 nm. Finally, the transmitted electron microscope images showed that the synthesized silicate particles were hollow, so that the diameter of the hollow chamber and its total diameter were about 30 and 80 nm, respectively.

1. Introduction

Recently, various studies were performed on the synthesis of oxidized nanoparticles having controlled and engineering properties, in which silica nanoparticles are of particular importance because of their significant and varied properties such as high chemical stability, high strength, bioactive properties, and controlled structure (proper size and shape). These particles are obtained by various methods such as chemical deposition, steam decomposition, sol-gel etc. [1–4]. An important feature of chemical synthesis methods is the formation of stable particles in the suspension and their lack of agglomeration. Because in case of agglomeration, the size of the particles in the suspension is increased, this causes the thermodynamic instability of the system to eventually lead to the deposition of particles inside the system. To avoid the agglomeration phenomenon, additives are needed to stabilize particles inside the suspension. For this purpose, the CTAB surfactant has been used to prevent particle aggregation [5–11]. Since the early 1990s, numerous fundamental investigations have been made on mesoporous silica nanoparticles. The results of this research led to the production of products with optimal and unique properties such as uniform distribution and regular arrangement of pores, the ability to connect properly to other particles [12–14]. One of the important goals of the synthesis of silicate nanoparticles is to achieve properties such as uniform distribution and controlled structure, which have important applications in the pharmaceutical industry, manufacturing of catalysts, sensors and chromatography [15,16]. For this purpose, Zhang, Sedaker and their colleagues synthesized mesoporous silica nanoparticles by using a specific compound and changing the pH. In the research, initial silicate nuclei were formed in pH ≈ 2 without sedimentation. With increasing pH (in the range of 6–9), the particle density increased and the electrostatic particle interaction led to the rapid growth of surfactant-containing nuclei [17,18]. Singh et al. synthesized broad spectrum silica mesoporous particles by using a CTAB surfactant and changing the TEOS ratio [19]. Chandra and his colleagues examined the rate of nucleation and growth of mesoporous silicate particles by controlling the pH of reaction, which led to the production of particles with spherical morphology [20]. From the discovery of mesoporous silica synthesized using cationic surfactant templates, templating methods

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