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Review

Recent progress in hollow silica: Template synthesis, morphologies and applications

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ABSTRACT

Hollow silica is a special type of novel inorganic material with one or more cavities inside. In addition to the excellent properties as with its solid counterparts, hollow silica exhibits unique characteristics, such as low density, high specific surface and good adsorption performance. Researchers have developed many routes to prepare mono-dispersed hollow silica with regular morphology. However, most studies focused on hollow silica spheres, ignoring the structural superiority of other hollow structures. Template synthesis is highly prominent due to its flexibility and versatility. What's more, it is suitable for the preparation of hollow silica with various morphologies. In this article, the research progress of template synthesis was firstly provided. Then different morphologies of hollow silica were introduced, including hollow spheres, hollow tubes, hollow cubes, etc. To better demonstrate the advantages and potential value of hollow silica materials, their performance in diverse applications were discussed. Finally, some perspectives on the future research and development of hollow silica were put forward.

Contents

1. Introduction

Hollow inorganic materials have attracted broad interests in recent years for their innovative structure, singular properties and a wide range of potential applications [1–5]. Hollow space inside

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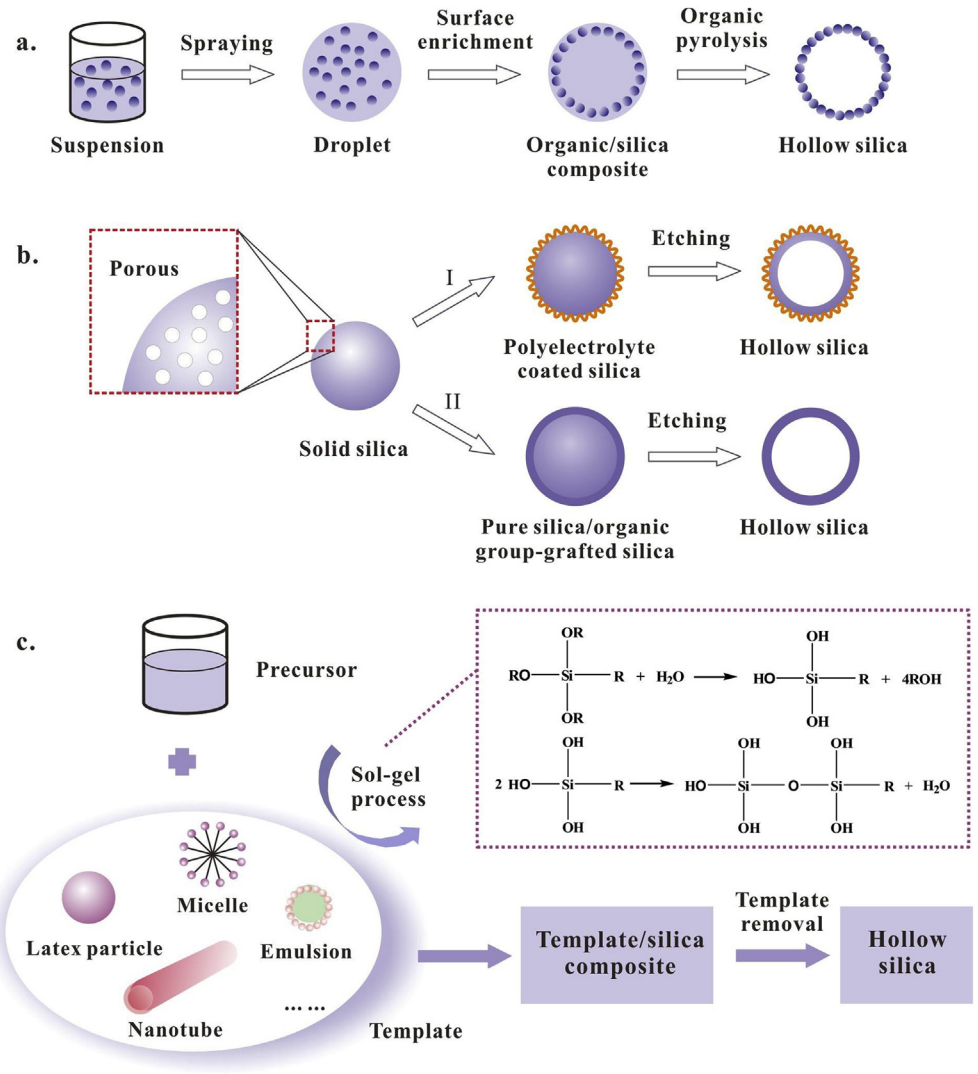

Fig. 1. Schematic illustration for: (a) spray drying, (b) self-templating method and (c) template synthesis.

endows them with low density, large specific surface area, enhanced optical performance and many other good properties [6–9]. As a result, they have been widely applied in catalysis, optics and electronics, waste removal and controlled release system in the past decades [10–14]. Of the available inorganic matrix, silica has been demonstrated to be nontoxic, highly biocompatible, thermally and mechanically stable, and easy to be functionalized. Therefore, hollow silica has greater utilization potentiality than other hollow inorganic materials, especially in the field of biomedicine [15–17].

Since the pioneering works carried out by Kowalski and Colleagues at Rohm and Haas [18,19], numerous techniques have been developed to prepare hollow silica, including template-assisted synthesis, self-templating method and spray drying [20–26]. For example, spray drying (Fig. 1a) is a common method to fabricate hollow silica spheres from suspension of tiny silica particles [27,28]. It is fit for the mass-production with a continuous process. Bust most products obtained by this method are of micron scale in diameter [29], which limited its application. As a typical representative of self-templating method (Fig. 1b), selective leaching is also known as silica-templating method, wherein the starting material is solid silica or its analogous species [30,31]. The outer silica layer protected by polyelectrolyte or grafted by organic group shows higher stability against etching than pure solid silica, which will cause preferential etching from the interior of silica, generating well-defined hollow silica shell [32–34]. Particle size of hollow silica is largely determined by the size of the starting silica. In this method, controlling the structure parameters of hollow silica is a challenge, because the solid-to-hollow evolution will continue until the pure silica core is completely consumed [35–37].

Despite the increasing number of reports on self-templating or other novel routes for preparing hollow silica, most fabrication approaches still rely on the conventional template method (template synthesis) [38,39]. Template synthesis is an easy strategy to regulate the final morphology of hollow silica with the aid of heterogeneous template. Three steps, as illustrated in Fig. 1c, namely template preparation, shell formation and template removal are usually indispensable in the template synthesis of hollow silica. By coating silica layer on the periphery of templates, the template/silica composites are produced. Hollow silica is then created simply by removing the heterogeneous template core. The advantages of this method lie in its economy, efficiency and especially the structure parameters controllability of products. Moreover, it doesn't require any expensive equipment or uncommon materials.

It has been well accepted that the morphology and size of materials significantly influence their physical and chemical properties, hence their applications. In view of this, considerable efforts