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Full Length Article

Foaming inhibition of SiC-containing porcelain ceramics by using Si powders during sintering

Xiuan Xi[a,*], Hao Xiong[a], Anze Shui[b], Miaojun Huang[a], Shuiqing Xiao[a], Hua-Tay Lin[a]

[a] School of Electromechanical Engineering, Guangdong University of Technology, Guangzhou 510006, China
[b] School of Materials Science and Engineering, South China University of Technology, Guangzhou 510641, China

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ABSTRACT

Porcelain green bodies were prepared using porcelain stoneware tile powder as the major raw material, with silicon carbide (SiC) and Si powders as additives. These were fired at 1000–1200 °C. The effects of Si powder addition on the microstructure, crystalline phases, and relative density of SiC-containing porcelain bodies were systematically investigated, and the related mechanism was also discussed in detail. The results show that even with the addition of a small amount of Si powder, the foaming degree of the porcelain bodies containing SiC with particle size and content in a wide range can be effectively inhibited. In particular, this effect becomes more pronounced as the Si powder particle size is reduced. It is believed that this work will have important scientific value for the oxidation protection of SiC and the foaming inhibition during the direct recycling of large amounts of polishing porcelain tile residues in the world.

1. Introduction

Porcelain stoneware tiles are building materials with outstanding technical properties such as mechanical strength, wear, and chemical resistance. Its low porosity is an essential feature which provides excellent mechanical and chemical properties, and makes the material stain and frost resistant [1,2]. In the last decade, the global production of porcelain stoneware tiles has increased markedly when compared with that of other ceramic tiles [3,4].

Porcelain stoneware tiles are usually surface-polished to improve the aesthetic quality and increase competitiveness with natural stone [5,6]. In this process, long polishing lines are used to produce a flat and smooth final product with a high optical reflectivity; this typically consists of 20 or more polishing stages, with a steadily decreasing abrasive particle size from several hundred micrometers to just a few micrometers [7–9]. During the polishing process, approximately 0.4–0.8 mm of the porcelain tile surface is removed to create a gloss surface level of 65–70%. This results in the generation of large amounts of polishing porcelain stoneware tile residues (PPR), which usually contain approximately 1–5 wt% of the silicon carbide abrasive from the polishing tool. It has been reported that the output of PPR has reached about 6 million tons per year in China and increases every year [10].

A valid alternative to landfill confinement of PPR could be the direct recycling back into the production of porcelain stoneware tiles. This could form a closed process that, following a logical chain of events, allows the consumption of the waste in the same production line as the starting material. However, previous investigations reported that the relevant amount of silicon carbide prevented the processing of dense ceramics [8,10,11]. At the usual firing temperatures adopted in the production of ceramic tiles (> 1100 °C), silicon carbide (SiC) decomposes in the presence of oxygen and releases gases such as SiO, CO, and CO_2, giving rise to porous microstructures [11–13], as shown in Fig. 1.

Generally, to avoid the oxidation of SiC, many researchers covered SiC with a barrier layer to isolate the SiC from oxygen by using a number of methods including oxidation treatment [14], pack cementation [15–17], chemical vapor deposition [18–20], and slurry method [21,22]. Oxidation treatment thickened the SiO_2 coating by heating SiC in air conditions to ensure that the SiO_2 coating existed throughout the sintering. Pack cementation, chemical vapor deposition (CVD), slurry method, and in-situ reaction method were used to apply antioxidation coatings such as rare earth oxides coating, C/SiC composites coating, and so on. These coatings had excellent antioxidation properties. However, these methods are

* Corresponding author.
E-mail addresses: xixiuan@163.com, huakaihui219@163.com (X. Xi).

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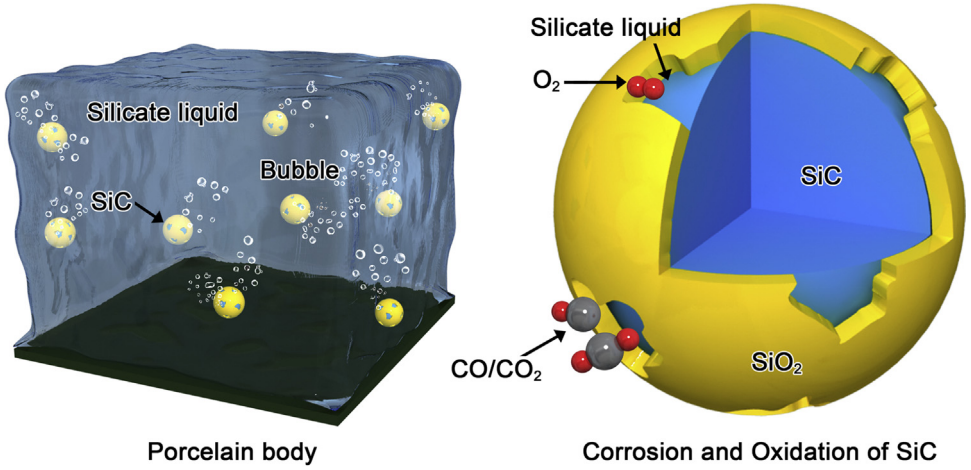

Fig. 1. Schematic illustration for the foaming process of a porcelain body containing SiC during sintering.

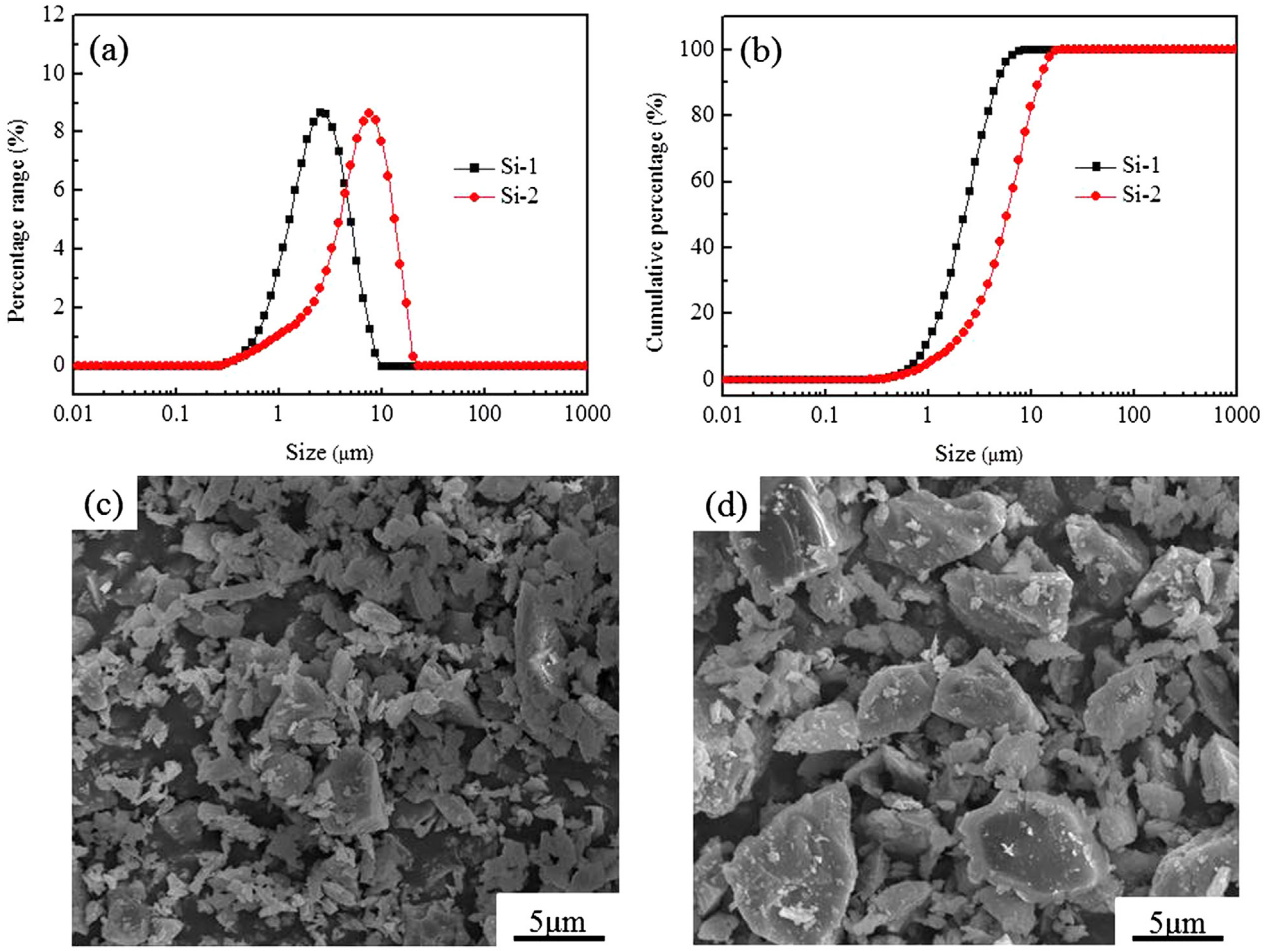

Fig. 2. Particle size distributions of Si-1 powder and Si-2 powder: (a) and (b); SEM images of Si-1 powder (c) and Si-2 powder (d).

difficult to apply to the SiC particles that already exist in porcelain stoneware tile powders.

In this work, Si powder was introduced into the porcelain tile ceramics to avoid the oxidation of SiC particles. It was expected that SiC would be protected by the preferential oxidation of Si powder or its continuous oxygen consumption during sintering, and that the foaming properties of the porcelain bodies containing SiC could be inhibited effectively. For this purpose, the effects of Si powder addition on the microstructure, crystalline phases, and relative density of the porcelain bodies containing SiC were systematically investigated, and the related mechanism was also discussed in detail. The results demonstrate that it is a promising method to effectively inhibit the foaming properties of porcelain ceramics containing SiC with particle size and content in a wide range by adding a small amount of fine Si powder during sintering.

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