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Deposition of silver nanoparticles on silica spheres and rods

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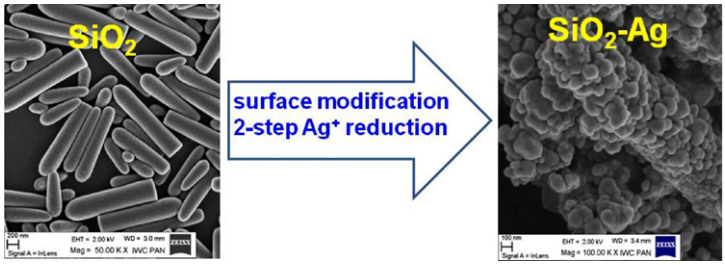
HIGHLIGHTS

- TEOS concentration affects the morphology of silica particles.
- Aminopropyl-modified silica spheres and rods were used to form Ag nanoshells.
- Two-step Ag^+ reduction was used to obtain densely packed silver nanoshells.

GRAPHICAL ABSTRACT



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ABSTRACT

Spherical and rod-like silica particles were used as cores to deposit shells of silver nanoparticles. Prior silver deposition the siliceous cores were modified with 3-aminopropyltrimetoxysilane to facilitate Ag deposition on the surface of silica particles. The process of Ag deposition was carried out in two consecutive steps: first, silver nanoparticles were deposited on the silica cores from silver nitrate solution in the presence of ammonia and Sn^{2+} ions. Next, further deposition of silver was achieved by reducing silver cations with formaldehyde. This process led to the formation of a densely packed silver layer that consisted of non-uniform silver nanoparticles (size from several to about 100 nm), on the surface of spherical and rod-like siliceous cores.

1. Introduction

Studies of the silica–metal core-shell particles are fascinating mainly because of their unique structures and interesting physicochemical properties, which make them attractive for a variety of applications [1]. These structures are of great interest in biological and biochemical studies [2], for instance, in cancer diagnostics or pathogens identification [3], spectroscopy, e.g., surface-enhanced Raman spectroscopy [4], optical signal modulations [5], photonics [6], magnetic field studies [7], or as novel biocatalysts [8]. Among all silica–metal core-shell particles, silica–silver particles belong to the most popular ones, mostly because they can be synthesized by using various methods. In particular, electrocatalytic deposition [9], seeding plating [10], surface functionalization [11], or layer-by-layer deposition processes [12] are worth mentioning. The latter approach ensures the formation of a continuous and uniform silver nanolayer of 20–100 nm thickness. Silver has attracted a lot of attention and is widely used to coat silica particles due to its antimicrobial and non-toxic character. Recently, there is a great interest in fabricating silica–silver core-shell particles. Ye et al. [13] proposed a two-step method, where in the first step Ag cations ($AgNO_3$) were reduced to form Ag nanoparticles using polyvinylpyrrolidone (PVP) in the presence of N,N-dimethylformamide. PVP was not only a reducing agent but also a stabilizing agent. In the second stage, deposition of Ag nanoparticles on the pre-decorated siliceous particles was continued by

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