Journal of the European Ceramic Society xxx (2017) xxx–xxx

Contents lists available at www.sciencedirect.com

Journal of the European Ceramic Society

journal homepage: www.elsevier.com/locate/jeurceramsoc

Feature article

In-situ coagulation of yttria-stabilized zirconia suspension via dispersant hydrolysis using sodium tripolyphosphate

Ke Gan [a], Jie Xu [b,*], Yan-Jiao Gai [c], Jia-Min Wu [d], Shi-Ji Li [c], Yu-Ju Lu [a], Wen-Long Huo [a], Xiao-Yan Zhang [a], Jin-Long Yang [a,*]

[a] State Key Laboratory of New Ceramics and Fine Processing, School of Materials Science and Engineering, Tsinghua University, Beijing 100084, China
[b] State Key Laboratory of Solidification Processing, School of Materials Science and Engineering, Northwestern Polytechnical University, Xi'an 710072, Shaanxi, China
[c] School of Materials Science and Engineering, North University of China, Taiyuan 116028, China
[d] State Key Laboratory of Material Processing and Die & Mould Technology, School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, China

ARTICLE INFO

Article history:
Received 27 February 2017
Received in revised form 21 May 2017
Accepted 23 May 2017
Available online xxx

Keywords:
In-situ coagulation
Sodium tripolyphosphate
Dispersant hydrolysis
Mechanical properties
YSZ

ABSTRACT

A novel in-situ coagulation method without coagulation agent and adjusting pH value for yttria-stabilized zirconia (YSZ) suspension via dispersant hydrolysis is reported. Sodium tripolyphosphate (STPP) is used as dispersant to prepare electrostatic stabilized YSZ suspension. Influences of STPP contents on the dispersion and pH value of YSZ suspension were investigated. It indicated that there was a well-dispersed YSZ suspension with the addition of 0.3 wt% STPP at pH = 10. Influence of coagulation temperature on coagulation process and properties of green body was investigated. The sufficiently high viscosity suspension to coagulate was achieved at 60–80 °C. The coagulation mechanism was different from traditional direct coagulation casting. The suspension was coagulated by directly shifting the isoelectric point to the original state without increasing the ionic strength and adjusting the pH value. It was proposed that the YSZ suspension could be destabilized via decrease of zeta potential by sodium tripolyphosphate hydrolyzing at elevated temperature. Coagulated samples with wet compressive strength of 3.60 MPa could be demolded without deformation by treating 50 vol% YSZ suspension with 0.3 wt% STPP at 60 °C for 30 min. Dense YSZ ceramics with flexural strength of 887 ± 110 MPa and relative density of 98.9% had been prepared by this method sintered at 1450 °C for 3 h.

1. Introduction

Yttria-stabilized zirconia ceramics have been widely used as an advanced structural material due to the excellent performances such as high strength, high toughness, good wear resistance, high thermal expansion coefficient and low thermal conductivity [1–4]. In various applications, YSZ ceramics components with complex shape and homogeneous microstructure are highly demanded. Direct coagulation casting (DCC) is a promising and effective method for the fabrication of complex shape ceramic parts which is based on the idea of that a high solid loading suspension is destabilized by a time–delayed internal reaction using a catalyst [5–7]. The suspension can be coagulated by either shift pH to isoelectric point (IEP) or increase the ionic strength into suspension [8,9]. Up to now, there are enormous amounts of investigation on DCC of YSZ ceramic [10–12].

In the previous studies, dense non-oxide ceramics including both silicon nitride and silicon carbide ceramics had been prepared by direct coagulation casting via dispersant reaction [13,14]. In this method, the non-oxide ceramic suspensions were coagulated via the decrease of zeta potential by an acid-base reaction between basic dispersant and an acid which was hydrolyzed from coagulation agent. Although there were many advantages of dispersant reaction and other colloidal forming methods, some corrupt practices of these methods for aqueous suspension were not avoided due to the addition of coagulation agents, such as using slightly soluble coagulation agent, non-uniform coagulation, long coagulation time, superfluous organic additives and so on [15–17]. Sodium tripolyphosphate (STPP) is a kind of polyphosphates which includes ammonium polyphosphate (APP) and sodium hexametaphosphate (SHMP) etc. There are wide applications of polyphosphate as water

* Corresponding authors.
E-mail addresses: xujie@nwpu.edu.cn (J. Xu), jlyang@mail.tsinghua.edu.cn, jdzganke@163.com (J.-L. Yang).

http://dx.doi.org/10.1016/j.jeurceramsoc.2017.05.044
0955-2219/

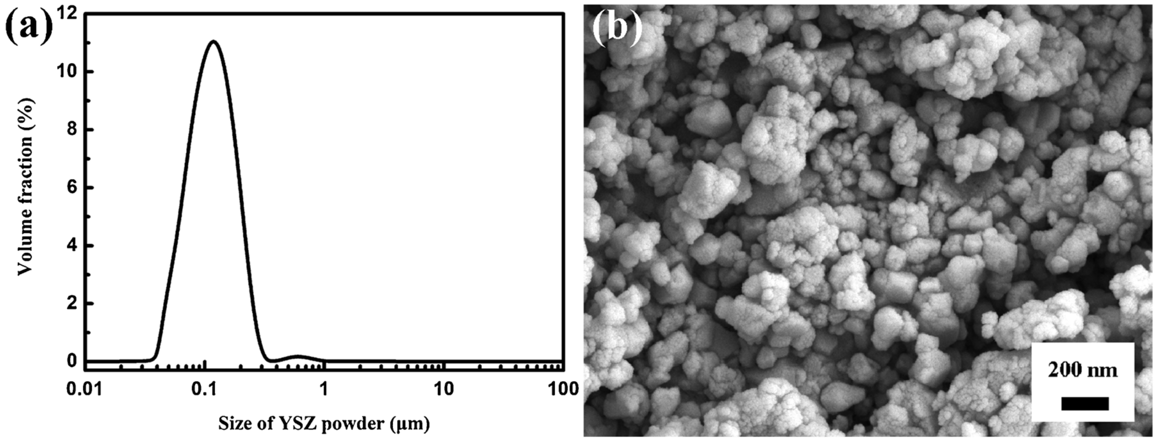

Fig. 1. (a) Particle distribution and (b) microstructure of YSZ powder.

retention agent, pH regulator, detergent builder and metal-chelator to be employed in food processing, waste water treating and other commercial productions [18]. It is also used as dispersant to prepare suspension [19–21]. A large amounts of research focused on the chemical properties of polyphosphate and the application of sodium tripolyphosphate hydrolysis in industrial production [22–24].

In the present work, the chemical properties of dispersant are still used in experiment. The YSZ suspension with high solid loading and low viscosity was prepared using sodium tripolyphosphate as dispersant. It was coagulated by dispersant hydrolysis method which abandoned the addition of coagulation agent. The influences of coagulation temperature on zeta potential, pH value and rheological properties of YSZ suspension with STPP were investigated. The YSZ suspension could be directly coagulated in-situ without any coagulation agents and pH regulators at elevated temperature. A novel in-situ coagulation method for YSZ suspension was proposed by controlling the dispersant hydrolysis with temperature increase.

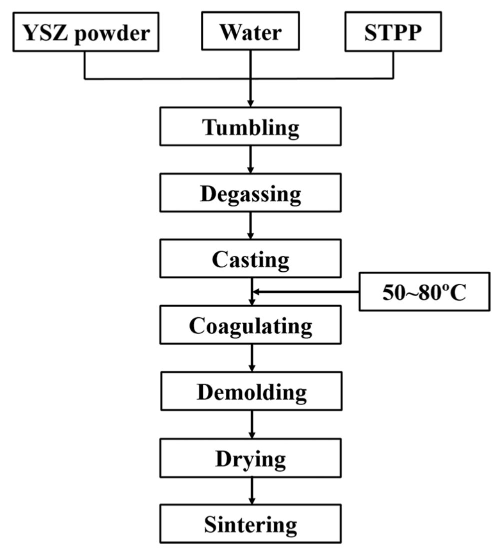

Fig. 2. Flowchart of the in-situ coagulation process via dispersant hydrolysis.

2. Experimental

2.1. Materials

Fig. 1 shows the particle distribution and microstructure of YSZ powder. Tetragonal zirconia powder (OZ-3Y, stabilized with 3 mol% Y_2O_3) with average particle size of 0.13 μm and specific surface area of 8.53 m^2/g was produced from Guangdong Orient Zirconic Ind. Sci. & Tech. Co., Ltd., China. Sodium tripolyphosphate was used as dispersant with different concentrations. $Na_4P_2O_7$, NaH_2PO_4 and Na_2HPO_4 were used in proportion as the hydrolysates of sodium tripolyphosphate to investigate the effect of hydrolysates on viscosity of alumina suspension. All of the chemicals were analytic reagent and produced from Sinopharm Chemical Reagent Co., Ltd., China. Also, deionized water was used in the preparation of suspension.

2.2. Preparation of YSZ ceramics

Fig. 2 shows the flowchart of the in-situ coagulation process via dispersant hydrolysis. Different solid loadings YSZ suspensions were prepared by tumbling the YSZ powder, dispersant, water and grinding media for 24 h. Grinding media was zirconia balls with diameter of 5–10 mm. The mass ratio between YSZ powder and grinding media was 2:1. The suspensions were degassed for 15–20 min under vacuum condition. Then, the YSZ suspensions were cast into plastic molds. The molds were placed in a water bath which was set a heating rate of 5 °C/min. The heating was lasted a period of time at different temperatures and then demolded. The samples were dried at 80 °C for 24 h. Finally, the green bodies were sintered at 1450 °C for 3 h.

2.3. Characterizations

LE438 pH meter (Mettler, Toledo, Switzerland) was employed to measure the pH value of YSZ suspension. Zeta Potential Analyzer (CD–7020, Colloidal Dynamics Co., Ltd., Ponte Vedra Beach, FL, USA) was employed to measure the zeta potential of YSZ suspensions with a stirring speed setting at 300 r/min. 10 vol% YSZ suspension was used in the test. HCl (1 mol/l) and NaOH (3 mol/l) aqueous solutions were prepared and used to adjust the pH value of the suspensions. In order to analyze the influence of pH value on zeta potential of alumina suspension, the ionic strength and conductivity of the suspension were maintained a constant via adding NaCl (analytic reagent). Rheometer (KINEXUS PRO, Malvern Instruments, Worcestershire, UK) attached with PC25 C0138 AL cylinder and C25 R0634 SS spindle was employed to measure the rheological properties of the YSZ suspensions. FTIR spectra were collected on Vertex 70 v Fourier Spectrophotometer (Bruker, Germany) using pressed KBr pellets as reference substance. AG–IC20KN (Shimadzu, Tokyo, Japan) testing machine with a cross head speed of 0.5 mm/min was employed in the wet com-

Please cite this article in press as: K. Gan, et al., In-situ coagulation of yttria-stabilized zirconia suspension via dispersant hydrolysis using sodium tripolyphosphate, J Eur Ceram Soc (2017), http://dx.doi.org/10.1016/j.jeurceramsoc.2017.05.044