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Facile synthesis of mesoporous SnO_2 microspheres using bioactive yeast cell

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ABSTRACT

Mesoporous structure SnO_2 microspheres with core-shell structure were synthesized through a facile method using $SnCl_4$ as raw material, bioactive yeast cell as a bio-template, respectively. The products were characterized by powder X-ray diffraction, high resolution scanning electron microscopy, transmission electron microscopy, Fourier transformed infrared spectroscopy and nitrogen adsorption/desorption measurements. Results showed that regular oval-like microspheres with core-shell structure can be formed when the bioactive yeast cell was added, and the mean size of the microspheres was in the range of 2 to 3 μm. The as-prepared SnO_2 microspheres presented a high specific surface area of 85.7 m^2/g and a mesoporous structure with the pore size of 38.8 nm. TEM showed that the crystal size of SnO_2 was about 6 ± 0.5 nm. A possible formation mechanism for this kind of core-shell structure was proposed.

1. Introduction

SnO_2 a typical n-type metal oxide, with a wide band gap of 3.6 eV (at 300 K) has been proved to be one of the most attractive semiconducting metal oxides due to its excellent chemical and physical properties. It has been studied extensively in the fields of gas sensors [1–7], photocatalysis [8], super capacitor [9,10] and high-capacity anode material for lithium-ion batteries [11,12]. As we all know, new structures often play an important role in deciding the properties of materials. In order to improve the performance of SnO_2, SnO_2 products with different structures have been successfully developed including nanoparticles [1], nanoflowers [2], nanowires [4], porous structure [5,6], hollow nanofibers [7], hollow spheres [13–20] in the past few years, and all these special structures also show unique performance. Especially, due to the hollow structure and high specific surface area, SnO_2 hollow spheres have been synthesized by template-directed synthesis [13–17], self-assembly [18] and hydrothermal processing [19,20]. Among these methods, template-directed synthesis has been widely used and found to be a simple, inexpensive and effective technique. Up until now, a number of SnO_2 hollow microspheres have been prepared by using polystyrene (PS), carbon and poly methyl methacrylate (PMMA) spheres as the templates. In recent years, bio-active microorganisms have been used as template to prepare unique structure inorganic materials, such as yeast cells. It has been applied successfully in the preparation of microspheres, such as ZrO_2, ZnO, CdO, and CuO [21–24]. In particular, mesoporous structure can effectively increase the active surface area and offer more active centers due to the porous hollow structure, which is important for the applications [5].

The objective of the present work is to fabricate SnO_2 microspheres composed of mesoporous structure, using bioactive yeast cell as a bio-template. The microstructure, pore size distribution and the possible formation mechanism for the microspheres were investigated.

2. Experimental

2.1. Materials and experiment process

$SnCl_4 \cdot 5H_2O$ (AR grade, CAS#: 10026-06-9) was purchased from Sinopharm Chemical Reagent Co., Ltd., Shanghai, China. Bioactive yeast cell cultivated by instant dry yeast (CAS#: 8013-01-2, Angel Yeast Co. Ltd., China) was used as the bio-template.

Firstly, dry yeast was cultivated in a beaker with agitation at the temperature of 32 °C aged for 0.5–1 h, and 50 ml of $SnCl_4 \cdot 5H_2O$ ethanol solution was added into the yeast solution under stirring (the mass ratio of yeast to synthesized SnO_2 was 1:1). The reaction system was further stirred continuously at 32 °C for 1 h. The suspension was filtered to obtain the fawn precipitates. Then the precipitates were washed with deionized water and ethanol. The resulting precipitates were dried at 40 °C and calcined in air with proper temperature-programmed to 550 °C for 2 h by a chamber electric furnace.

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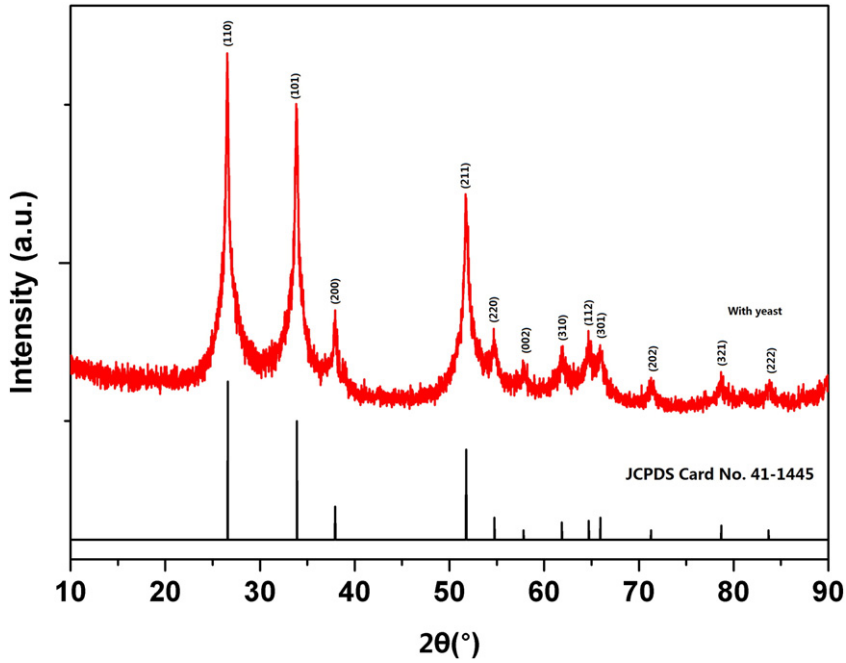

Fig. 1. XRD pattern of the microspheres calcined at 550 °C for 2 h (mass ratio of yeast to SnO_2 is 1:1).

2.2. Characterization

The phase identification of the microspheres was performed using an X-ray diffractometer (XRD) (D/MAX2500PC model, Rigaku Co., Japan) using CuKα radiation at room temperature over a 2θ range of 10° to 90°. The microstructure of the microsphere coated with Pt was observed by field emission high resolution scanning electron microscopy (SEM) (Nova Nano SEM450, FEI, America). The crystal structural properties of the prepared materials were characterized by transmission electron microscopy (TEM; JEOL JEM2100F) equipped with high-resolution imaging features. The porous characteristics of the prepared microspheres were examined by N_2 adsorption/desorption experiments at 77 K on a Micromeritics Quadrasorb-EVO (Quadrasorb-EVO, Quantachrome Corporation, America) gas adsorption apparatus. The specific surface area was measured according to the Brunauer-Emmett-Teller (BET) method, and the BJH model was used to calculate the pore size distribution. Fourier transformed infrared spectroscopy (FTIR) spectrum was measured using (NEXUS670, Thermo Nicolet Corporation, America) FTIR Spectrophotometer over the range of 4000–500 cm^{-1} at room temperature. Diffuse Reflectance UV–visible property of the microspheres was determined using a Shimadzu UV-3101 PC spectrophotometer equipped with an integration sphere.

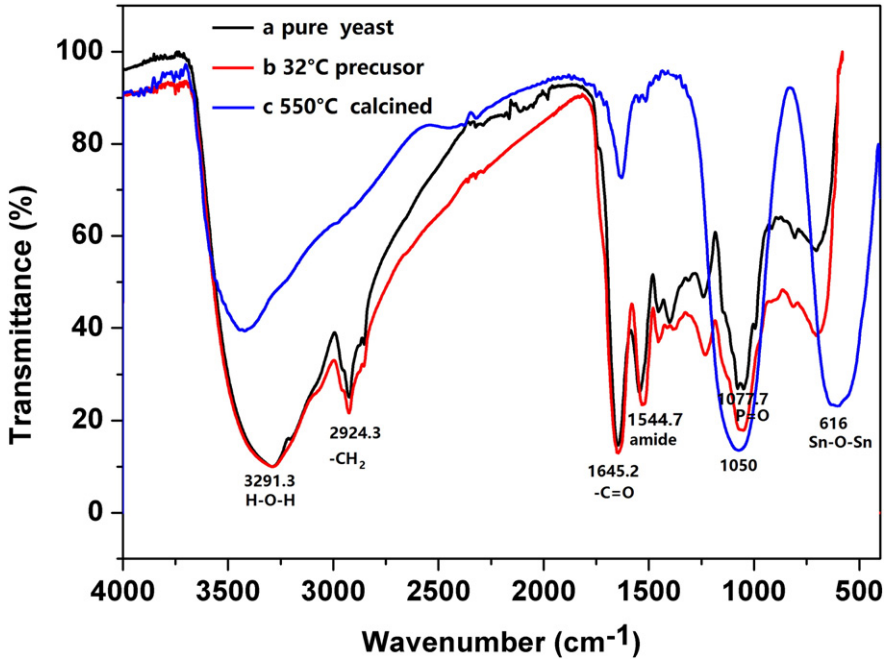

Fig. 2. FTIR spectra of original yeast (a), precusor with yeast (b) and sample calcined at 550 °C (c).