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Microstructure formation of porous silicon carbide ceramics during β-α phase transformation

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ABSTRACT

The effect of particle size and initial powder phase on the microstructure of porous SiC ceramics was investigated. When β-SiC powder was used as a starting material, porous SiC ceramics were formed by rapid grain growth of α-SiC during the β-α phase transformation. As the particle size of the initial powders decreased, β-α SiC phase transformation and rapid grain growth of α-SiC occurred earlier. Grain and pore size of SiC porous ceramics can be controlled by the addition of α-SiC seed. Grain and pore size decreased as the concentration of α-SiC seed increased. The bending strength of porous SiC ceramics did not depend on pore size.

1. Introduction

Porous silicon carbide (SiC) ceramics are widely used for environmental applications and in the energy industry; for example, they are used in hot-gas and molten metal filters, catalyst supports, diesel particle filters, gas burner media, and thermal insulators because of their excellent oxidation resistance, high mechanical strength at elevated temperatures, high corrosion resistance, high thermal conductivity, and high thermal shock resistance [1–3]. Various processing routes have been used to prepare porous SiC ceramics with sufficient strength and appropriate porosity and pore sizes for these applications [4–9].

SiC shows many polytypes which take a close packed structure with various sequences. The cubic β-SiC phase has been reported as the low temperature stable form of SiC up to 2100 °C whereas α-SiC with hexagonal structure is stable at 2100 °C and above. The stability of SiC polytypes seems to be affected by not only temperature but also pressure, atmosphere and impurities. Two kind of mechanisms have been reported to explain β-α SiC phase transformation. One is a phase transformation via vapor phase and other one is a solid state phase transformation [10–12].

In our previous work, a unique method of creating porous SiC ceramics with interconnected network structures composed of huge plate-like α-SiC grains, was reported [13]. During the β-α SiC phase transformation, rapid grain growth of α-SiC occurred through vapor transport and resulted in an interconnected network structure composed of huge plate-like α-SiC grains.

In this work, the effects of processing variables such as particle size of initial raw β-SiC powder and the addition of α-SiC seeds on the microstructure of porous SiC ceramics were investigated.

2. Experimental Procedures

Three commercially available β-SiC powders were used as starting materials, and α-SiC was used as a seed. The characteristics of the β-SiC and α-SiC starting powders are listed in Table 1. The particle sizes of the starting powders were evaluated using a particle size analyzer (PSA, Master size 2000, Malvern Co. UK) and the oxygen and carbon contents were analyzed by oxygen and carbon analyzer (Leco, TC 600,

Table 1
Characteristics of initial SiC Powders.

Powder	Mean particle size (μm)	Phase	Chemical analysis before oxidation (wt%)		Chemical analysis after oxidation (wt%)		Supplier
			Oxygen	Carbon	Oxygen	Carbon	
PM	0.185	β(3C)	0.84	32.1	2.73	27.0	Pred Material, U.S.A.
IB	0.476	β(3C)	0.94	31.0	2.99	29.0	Ibiden, Japan
ST	1.362	β(3C)	0.38	28.8	0.88	30.6	H.C. Starck, Germany
α-SiC Sead	0.541	α(6H)	1.20	29.9	–	–	Norton

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CS 600, respectively). The mean particle sizes of PM powder were larger than stated by the supplier, 50 nm, because of powder aggregation. The morphologies of raw SiC powders are shown in Fig. 1.

Starting β-SiC powders were oxidized at 650 °C for 1 h in order to remove free carbon and reduce the carbon potential. If the carbon potential in the starting powder is high, the vapor pressure in the dissociative phase from β-SiC will be low and the rate of grain growth will be reduced [13,14].

Carbon contents of PM and IB powders decreased, however, that of ST powder increased slightly after the oxidation. The loss of carbon was attributed to the removal of free carbon. It is considered that the carbon content of ST powder increased because of the lower free carbon content and higher impurity content than those of PM and IB powders, which could be removed after the oxidation, such as humidity.

The oxidized β-SiC powders, 1 wt% B_4C (H·C. Starck, Munich, Germany) as sintering additives and α-SiC seed, if necessary, were mixed by spex milling for 15 min in a plastic jar using Si_3N_4 balls and alcohol as media. After milling, the slurry was dried and granulated using a 100 mesh sieve. The granulated powders were uniaxially pressed at a pressure of 150 MPa to form 10 mm diameter pellets. The specimens were sintered in a graphite furnace at 2000–2100 °C in an Ar atmosphere. The density and porosity of the sintered specimens was measured using the Archimedes method and pore size was measured using a mercury porosimeter (Micrometric Instrument, USA). XRD was used to analyze the SiC phases of the specimens with a Cu target

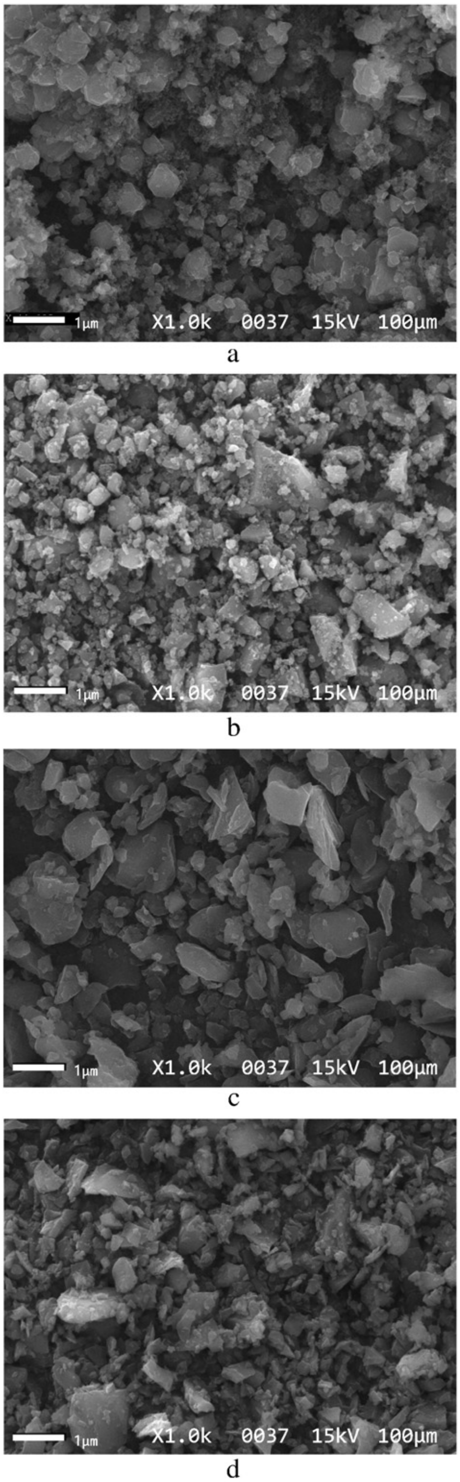

Fig. 1. Morphologies of raw SiC powders: (a) PM, (b) IB, (c) ST (d) α-SiC seed.

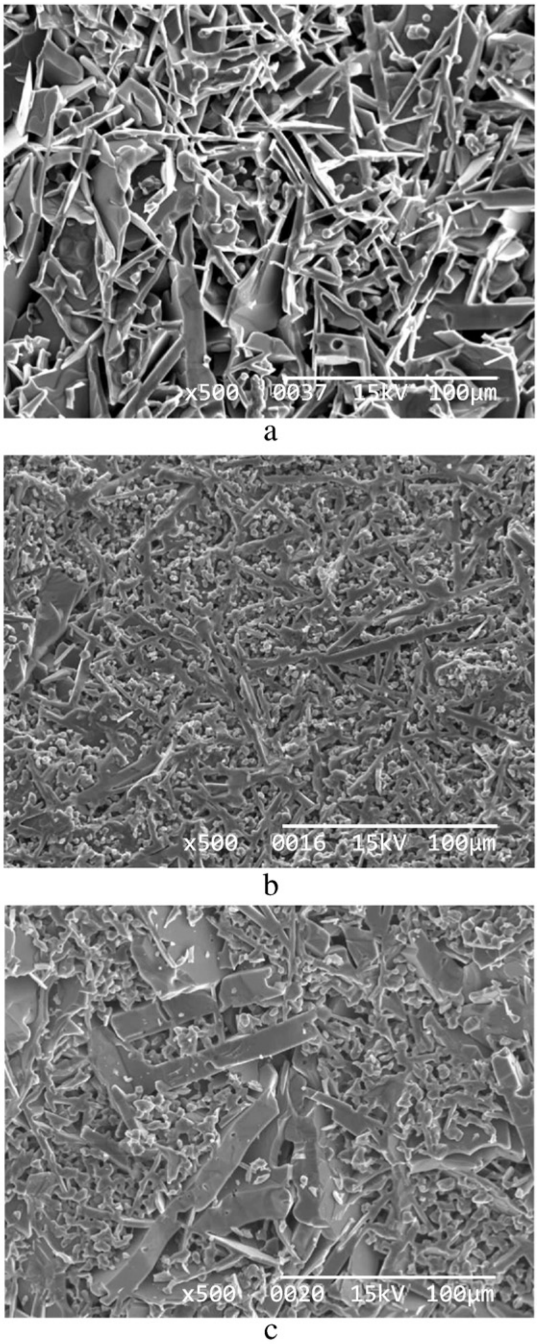

Fig. 2. Fracture surfaces of SiC specimen sintered at 2000 °C for 1 h: (a) PM, (b) IB, (c) ST.