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Preparation and Properties of SiC Porous Ceramics with Double-Particle Size

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Abstract. In this paper mixed two kinds of SiC particles with different diameter (50-70 mesh and 80-90 mesh) as aggregate of SiC porous ceramics. And the porous ceramic properties were measured when the pore-making agent was 7.5wt%, 10wt% and 15wt% respectively. The experiments show that the porosity, flexural strength and filtration pressure drop of double-particle size porous ceramics is optimized compared with single size porous ceramics. In the pore-forming agent was 10wt% and 50-70 mesh SiC particle was 10wt%, the flexural strength was 40.71MPa, and porosity was 35.69%. It was 4.76MPa and 6.9% higher than single-particle size sample, and the filtration pressure drop has a significant decrease.

1. Introduction

SiC porous ceramic was a kind of green and environmentally friendly functional material with many advantages, like good chemical stability, low thermal expansion coefficient, very high thermal conductivity and good high temperature strength, and it will not cause secondary pollution to the environment [1-4]. Because of the excellent properties of SiC itself, In recent years, the study of SiC as the raw material of porous ceramic filter membrane has been increased [5-7].

Naturally, soils and rocks are mostly mixed materials of different particle sizes [8]. The experimental results show that the small particle size plays a certain role in improving the tensile strength and yield strength of the composites, and the large size particles can carry a greater load [9]. The double-particle size mixing method can not only save resources and cost, but also improve the properties of composite materials, so as to meet the requirements of their properties under different working conditions.

In this paper, preform body were prepared with different ratios of 50-70 mesh and 80-90 mesh SiC as aggregate, and carboxymethylcellulose sodium (CMC), potassium feldspar, kaolin, quartz, graphite and activated carbon as additives. By analyzing the section SEM diagram, phase structure by X-ray, porosity, flexural strength and filtration pressure drop of the samples. Then study the effect of the ratio of double particle aggregate on the porous ceramics.

2. Experimental

2.1. Preparation of SiC Porous Ceramic

Add and stir SiC particles with different sizes, carboxymethylcellulose solution(CMC, 2g/ml) binder(potash feldspar 64.53wt%, quartz 23.27wt% and kaolin 12.2wt%), pore forming agent(half graphite and half activated carbon) in turn according to Tab.1. Then pressed billet, and sintered at 2°C per minute to 1300°C in a muffle furnace.

Table 1. Lwast of SiC ratios with different Particle sizes (/wt%)

	L1	L2	L3	L4	L5	L6
50-70 mesh SiC	--	5	10	15	20	100
80-90 mesh SiC	100	95	90	85	80	--

2.2. Characterization of Samples

Analys was of material characterization by SEM S4800/TM3000. The phase structure of sintered support was analyzed by Bruker D8A. The system composed of vacuum pump, glass rotamer and differential pressure meter to test filter pressure drop. And the porosity was measured by the Archimedes drainage method by using the OHAUS electronic analytical balance, the flexural strength was measured by three-point method by YLN electronic press.

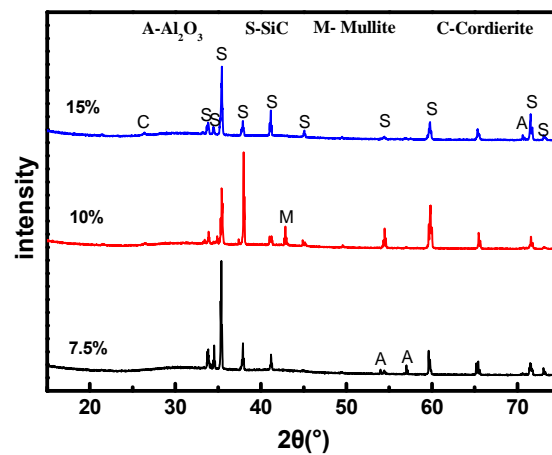**3. Results and Dwascussion**

3.1. XRD of SiC Porous Ceramics

Figure 1. XRD diagram of different pore-forming agent content

Figure 1 was the XRD diagram of SiC porous ceramics when the pore-forming agent was 7.5wt% and 10wt% and 15wt% respectively. The mullite peak was obvious when the pore-forming agent was 10wt%. The mullite phase has good chemical stability, and the coefficient of thermal expansion of mullite was close to that of SiC, so it can bond well with SiC particles. With the increase of carbon content, as oxygen was depleted in the furnace room, carbon binds oxygen in the binder. And cordierite phase will appear in binder under high temperature and hypoxia condition. When the carbon content was reduced, the binder will appear simple substance oxide Al_2O_3 at high temperature and oxygen enrichment.

3.2. Section Characterization of SiC Porous Ceramics

(a). 7.5wt% pore-forming agent　　　　　　**(b).** 10wt% pore-forming agent

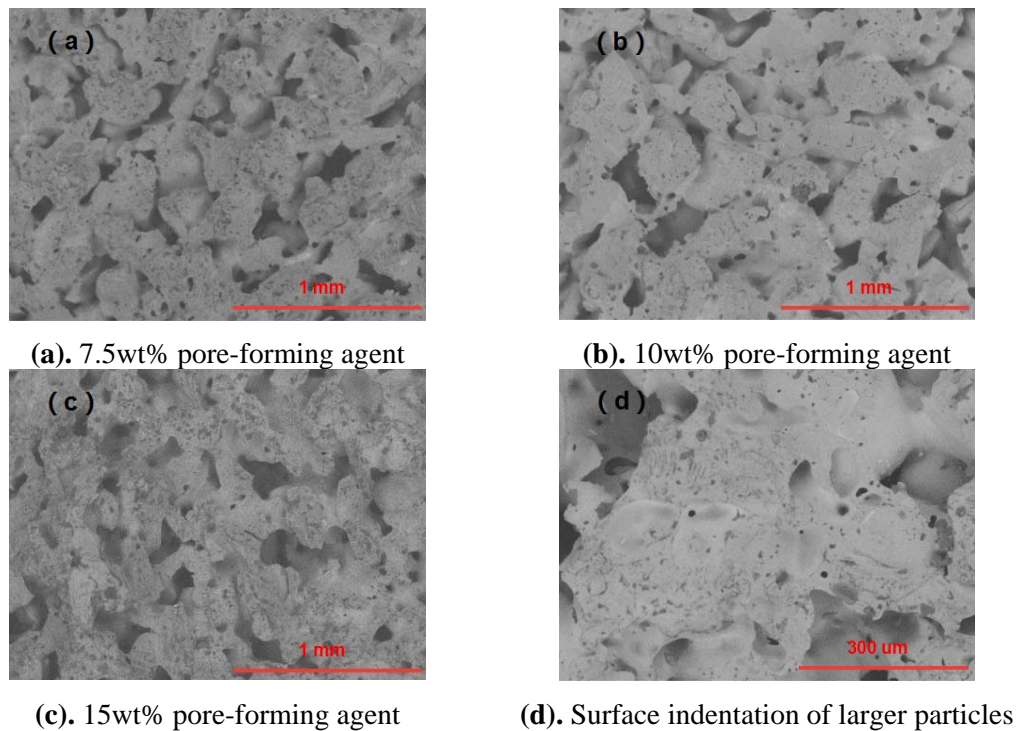**(c).** 15wt% pore-forming agent　　　　**(d).** Surface indentation of larger particles

Figure 2. SEM diagram of section

From the figure 2. The pore size increases with the increase of the content of pore-making agent by comparing figure a, b and c. And from figure d, some indentations on the surface of larger particles due to the separation of smaller particles, which indicates that the larger particles can play a good role in stress bearing.

3.3. Effect of Double-particle Size Aggregate on Flexural Strength and Porosity of Sample under Different Content of Pore-making Agent
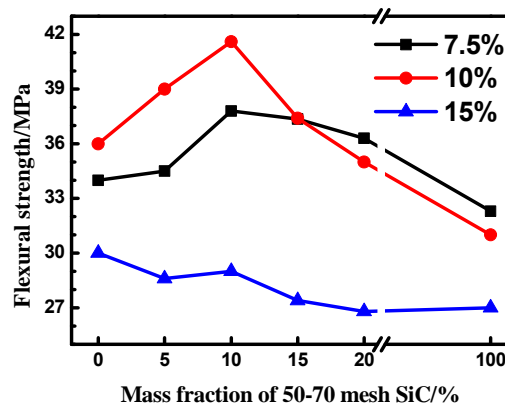

Figure 3. Flexural strength of sample with different pore-forming agent content

Figure 3 shows the change of flexural strength. Flexural strength refers to the ability of the material to bend without fracture [10]. When the pore-making agent was 7.5wt%, the highest flexural strength was 37.82MPa at the 50-70 mesh SiC was 10wt%. Its flexural strength was 3.78MPa and 5.5MPa higher than single particle size sample L1 and L6, respectively. When the pore-making agent was

10wt%, the highest flexural strength was 40.71MPa at the 50-70 mesh SiC was 10wt%. Its flexural strength was 4.76MPa and 9.73MPa higher than single particle size sample L1 and L6, respectively. And when the pore-making agent was 15wt%, reduction of contact area with large particle mixed plays a leading role, so the flexural strength decreases gradually with the increase of the content of large particle.
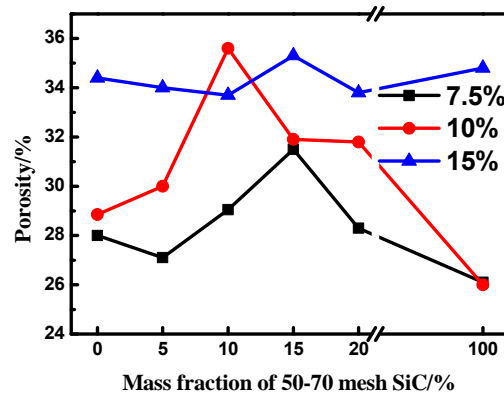

Figure 4. Porosity of sample with different pore-forming agent content

Figure 4 shows the change of porosity. When the pore-making agent was 7.5wt%, the highest porosity was 31.44% at the 50-70 mesh SiC was 15wt%. Its porosity was 3.46% and 5.36% higher than single particle size sample L1 and L6, respectively. When the pore-making agent was 10wt%, the highest porosity was 35.69% at the 50-70 mesh SiC was 10wt%. The porosity was 6.9% and 9.95% higher than single particle size sample L1 and L6, respectively. And when the pore-making agent was 15wt%, the highest porosity was 35.26% at the 50-70 mesh SiC was 15wt% and the porosity change was not obvious because of that the pore size was too large to dislocation effect by large particle size.

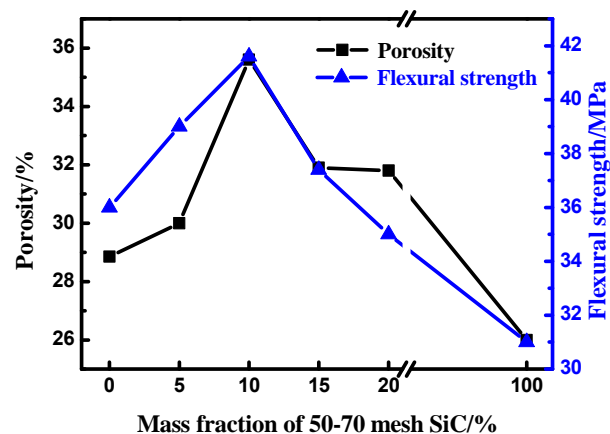*3.4. Properties of the Sample when the Pore-making Agent was 10wt%*

Figure 5. Porosity and flexural strength of sample with 10wt% pore-forming agents

Figure 5 shows the porosity and flexural strength change with the increase content of 50-70 mesh SiC when the pore-forming agent was 10wt%. The flexural strength of L1 was higher than that of L6. The main reason was the smaller particle size sample has larger specific surface area, the contact area of the binder of L1 was larger than that of L6 [11]. In the sample interior the stress concentration of small particle was more obvious, and the bearing load of large particle was larger. When a small amount of large particle size was mixed in, the large particle size plays a supporting role, which

effectively causes the release of small particle [12-13]. The porosity was inversely proportional to the stacking density of particles. The specific surface area of particles decreases, lead to the friction between particles decreases and the particles can be stacked well, so with the increase of particle size, the stacking density increases and the porosity decreases, the porosity of L1 was larger than L6. The stacking density also decreased with the increase of roughness. In this experiment, adding some larger particle size SiC to it could effectively enhance the roughness. There was a formula for stacked density f of double-particles:

$$f = \frac{0.64}{1.0 - (0.362 - 0.315(\lambda)^{0.7})X_L + 0.955(\lambda)^4(\frac{X_L^2}{1 - X_L})}$$

In this formula, λ was the ratio of small to large particle size, and X_L was the mass fraction of large particles. According to the formula, the bigger the particle size difference, the bigger the stacking density and the smaller the porosity. When λ less than 0.154, the mixing mechanism belongs to the interstitial mechanism, and λ more than 0.714, the mixing mechanism belongs to the replacement mechanism. In this experiment, λ was between 0.64 to 0.849, the replacement mechanism was dominated[14]. So the impact of reduction of pore caused by incorporation of large particle size base particles was little in the experiment. And stacking faults have great influence on porosity.
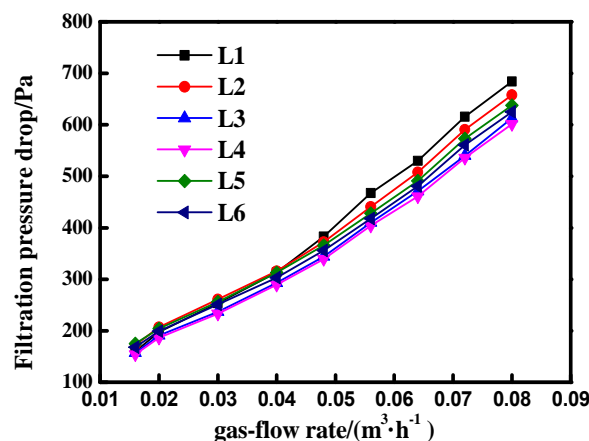

Figure 6. Filtration pressure drop of sample with 10wt% pore-forming agents

Figure 6 was the filtration pressure drop of different content 50-70 mesh SiC when the pore-forming agent was 10wt%. Filtration pressure drop was the resistance of gas flow; it was mainly related to pore size, morphology, quantity and uniformity. The filtration pressure drop of L6 was smaller than L1, because the particle was larger, the pore between the particles was larger, and the filtration pressure drop was lower. With the incorporation of 50-70 mesh SiC, the pore becomes distorted and larger. So the filtration pressure drop of L2, L3 and L4 was decreasing gradually. Due to the uniformity was seriously damaged; the filtration pressure drop of L5 and L6 has risen again.

4. Conclusion
When the content of pore-forming agent was 7.5wt% and 10wt%, the method of mixed billet with double-particle size can effectively increase the flexural strength and porosity, and reduce the filtration pressure drop. But when the pore-forming agent was 15wt%, the impact of this approach was minimal.

5. Acknowledgments

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