Available online at SciVerse ScienceDirect
SciVerse ScienceDirect
J. Mater. Sci. Technol., 2013, 29(5), 429—433
JMST
www.JMST.org

Effect of Microstructure of Composite Powders on Microstructure and Properties of Microwave Sintered Alumina Matrix Ceramics

Hanmin Bian[1,3], *Yong Yang*[1,2]*, *You Wang*[1], *Wei Tian*[4], *Haifu Jiang*[5], *Zhijuan Hu*[3], *Weimin Yu*[3]

1) Department of Materials Science, Harbin Institute of Technology, Harbin 150001, China
2) School of Materials Science and Engineering, Hebei University of Technology, Tianjin 300132, China
3) Tianjin Cement Industry Design & Research Institute Co., Ltd., Tianjin 300400, China
4) China Gas Turbine Establishment, Chengdu 610500, China
5) National Defense Science and Technology Key Lab for Reliability and Environment Engineering Technology, Beijing Institute of Spacecraft Environment Engineering, Beijing 100029, China

[Manuscript received December 7, 2011, in revised form January 24, 2012, Available online 26 March 2013]

Two kinds of different structured alumina—titania composite powders were used to prepare alumina matrix ceramics by microwave sintering. One was powder mixture of alumina and titania at a micron—submicron level, in which fused-and-crushed alumina particles (micrometers) was clad with submicron-sized titania. The other was powder mixture of alumina and titania at nanometer—nanometer level, in which nano-sized alumina and nano-sized titania particles were homogeneously mixed by ball-milling and spray dried to prepare spherical alumina—titania composite powders. The effect of the microstructure of composite powders on microstructure and properties of microwave sintered alumina matrix ceramics were investigated. Nano-sized composite (NC) powder showed enhanced sintering behavior compared with micro-sized composite (MC) powders. The as-prepared NC ceramic had much denser, finer and more homogenous microstructure than MC ceramic. The mechanical properties of NC ceramic were significantly higher than that of MC ceramic, *e.g.* the flexural strength, Vickers hardness and fracture toughness of NC ceramic were 85.3%, 130.3% and 25.7% higher than that of MC ceramic, respectively. The improved mechanical properties of NC ceramic compared with that of MC ceramic were attributed to the enhanced densification and the finer and more homogeneous microstructure through the use of the nanostructured composite powders.

KEY WORDS: Al_2O_3; Composites; Microwave processing; Mechanical properties

1. Introduction

Alumina matrix ceramics are widely utilized in many fields due to their unique mechanical, electrical and optical properties and biocompatibility. However, the relatively high sintering temperature and low fracture toughness have limited its wide application. It had been proved that incorporating suitable second phases into alumina was an effective way to lower its sintering temperature, control its microstructure and therefore improve its mechanical properties[1—4]. It was reported that addition of titania to alumina considerably changed its sintering behavior to manufacture dense ceramics[5]. In addition, the fracture toughness and wear resistance of alumina was improved with dispersion of titania[6]. Alumina—titania ceramics could be a good ceramic material for the femoral head of total hip joint replacement, high-power millimeter-wave application and as support for transition metal catalyst[7—10].

On the other hand, several investigations had shown that a smaller grain size (grain refinement) in alumina ceramics led to improved mechanical properties[11—15]. Fine-grained alumina matrix ceramics have been considerably investigated and reported to possess superior and attractive properties compared to their conventional coarse-grained counterparts[16—18].

In recent years, a number of techniques have been attempted to produce fine-grained alumina matrix ceramics, such as hot pressing, hot isostatic pressing, spark plasma sintering, microwave sintering, thermal spraying, laser-based techniques, *etc*[14]. Among the possible processes, microwave had been widely employed in ceramic processing by virtue of a multitude of

* Corresponding author. Tel.: +86 451 86402752; Fax: +86 451 86413922; E-mail address: hityangyong@163.com (Y. Yang).

http://dx.doi.org/10.1016/j.jmst.2013.03.024

benefits, which included rapid heating and cost savings in general, and selective and volumetric heating in particular[19], together with the presence of “microwave effect”[20,21]. Processing of fine-grained alumina matrix ceramics *via* microwave sintering was highlighted also since the consolidation could be achieved at much lower temperatures[14].

It is known that the properties of alumina matrix ceramics depend much on the final microstructures which are inseparably influenced by the characteristics (size, shape, chemistry, *etc*.) of the starting powders[22]. However, there were few reports on the effect of the microstructure of composite powders on the microstructure and properties of alumina matrix ceramics, especially microwave sintered alumina matrix ceramics.

In the present investigation, two kinds of differently structured alumina−titania composite powders were used to prepare alumina matrix ceramics by microwave sintering. The effect of the microstructure of composite powders on microstructure and properties of microwave sintered alumina matrix ceramics were investigated in detail.

2. Material and Methods

2.1. Composite powders

Two kinds of differently structured alumina−titania composite powders with composition of 87 wt% alumina and 13 wt% titania were used to prepare alumina matrix ceramic composites. One was a powder mixture with alumina and titania mixing at a micron−submicron level, in which fused-and-crushed alumina particles (micrometers) was clad with submicron-sized titania. Fig. 1 shows the SEM micrographs, particle size distribution and XRD pattern of the micro-sized alumina−titania composite powders (referred to MC powders). The MC powders consisted of α-alumina and anatase. The MC powders presented polyhedral, irregular and angular shapes with particle sizes ranging from 10 to 90 μm and the average particle size was about 38.6 μm. The other was a powder mixture with alumina and titania mixing at a nanometer−nanometer level, in which nano-sized alumina and nano-sized titania particles were homogeneously mixed by ball-milling and spray dried to prepare spherical alumina−titania composite powders. The preparation process of nanostructured alumina−titania composite powders included three stages: (1) raw powders mixing by wet ball-milling to prepare composite slurry, (2) spray drying of the slurry to fabricate nanostructured composite powders and (3) heat treatment of nanostructured composite powders. Fig. 2 showed the XRD pattern and the SEM micrographs of the nanostructured alumina−titania composite powders (referred to NC powders). The NC powders consisted of α-alumina and rutile. Nanostructured spherical composite powders had been obtained after reconstitution processing. The spherical particle size ranged from 10 to 50 μm in diameter. Each spherical particle consisted of a great deal of nano-sized alumina and titania grains (about 50−100 nm).

2.2. Preparation of the alumina matrix ceramics by microwave sintering

The microstructured and nanostructured composite powders were cold pressed uniaxially at 60 MPa into green compacts of

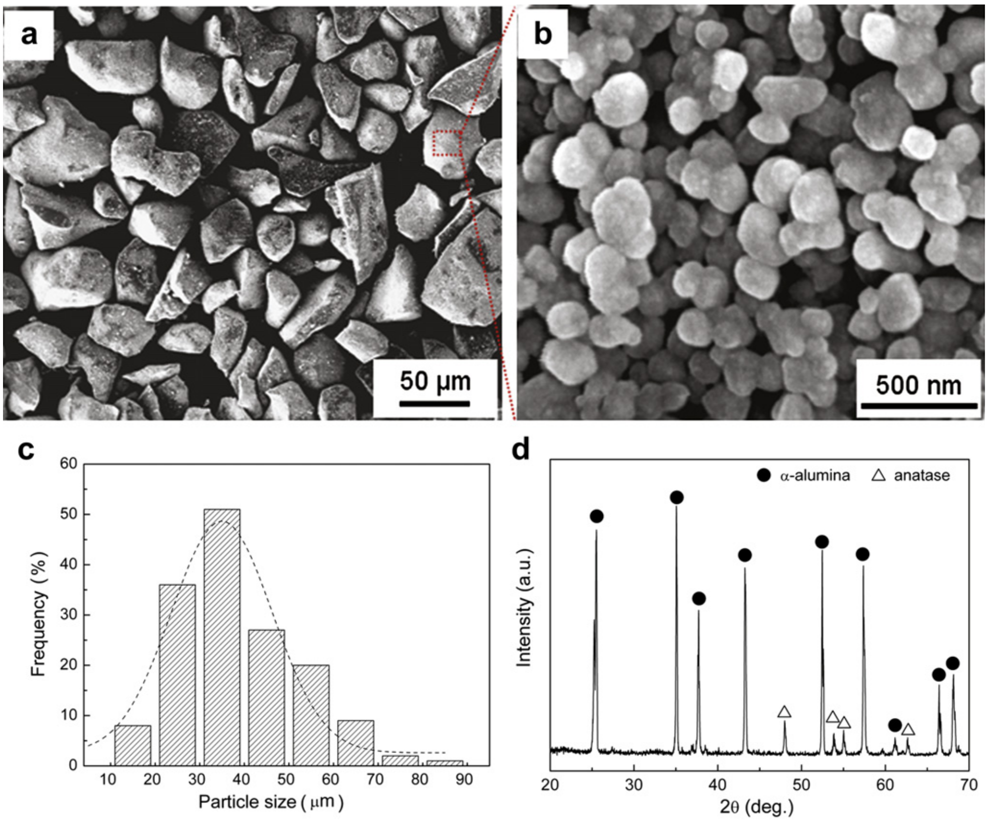

Fig. 1 SEM micrographs, particle size distribution and XRD pattern of the micro-sized alumina−titania composite powders: (a) overall SEM morphology, (b) high magnification SEM morphology of the particle surface showing the submicron-sized titania, (c) particle size distribution and (d) XRD pattern.