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Insights into the physicochemical aspects from natural halloysite to silica nanotubes

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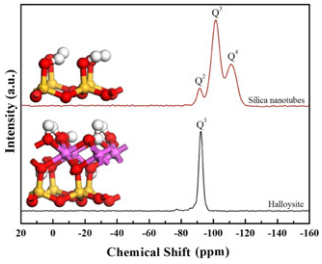
HIGHLIGHTS

- Silica nanotubes (SiNTs) were synthesized from natural halloysite (HNTs).
- SiNTs retained the tubular morphology as the natural halloysite.
- Atomic structure analysis conformed the chemical shift from HNTs to SiNTs.

GRAPHICAL ABSTRACT



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ABSTRACT

Silica nanotubes (SiNTs) were synthesized by acid-leaching the natural halloysite nanotubes (HNTs). Transmission electron microscopy (TEM) and scanning electron microscope (SEM) images showed that SiNTs retained the morphology of HNTs. The specific surface area (183.6 m^2/g) and pore volume (0.74 cm^3/g) of SiNTs were three times higher than those of HNTs, which indicated more active groups on the surface of SiNTs than HNTs. The ^{29}Si nuclear magnetic resonance (NMR) and Fourier transform infrared spectroscopy (FTIR) were used to trace the variations of chemical structures. NMR spectroscopy demonstrated the disappearance of Q^2 structure ($Si(OSi)_2(OH)_2$) and Q^4 framework structure ($Si(SiO)_4$), and the partial chemical shift of Q^3 structure ($Si(SiO)_3(OH)$) from HNTs to SiNTs. Photoluminescence (PL) analysis showed the higher blue PL intensity of SiNTs than that of HNTs, which indicated that the as-synthesized SiNTs could have potential application in the fields of light localization and optical devices.

1. Introduction

Nanotube structures of silica materials showed unique physicochemical properties due to their nanosized wall thickness between the outer and inner surface. However, the potential applications of silica nanotubes (SiNTs) were still in the early stages of their development, scientists and engineers had already started to consider the possible applications for this kind of new material. It had been considered for use in drug-delivery systems [1,2], molecular separation [3], single-DNA sensing [1], pollutants decomposition [4,5], hydrogen fuel production [6], nanoscale reactors [7]. Template synthesis of SiNTs had been investigated vigorously [8], generally on the surface of various templates by hydrolysis of TEOS (i.e., silica source), and followed by the removal of templates. Anodic aluminum oxide membranes [9], organic gelators [10–12], cholesterol nanotubes [13], carbon nanotubes [14], crystalline fibers [15–17], and silicon nanowires [18] had also been widely used as the templates for the silica nanotube syntheses.

Treatment of halloysite nanotubes (HNTs) or other clay minerals by organic or inorganic acids led to the leaching of the diaspore-like

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