

Preparation of Silicon Nitride-silicon Carbide Composites from Abrasive SiC Powders

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Abstract

Silicon nitride - silicon carbide composite was developed by using an abrasive SiC powders as a raw material. The composites were prepared by mixing abrasive SiC powder with silicon, pressing and sintering at 1400°C under nitrogen atmosphere in atmosphere controlled vacuum furnace. The proportion of silicon in the initial mixtures varied from 20 to 50 wt%. After sintering, crystalline phases and microstructure were characterized. All composites consisted of α -Si₃N₄ and β -Si₃N₄ as the bonding phases in SiC matrix. Their physical and mechanical properties were also determined. It was found that the density of the obtained composites increased with an increase in the Si₃N₄ content formed in the reaction.

Keywords : silicon nitride, silicon carbide, composites, abrasive powders

1. Introduction

Si₃N₄-SiC composite is one of the important refractory materials. It has high fracture toughness, high strength at high temperature and good corrosion resistance properties. Therefore, it is widely used in many applications such as cutting tools, refractories, mechanical sealing, bearings, heat exchangers, and components in heat engines [1-2]. However the cost of silicon nitride and silicon carbide powders used as raw material is very expensive. Furthermore, high cost techniques (hot press and hot isostatic press) of sintering process and high cost of machining after sintering are required. These are all the limitations for their applications. Among the various fabrication techniques, reaction sintering technique which Si₃N₄ is formed as a bonding phase by nitridation of silicon at relative low temperature has attracted much interest because this method offers near-net-shape product and has a low cost of manufacturing [3-8]. In this work, Si₃N₄-SiC composites were fabricated via reaction sintering at 1400°C and an abrasive SiC powder was used as the starting powder in order to study the possibility of using abrasive powder in the Si₃N₄-SiC composite processing and introduces a new low-cost route for the production.

2. Experimental and Results

Commercial silicon (Si) powders (97% purity, Riedel-deHaen) and abrasive α -SiC powders (GC grade, Showa Denko, Japan) were used as starting materials. The compositions of samples are listed in Table 1. The mixtures

were prepared by ball milling in ethanol for 24 h, using Al₂O₃ media and a polyethylene container. After drying, the green compacts were formed by pressing and cold isostatic pressing (CIP) under pressure of 250 MPa. The sintering was carried out at 1400 °C for 6 h under a nitrogen atmosphere. The densities, porosities and mechanical properties of samples were determined. Crystalline phase identification and microstructure were performed by using x-ray diffractometer and scanning electron microscope, respectively.

Table 1. Starting composition of samples

Samples	Composition (%wt)	
	Si	SiC
G-20	20	80
G-30	30	70
G-40	40	60
G-50	50	50

After sintering, the composites reached a density of about 60 % theoretical density. The properties of the Si₃N₄-SiC composites are summarized in Table 2. The density of the composites increased and porosity decreased with an increase in the content of silicon in the composites. As the density increased, the mechanical properties of the composites increased.

Fig. 1 shows the XRD patterns of Si₃N₄-SiC composites. Besides α -SiC phase, the presence of α -Si₃N₄ was found as the major bonding phase along with a minor amount of β -Si₃N₄ and trace amount of silica.

The microstructure of composites was mixed as shown in SEM micrographs in Fig. 2. The micrographs reveal that

Table 2. Properties of SiC-Si₃N₄ composites

Samples	Density (g/cm ³)	Porosity (%)	Water absorption (%)	Young's Modulus (GPa)	Flexural strength (MPa)
G-20	1.75	44.9	25.6	36.0	53.1
G-30	1.80	43.1	23.9	44.1	59.8
G-40	1.88	40.6	21.6	53.4	84.0
G-50	1.92	39.1	20.3	62.7	84.0

the composites consisted of fine grain of SiC and small needle like or elongated grain of Si₃N₄. Fibrous structure of Si₃N₄ was also observed in sample containing 50wt% Si.

3. Summary

Si₃N₄-SiC composites was successfully fabricated from abrasive SiC and silicon powders by reaction sintering. Physical and mechanical properties are dependent on the amount of Si₃N₄ formed in the composites. The obtained composites contained Si₃N₄ as the bonding phase in SiC matrix. The bonding phase consisted of α-Si₃N₄ as a major phase in form of needle like and fibrous structure with minor amount of β-Si₃N₄. The microstructure has a strong influence on the properties of the composites.

4. References

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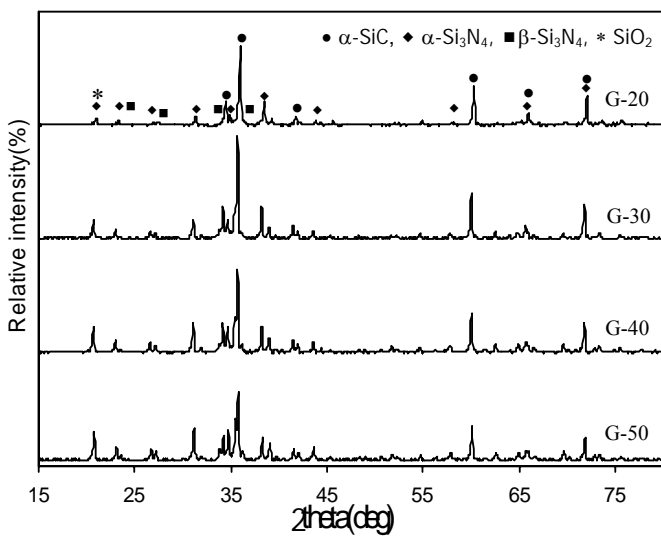


Fig. 1. XRD patterns of Si₃N₄-SiC composites.

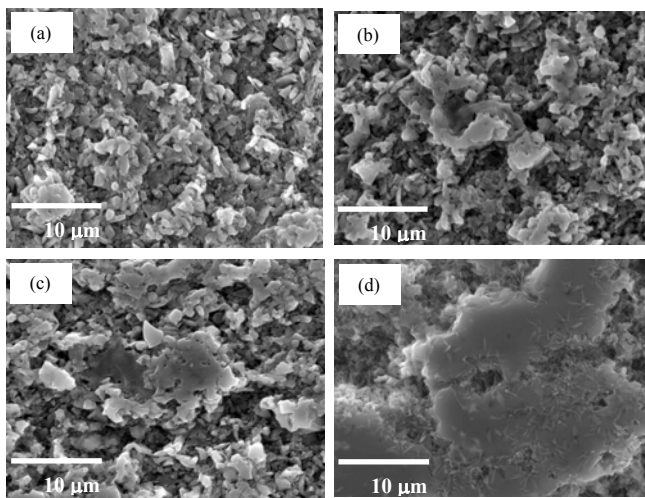


Fig. 2. Microstructures of SiC-Si₃N₄ composites (a) 20wt%Si; (b) 30wt%Si; (c) 40wt%Si and (d) 50wt%Si.