



Tailoring Microstructure of Silica Xerogels via a Facile Synthesis Approach

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Abstract

Silica xerogels of tailored microstructure were prepared via a facile synthesis approach. This approach entails the preparation of silica nanoparticles using the sol-gel method under the influence of low frequency ultrasonication. By applying optimum synthesis conditions, silica nanoparticles of tailored mean sizes in the form of silica sol type B (158.3 ± 14.1 nm), and silica sol type M (83.1 ± 22.5 nm) were successfully synthesized. The various mean particle sizes were then mixed in predetermined molar ratios, and subsequently gelation under controlled conditions. The effect of adding polyvinyl pyrrolidone (PVP) as a polymeric surfactant on the microstructure of silica xerogels was also investigated.

Keywords: silica xerogels, mean particle size, surfactant

1. Introduction

Nanomaterials of substantially enhanced properties over their bulk counterparts have led to intensified research interest and increased industrial demands in recent years. Silica-based nanomaterials such as silica nanoparticles and xerogels have been extensively studied by scientists worldwide due to their ease of preparation and numerous potential applications. Silica nanoparticles possess superior properties such as adjustable refractive index, high porosity, low thermal conductivity and low dielectric constant. They are widely being used in various applications including catalysis [1-2], drugs delivery [3-4], thin-film substrates [5], corrosion protection [6], stabilizers [7], humidity sensors [8] and optical sensors [9]. Silica nanoparticles are mainly synthesized by the sol-gel process [10-12] and water-in-oil emulsion [13]. The mean sizes of silica nanoparticles can be easily controlled by varying the synthesis parameters, such as the reaction temperature [11], aging duration and conditions [14], washing solvent [15] and drying conditions [14, 16]. Since the discovery of surfactant-templated mesoporous silica in 1992 [17], studies on microstructural control of silica had been carried out extensively. However, the removal of template from synthesized silica literally created problems. For example, mesoporous molecular sieves of MCM-48 were usually synthesized in basic conditions by self-assembly, using tetraethylorthosilicate (TEOS) as the silica source and cetyltrimethylammonium bromide (CTAB) as the template which was eventually removed by calcination. Calcination is a process of decomposing the organic template into carbon dioxide and organic amine compounds [18]. The pore diameters decreased as a result of silica lattice shrunk during calcination. Besides that, silica xerogels were also synthesized by the acidification of sodium silicate using hydrochloric acid and acetic acid via a sol-gel process. The microstructure of resulting silica xerogels were affected by the concentration of acetic acid used [19].

In this study, preformed silica nanoparticles of different mean sizes were used to prepare silica xerogels of desired microstructure. Two different types of silica sols were prepared: silica nanoparticles of mean diameter 158.3 ± 14.1 nm (designated as Type B), and silica nanoparticles of mean diameter 83.1 ± 22.5 nm (designated as Type M). Silica sols of both Type B and Type M were used for preparing silica xerogels. The effect of varying molar ratios of Type B and Type M of silica sols on the microstructure and surface morphology of silica xerogels formed were investigated. Besides, effect of adding a polymeric surfactant polyvinyl pyrrolidone (PVP), on the resulting microstructure of silica xerogels was investigated.