Fabrication of Porous SiC Based Ceramics in Air Atmosphere

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Abstract

High sintering temperatures or/and liquid phase sintering is necessary to produce dense SiC based ceramics owing to the covalent character of the Si-C bond. In this study, sodium borate was used as sintering additive to lower the sintering temperature. Starch consolidation technique was used to produce SiC green bodies. SiC, borax decahydrate, corn starch and limited amount of other additives containing suspensions were prepared in a planetary ball mill. SiC green bodies were manufactured by heating the prepared ceramic suspensions in non-porous molds at ≤80°C. After gelatinization process was completed green samples were dried at room temperature for 24 hours. Binder burn out process and sintering process were conducted simultaneously at 575-600°C for 1 h under atmospheric conditions. Microstructural analysis revealed that highly porous sodium borate-bonded SiC based ceramics were fabricated via starch consolidation technique. XRD analysis confirmed that cristobalite free SiC based ceramics were produced by optimizing the composition and processing conditions.

I. Introduction

Porous SiC ceramics exhibit multifunctional and very attractive properties such high thermal conductivity, low thermal expansion coefficient, good corrosion, wear and thermal shock resistance, excellent mechanical properties such as high hardness etc. [1, 2] Due to these challenging properties porous SiC ceramics has potential for a wide range of applications such as filters, catalyst supports, heat exchangers, electrodes, and sensors [3-5].

Considerable effort has been devoted to produce porous SiC ceramics for various applications by using numerous shaping techniques such as sol-gel and carbothermal reduction [6], polymeric sponge [7], freeze casting and solid state sintering [8], adding fugitive additives, gel casting [9], sintering of hollow spheres as sacrificial templates [10] and direct foaming. However, these porous SiC fabrication studies were performed under controlled atmosphere such as nitrogen, argon or vacuum. In the present work, it was aimed to produce porous SiC ceramics under atmospheric conditions and at lower sintering temperatures to explore the applications of these porous ceramics.

Starch consolidation technique is a relatively new consolidation method that is used for forming various porous ceramics. [11-14] Starch has mainly two different function in starch consolidation technique. These are acting as consolidator/binder and pore former. [11]

2. Experimental Procedure

In this study, Alfa Aesar SiC powder was used in combination with Tekkim borax decahydrate (Na₂B₄O₇.10H₂O), corn starch and limited amount of other additives to prepare designed ceramic suspension having desired rheological properties. Weight ratio of SiC:starch is 7:3.

Slurries were prepared by wet milling in a planetary ball mill by using deionized water. Prepared slurries were poured into the non-porous molds which were heated in air at 575-600°C for 1 h under atmospheric conditions. Microstructural analysis revealed that highly porous sodium borate-bonded SiC based ceramics were fabricated via starch consolidation technique. XRD analysis confirmed that cristobalite free SiC based ceramics were produced by optimizing the composition and processing conditions.
XRD analysis. Starting powders and fracture surface of the samples were investigated by scanning electron microscopy (SEM). Microstructure of the starch is given in Fig. 1. As seen from the SEM micrograph starch size is ~10-20 μm.

![SEM micrograph of the corn starch](image)

**Figure 1.** SEM micrograph of the corn starch

### 3. Results and Discussion

#### Starch Consolidation

Shaping of the SiC ceramics were performed by starch consolidation technique. Green SiC samples produced by this technique are given in Fig. 2. Starch consolidation casting, a non-contaminating and low-cost consolidation technique, recently has become one of the most popular processing routes for the fabrication of numerous porous ceramics.[11, 15, 16]

![SiC green samples produced at different compositions](image)

**Figure 2.** SiC green samples produced at different compositions

#### Characterization by SEM

Microstructure investigations of the sintered samples revealed that highly porous samples were fabricated (Fig. 3).

![SEM micrograph of the porous SiC ceramics sintered at 600°C](image)

**Figure 3.** SEM micrograph of the porous SiC ceramics sintered at 600°C.

It was determined that there are mainly two different size pores. First type of bigger pores were developed by the removal of starch during the heat treatment process (Fig. 3). Second type of pores, smaller in size, were formed between SiC particles. SEM investigations also showed that there is good bonding between SiC particles and neck formations are clearly visible. It is observed that liquid phase formation during the sintering process significantly accelerated sintering process and resulted in enhanced sintering behavior at very low temperatures when compared with the literature.
**Characterization by XRD**

X-ray diffraction patterns of the sintered porous samples are given in Fig. 4. XRD results revealed that cristobalite free SiC ceramics were fabricated via sintering at 575-600°C for 1 hour under atmospheric conditions (Fig. 4).

![X-ray diffraction patterns](image)

**Figure 4.** X-ray diffraction patterns of the porous ceramics produced at (a) 600°C and (b) 575°C for 1 hour and (c) SiC starting powder.

4. Conclusion

- Microstructural analysis revealed that highly porous sodium borate-bonded SiC based ceramics were fabricated via starch consolidation technique.
- Sintering studies were conducted at very low temperatures (≤600°C) and in air atmosphere. It was determined that porous SiC based ceramics can be produced successfully at atmospheric conditions and at very low temperatures (575-600°C).
- Microstructure investigations of the porous ceramic samples revealed that due to high amount of borax decahydrate (Na₂B₄O₇·10H₂O) sintering additive significant amount of liquid phase was formed in the system and this liquid phase promoted sintering and neck formation between SiC grains.
- XRD analysis confirmed that cristobalite free SiC based ceramics were produced by optimizing the composition and processing conditions.

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**References**


