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Short Communication

One-pot hydrothermal synthesis of mesostructured silica nanotube

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ABSTRACT

Mesostructured silica nanotubes have been synthesized in a system of carbon nanotubes/cetyltrimethylammonium bromide/tetraethyl orthosilicate/$NH_3{\cdot}H_2O$ through one-pot hydrothermal route. The obtained sample was characterized with X-ray diffraction, nitrogen sorption, scanning electron microscopy, transmission electron microscopy and energy dispersive X-ray techniques. These results indicate mesostructured silica nanotubes exhibit small tube diameters (10–40 nm), uniform mesopores (2.5 nm), and a huge pore volume (1.7 cm^3/g).

1. Introduction

One-dimensional nanostructures in nanotechnology have received enormous interest for their fascinating physical properties and numerous potential applications [1–7]. Among these one-dimensional nanostructured materials, silica nanotubes (SNT) with features of biocompatibility, photoluminescence, and accessibility have been extensively applied to the fields of catalysis, optics, biosensor, nanoscale electronics, and storage and delivery system [3–7]. On the other hand, the synthesis of mesoporous materials (MCM-41, SBA-15 etc.) has become a fast-developing area in nano-science, because mesoporous materials have large surface area and adjustable pore size in nanometers [8,9]. Recently, the combination of mesostructure and one-dimensional silica tubes has attracted increasing research interests. Mesostructured silica tubes have been synthesized through liquid-crystal phase transformation or by using templates of anodic alumina and polycarbonate membranes [10–13]. For examples, Lin and Mou synthesized MCM-41 with the morphology of 'tubules-within-a-tubule' (0.3–3 μm in diameter) by careful control of the surfactant–water content and the rate of condensation of silica [10]. Yang et al. reported the synthesis of mesostructured silica tube with diameter of 150 nm by filtration of mesoporous silica within porous anodic alumina membranes [11]. Liang and Susha prepared mesostructured silica tube with diameters around 350 nm by deposition of a prehydrolysed silica sol with surfactant into a polycarbonate (PC) membrane [12]. More recently, Che et al. reported a synthesis of silica nanotube with tube diameter of 100 nm in the presence of chiral dopant [13]. In these cases, the obtained tube diameters were mainly from 100 nanometers to micrometer. Mesostructured silica nanotubes with tube diameter less than 100 nm are still desired because the fascinating properties of one-dimensional nanostructure were generally induced by nanosize-effect [3–7]. Previous study has shown that amorphous silica could be coated on carbon nanotubes (CNTs) by a sol–gel process [14,15]. One may expect that, if mesostructured silica precursor could be coated on the nanosized CNTs and followed by calcination to remove the CNTs and mesoscale organotemplate, mesostructured silica nanotubes can be obtained. It is known that the diameter of CNTs could be ranged from several to tens of nanometers, thus the synthesis of silica nanotubes within 100 nm is possible. By considering these aspects, herein we report on a one-pot hydrothermal synthesis of mesostructured silica nanotubes from a system of CNTs/cetyltrimethylammonium bromide (CTAB)/TEOS/$NH_3{\cdot}H_2O$.

2. Materials and methods

2.1. Synthesis

About 1.1–2.2 g of CTAB were mixed with 26 mL of water, followed by addition of 12 mL of $NH_3{\cdot}H_2O$ (25 %) solution and a certain amount of CNTs (0.4–2.4 g), and stirred for 3 h at room temperature. After addition of 5.0 mL of TEOS (>99 %) and further stirring for 2 h, the mixture was placed into an autoclave, crystallizing at the temperature of 100 °C for 72 h. After filtration, dryness, and calcination at 750 °C in air, the product designated as SNT-*n* (*n* = 1–3 for CNTs amount at 0.4, 1.2, and 2.4 g, respectively) was obtained.

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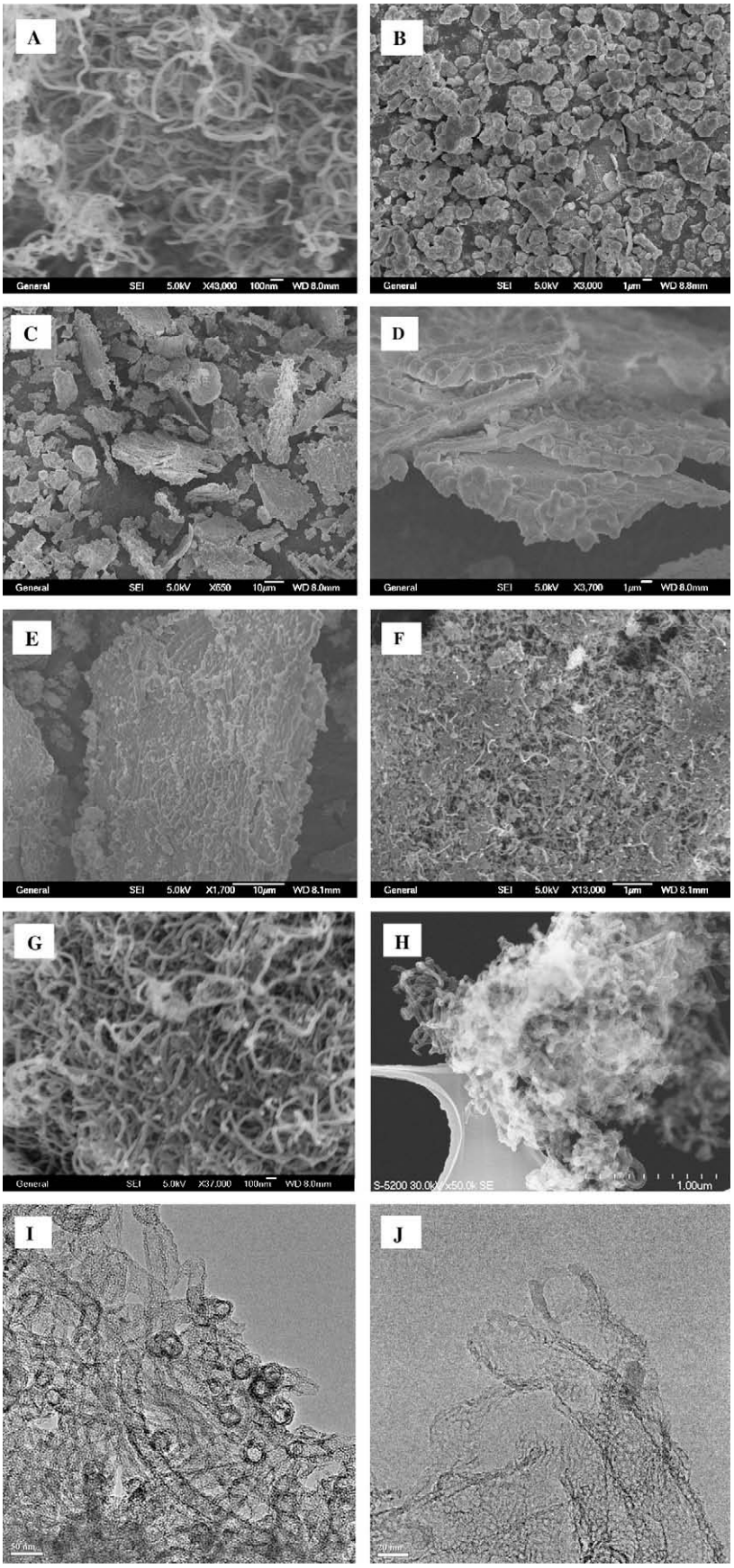

Fig. 1. SEM images of (A) carbon nanotubes, (B) calcined MCM-41, (C and D) calcined SNT-1, (E and F) calcined SNT-2, (G) as-synthesized SNT-3, (H) calcined SNT-3, and TEM images of (I and J) calcined SNT-3.