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Biotemplated fabrication of porous alumina ceramics with controllable pore size using bioactive yeast as pore-forming agent

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Abstract

Porous alumina ceramics with controlled pore size and pore morphology were prepared by precipitation method using $Al(NO_3)_3$ and ammonia as raw materials, bioactive yeast cell as a pore-forming agent, respectively. The formation mechanism of the porous structure, the effects of both mass ratios of bioactive yeast to alumina and calcination temperature on the phase development and microstructure of the products were examined. Results showed that core–shell composites of yeast cell/alumina precursor could be obtained via electrostatic attraction followed by filtration and calcination to produce porous alumina ceramic. Regular oval-like interconnected micron sized pores can be formed when the mass ratio of the yeast cell to alumina was 1:1, and the mean pore size is in the range of 0.1 to 3 μm.

Keywords: Alumina; Porous ceramics; Pore-forming agent; Yeasts; Microstructure

1. Introduction

Porous alumina ceramics, due to their chemical stability, high temperature resistance, high surface area and high porosity [1–3], have been widely used in many industrial fields, such as thermal insulation, catalyst support, liquid or molten-metal filtration, hot-gas purifier and biomedical implant. Up to now, many manufacturing processes have been applied to prepare porous alumina ceramics, such as partial sintering method [4], sol–gel synthesis [5,6], freeze-casting method [7,8], organic foam method [9] and pore-forming agent method [10–16]. Among these techniques, pore-forming agent method is the most widely used and effective technique. Many pore-forming agents such as rice husk, starch, graphite, organic particulates and sawdust, have been used commonly. Unfortunately, most of these pore-forming agents only form structures with randomly arranged irregular pores in the final structure which are caused by agglomeration and nonuniformity of pore-forming agents in the raw materials, and it is difficult to be avoided. The uncontrollable pore size and pore morphology of the porous alumina ceramics result in low mechanical properties and low filter accuracy, which, thereby, limits the applications of the porous ceramics in many areas.

The objective of the present work was to fabricate porous alumina ceramics with controlled pore morphology and narrow pore size distribution, using bioactive yeast cell as a pore-forming agent [17,18]. The effects of mass ratios of yeast cell to alumina and calcination temperature on the phase development, microstructure and pore size distribution of the porous ceramic were investigated.

2. Experimental

2.1. Materials and experiment process

$Al(NO_3)_3 \cdot 9H_2O$ (AR grade, CAS: 7784-27-2) was purchased from Shanghai Zhen-xin Chemical Reagent Factory.

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Ammonium hydroxide (AR grade, CAS: 133621-6) used as precipitators was purchased from Shanghai Lingfeng Chemical Reagent Co., Ltd. Bioactive yeast cell cultivated by instant dry yeast (CAS: 8013-01-2, Angel Yeast Co., Ltd., China) was used as the pore-forming agent.

First, dry yeast was cultivated in a beaker with agitation at the temperature of 32–34 °C aged for 0.5–1 h. Then 50 ml of $Al(NO_3)_3 \cdot 9H_2O$ aqueous solution was added into the yeast solution under stirring. Then the ammonium hydroxide solution with the concentration of 1 mol/l was added to the mixture system dropwise until the pH value of the mixture rose up to 9. The reaction system was further stirred continuously at 32–34 °C for 4 h, and aged for 5–10 h at ambient temperature. The suspension was filtered to obtain the fawn precipitates. Afterward, the precipitates were washed with deionized water. The resulting precipitates were then vacuum filtrated to pack the flocculated particles together, and different mass ratios of yeast to synthesized alumina (1:2, 1:1.5, 1:1, 2:1) were chosen. Finally all the green bodies were dried and calcined in air with proper temperature-programmed to various temperatures for 2 h by a chamber electric furnace, and specimens with the size of about 1–2 cm in diameter and 1–2 mm in thickness were obtained, the schematic procedure for fabrication of the macroporous alumina ceramic is shown in Fig. 1.

2.2. Characterization

The phase identification of the sintered specimens was performed using an X-ray diffractometer (XRD) (D/MAX2500PC model, Rigaku Co., Japan) using Cu *K*α radiation at room temperature over a 2θ range of 15° to 90°. Zeta potential of the yeast cell in solution was characterized by a laser electrophoresis analyzer (Zetasizer 3000HSA, Malvern Instruments Ltd., UK). The microstructures of the fracture surface of sintered specimens coated with Au or Pt were observed by electron probe micro-analysis (EPMA) (JXA-8230 model, Electron Optics Laboratory Co. Ltd., Japan) and scanning electron microscopy (SEM) (Nanosem450, FEI, Japan). Mercury porosimetry measurement was carried out on a Micromeritics Poresizer (PoreMaster 33G, Quantachrome Corporation, America) for characterizing the pore size distribution and

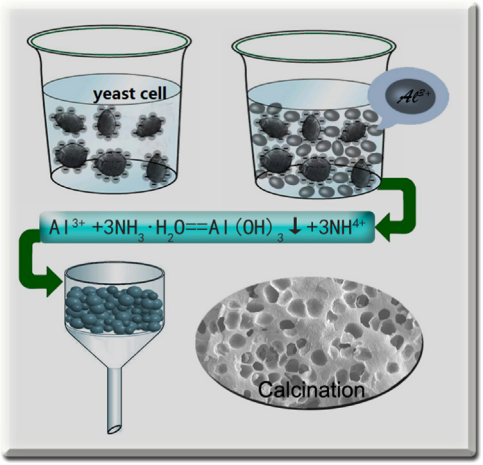

Fig. 1. Schematic procedure for fabrication of macroporous alumina ceramic.

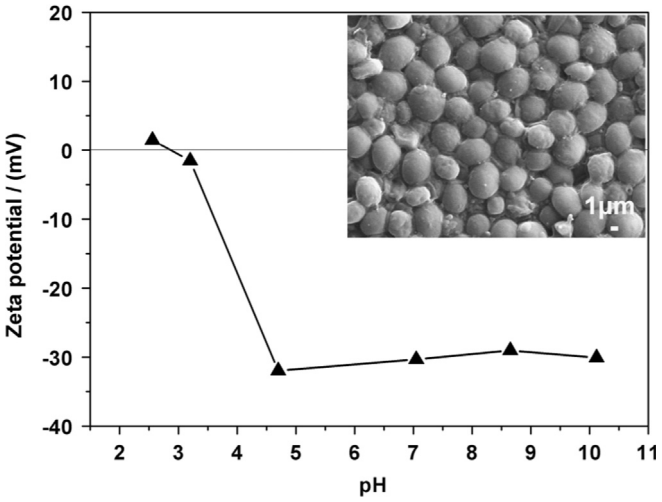

Fig. 2. Zeta potential and microstructure of the yeast cell.

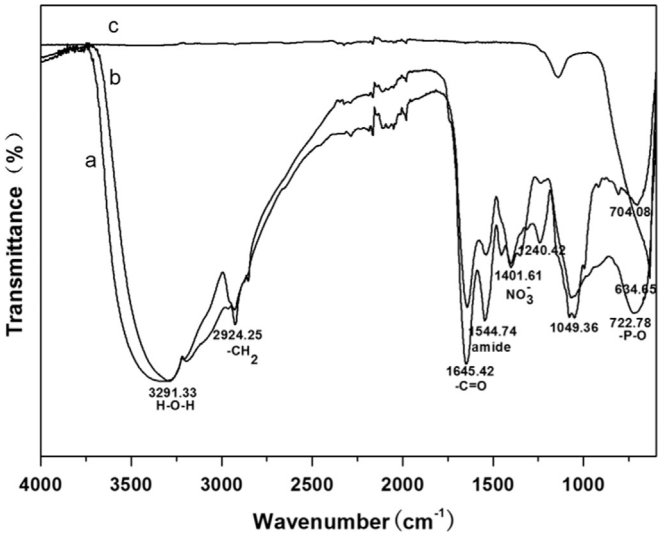

Fig. 3. FTIR spectra of original yeast (a), precipitates with yeast (b) and sample calcined at 550 °C (c).

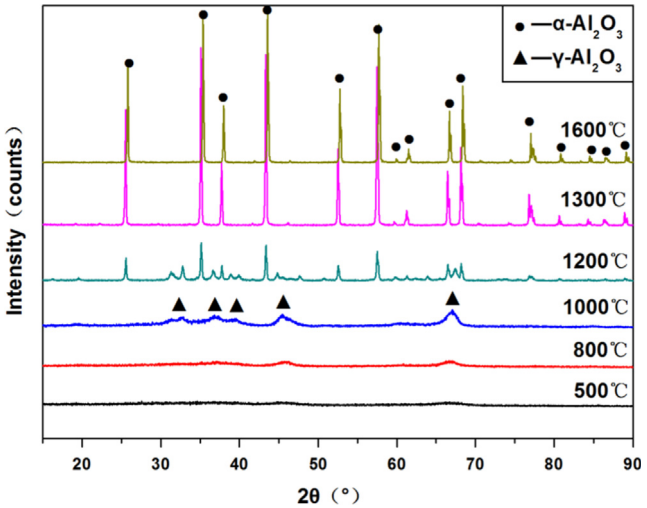

Fig. 4. XRD patterns of the specimen (mass ratio of yeast to alumina is 1:1).