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Effects of particle grading on porous gelcasted and solid-state-sintered SiC ceramics with improved connectivity

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A B S T R A C T

Porous gelcasted and solid-state-sintered SiC (S-SiC) ceramics with significantly improved connectivity were successfully prepared through the synergistic pore-forming mechanism of direct foaming and particle packing, using fine (D_{50} = 0.5 μm) and coarse (D_{50} = 5.0 μm) graded SiC powders as the main raw materials. As the proportion of coarse SiC powder increased, the viscosities of aqueous SiC-B_4C-C slurries sharply decreased, which thus flourished foaming and enlarged bubble-derived-pore diameter in porous S-SiC ceramics, accompanied with the increased amount and size of window. Moreover, abundant particle-packing pores in struts of bubble-derived pores were also formed and even interconnected with each other at 60 wt% of coarse SiC powder. Besides, there was a remarkable increase in porosity from 61.0% to 81.7% and accordingly a significant decline in density from 1.24 g cm^{-3} to 0.58 g cm^{-3} as the content of coarse SiC powder increased. The optimized multiple pore microstructures resulted in an amazing nitrogen gas permeability of 1.78×10^{-11} m^2 under the condition of an excellent compressive strength of 10.8 ± 2.7 MPa.

1. Introduction

Porous SiC ceramics have drawn considerable attentions in recent years due to the excellent combination effect of both SiC ceramics and cellular structures, such as outstanding high-temperature strength, superior chemical stability, high heat-exchange efficiency, large specific surface area and so on [1–4]. These unique properties enable them to withstand harsh physico-chemical environments and thus possess numerous potential applications in the metallurgy, energy and environment fields, including catalyst supports [5], high-temperature filters for melting metal and hot flue-gas [6], and volumetric absorbers of solar radiation [7]. The representative preparation methods of porous SiC ceramics were generally described as replica [8], sacrificial template [9], organic precursor method [10,11], and bonding technique [12]. In porous SiC ceramics prepared by these methods, the bonding types between SiC grains mainly included oxide (eg. silica, mullite) bonding, reaction-bonded sintering and polymer-derived-ceramic (eg. SiOC) bonding. However, these bonding types of porous SiC ceramics would inevitably decrease their service temperature and deteriorate their corrosion resistance, thus resulting in the reduction of life expectancy especially at high temperature or in strongly corrosive environments. Nevertheless, porous solid-state-sintered SiC (S-SiC) ceramic can conquer the above shortcoming owing to its clean and strong interface bonding between SiC grains, and shows significant preponderance under high-temperature and corrosive conditions, compared with other kinds of porous SiC ceramics bonded by the previously mentioned types.

Direct foaming-gelcasting process was considered to be one of the most commonly used method for the preparation of porous S-SiC ceramics, as reported by Mouazer [13], Ganesh [14], Jana [15], and our group [16]. This technology consisted of surfactant-assisted

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foaming in aqueous SiC-based suspensions and then in-situ solidification of foamed slurries by polymerization reaction, and shows its simplicity and high efficiency in tailoring pore microstructures (porosity, pore size, etc) [3]. However, porous gelcasted S-SiC ceramics through the single foaming mechanism usually presented inferior connectivity between bubble-derived pores, because of the limited amount and size of windows in the struts of bubble-derived pores [2,3]. Contradictorily, the connectivity between pores shows its extreme importance for the above-mentioned applications to supply fluid channels. Therefore, it is quite necessary for porous gelcasted S-SiC ceramics to overcome this conflict and obtain excellent connectivity.

Fortunately, a simple approach to promote the connectivity of porous gelcasted S-SiC ceramics has been mentioned and proved to be effective in our previous study [16]. Specifically, the composite pore-forming mechanism of direct foaming and particle grading (Fig. 1(a)) was conducted to introduce abundant particle-packing-derived pores (<2 μm) in bubble-derived-pore struts through partial sintering mechanism when micron-sized SiC powders with inferior sintering activity partially substituted for submicron-sized SiC powders as raw material. However, the effect of particle packing on microstructure and properties of porous gelcasted S-SiC ceramics has not been well investigated yet. Therefore, it is of great significance to further clarify the correlations so as to optimize the pore microstructures, mechanical properties and gas permeability of porous gelcasted S-SiC ceramics.

In the present work, porous S-SiC ceramics were prepared using the synergistic mechanism of direct foaming and particle packing, companied with gelcasting. The content of introduced coarse SiC powders in raw materials was adjusted in a wide range to tailor the

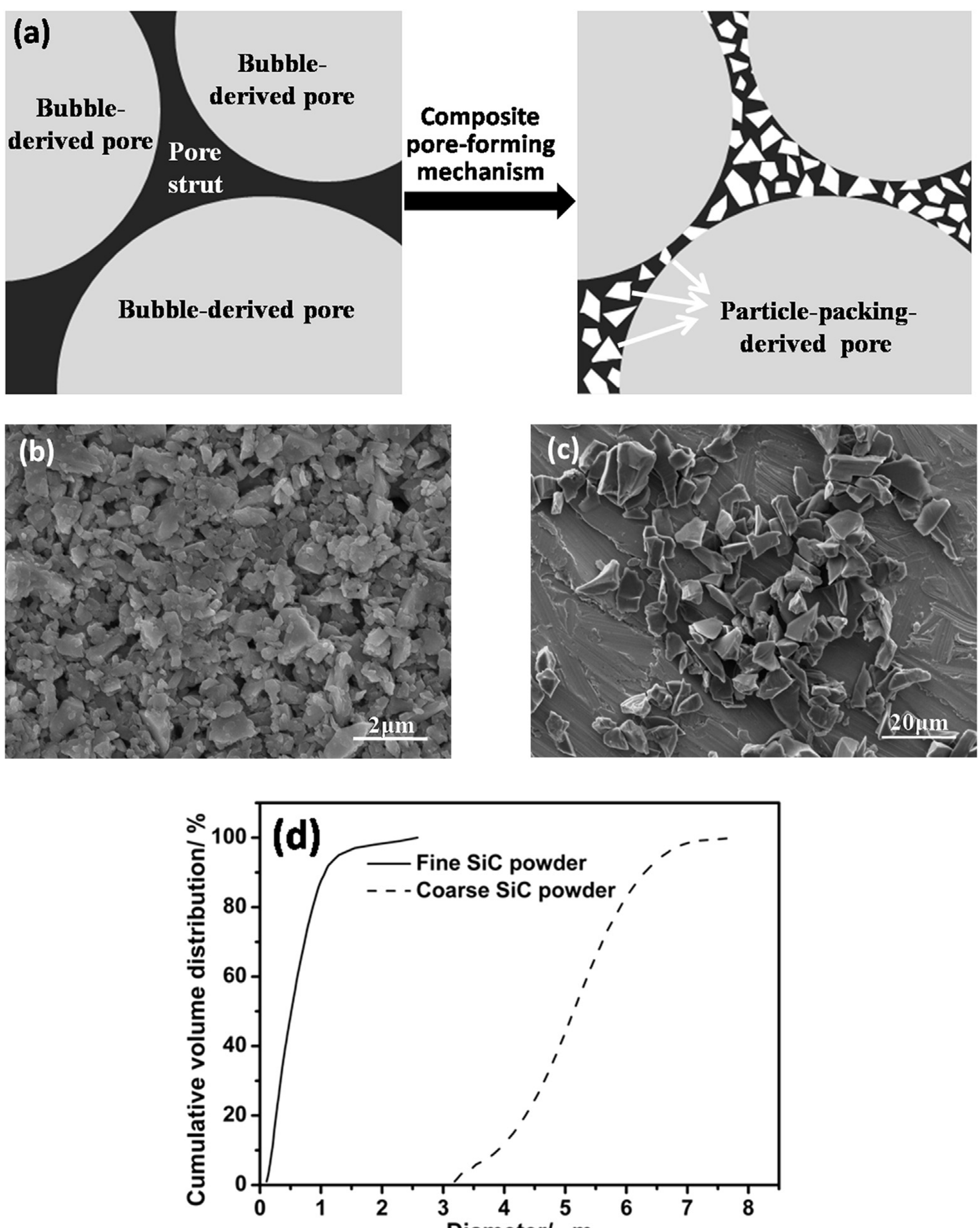

Fig. 1. (a) Schematic diagram of the composite pore-forming mechanism of direct foaming and particle grading; (b,c) Morphology pictures of fine (D_{50} = ~0.5 μm) and coarse (D_{50} = ~5.0 μm) SiC powder; (d) Particle size distribution curves of fine and coarse SiC powder.