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Development of α-β SiAlON ceramics from different Si_3N_4 starting powders

Nurcan Calis Acikbas[1,a], Ferhat Kara[2,b] Hasan Mandal[2,c]

[1]MDA Advanced Ceramic Ltd. Co., 26110, Eskisehir, Turkey,
[2]Department of Materials Science & Engineering, Anadolu University, Eskisehir, TURKEY

[a]ncalis@gmail.com, [b]fkara@anadolu.edu.tr, [c]hmandal@anadolu.edu.tr

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Abstract. α-β SiAlON ceramics were produced from different starting Si_3N_4 powders including β-Si_3N_4 and α-Si_3N_4 powders and mixtures of these powders. Gas pressure sintering was used for sintering. After sintering, resultant fracture toughness values were correlated with microstructure and starting powders. By optimizing chemistry and process parameters; α-β SiAlON ceramics with reasonable fracture toughness can be produced from rather coarse β-Si_3N_4 powder. This could improve the economic viability of SiAlON ceramics since β-Si_3N_4 powders are less costly.

Introduction

As known, two forms of silicon nitride powders; α-Si_3N_4 and β-Si_3N_4, may be used as a starting powder. High quality α-Si_3N_4 powders are generally used to achieve in-situ reinforced material and thus high fracture toughness [1]. However, these powders are expensive and this is one of the major obstacles for large scale applications of Si_3N_4 based materials. On the other hand, use of β-Si_3N_4 powder generally results in normal grain growth and hence lower fracture toughness [2]. However, β-Si_3N_4 powders can be produced cost effectively by such as combustion synthesis as no over pressure of nitrogen is needed and thus use of such powders may open up possibilities for wider applications [3].

Experimental Procedures

30α:70β SiAlON composition was designed where hardness of α-SiAlON and toughness of β-SiAlON wanted to be combined in the final material. Y-Sm-Ca multi cation system was chosen which may enable self reinforced microstructure. Three different silicon nitride powders were used (Table 1). β-Si_3N_4 particle size was reduced to 2, 1 and 0.5 μm (coded as B2, B 1and B0.5 respectively) and Silzot particle size was reduced to 1 μm (coded as A1). The mixed powders were uniaxially pressed and subsequently cold isostatically pressed. The pellets were sintered by gas pressure sintering under 2.2 MPa nitrogen gas pressure in a standard manner. α:β phase ratio was determined by x-ray diffraction (XRD) analyses and microstructures were examined by scanning electron microscope (SEM) by using back-scattered electron imaging mode. Hardness and fracture toughness measurements were carried out by Vickers indentation technique by applying 10 kg load for 10 seconds.

Table 1. Si_3N_4 starting powders

Powder	Code	α:β Phase Ratio	D50 (μm) (As-received state)	Production Method
UBE E-10	R	98α:2β	0.55	Diimide
Silzot HQ	A	89α:11β	1.70	Direct Nitridation
β-Si_3N_4	B	100β	4.70	Combustion Synthesis

Results and Discussion

Elongated shaped β-SiAlON grains were observed when α-Si_3N_4 rich powders were used (Fig. 1). Elongated grains of especially β-SiAlON provided good fracture toughness values (about 5.5 $MPam^{1/2}$) which is typical for SiAlON ceramics.

There are some conflicts about the influence of α:β Si_3N_4 powder phase ratio on development of microstructure and fracture toughness [1, 4]. To observe the effect of α/β phase ratio, three different powders (A1, 50A150B1 and B1) with a nearly same particle size was gas pressure sintered at the same sintering conditions. B1 powder resulted in the development of more uniform microstructure where no substantial development of β-SiAlON grains were observed. Hence, fracture toughness of B1 sample was about 3.8 $MPam^{1/2}$. Mixing of B1 with 50%A1 did not have a major effect on microstructure except the occurrence of elongated β-SiAlON grains with low in aspect ratio. This increased the fracture toughness to 4.2 $MPam^{1/2}$.

To determine the effect of β-Si_3N_4 particle size on resultant microstructures and fracture toughness B2, B1 and B0.5 powders were used. B2 powder resulted in the same microstructure as B1 but with coarser grains. However, use of fine β-Si_3N_4 powder (B0.5) caused bimodal grain size distribution where large grains with fairly high aspect ratio were scattered within a fine grain matrix (Fig. 2). Thus, good fracture toughness values (4.5 $MPam^{1/2}$) were obtained. It is thought that the large grains in this microstructure are due to large β-Si_3N_4 grains present in the powder acting as seeds.

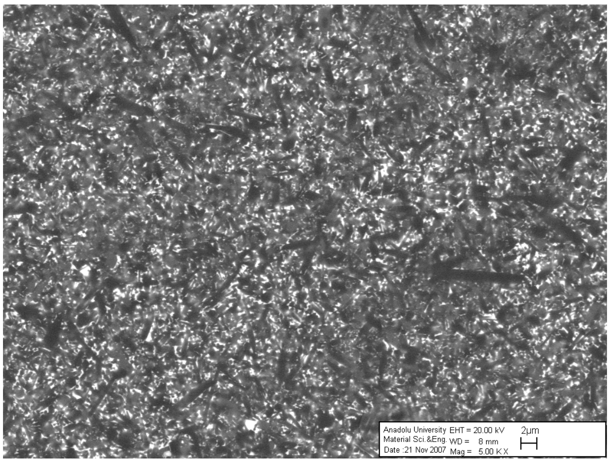

Fig. 1. Representative SEM images of sintered A1 powder

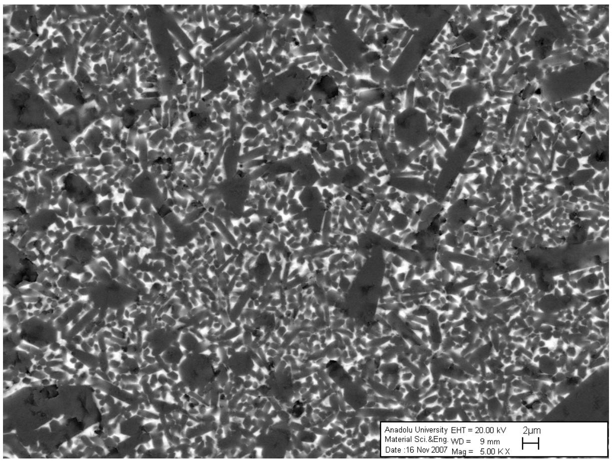

Fig. 2. Representative SEM images of sintered B0.5 powder

Summary

Compared to α-Si_3N_4 derived SiAlONs, microstructure of β-Si_3N_4 derived SiAlONs is coarse and development of large needle-like grains is rather limited. Therefore, toughness values after sintering were lower. In order to obtain good toughness values from β-Si_3N_4 powder, its particle size should be fine to provide fine grains sintered in microstructure, which is suitable for abnormal grain growth.

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SiAlONs and Non-oxides

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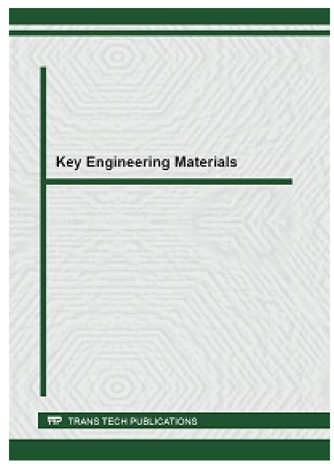

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