A STRONG POROUS CERAMIC BASED ON SILICON CARBIDE WITH DIMINISHED SINTERING TEMPERATURE

E. M. Tomilina, E. S. Lukin, and G. G. Kagramanov

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A strong porous ceramic based on silicon carbide has been obtained at a diminished roasting temperature. The effect of the roasting temperature, the amount of the binder, and the grain size of the filler on the ceramic and filtering properties of the material is described. The ceramic can be used as a base for filtering elements.

Porous ceramics are successfully used in industry as a material for various filters and membranes. An important requirement of such materials is a high mechanical strength at a high open porosity and a specified pore size. Depending on the service conditions the thermal and chemical stability of the material can also be specified quite strictly and the restrictions can be obeyed by using silicon carbide. Silicon carbide possesses several unique properties but has an important technological defect of inertness with respect to sintering. This circumstance makes it necessary to use high roasting temperatures in order to obtain the requisite degree of sintering or to introduce special sintering additives that substantially diminish the roasting temperature [1]. The nature of the binder influences considerably the properties of the final product, including its mechanical strength. If the binder is chosen correctly, a high strength of the product can be achieved at a high porosity and diminished roasting temperature.

With allowance for the previous studies performed at the Department of Chemical Technology of Ceramics and Refractories of the D. I. Mendeleev Russian Chemical Engineering University we have chosen a mixture of a disperse silicon carbide powder and an activating additive. The perspective of the use of such an additive for the production of porous ceramics has been shown convincingly in [2].

We began by studying the effect of various roasting temperatures on the strength characteristics of specimens based on commercial silicon carbide powder (No. 12, green) with a mean particle size of 120 μm and the mentioned additive introduced in an amount of 3%. The specimens were fabricated by semidry pressing under a pressure of 100 MPa and roasted in air at various temperatures. Then we determined their density and porosity and tested the ultimate bending strength. The results of the tests are presented in Table 1. The linear shrinkage of all the specimens did not exceed 1%.

The mean density changed insignificantly with the variation of the roasting temperature. The disperse silicon carbide oxidized and formed active silica that reinforced the composition considerably.

The material can be hardened still more by introducing disperse components into the initial charge together with the binder in order to prevent crack propagation in the material. We used alumina of grade GK as such a disperse component. In combination with the chosen binder it provided strong bonding between the SiC grains. The further study was devoted to the effect of the amount of the introduced alumina on the density and strength of the specimens. The charge bearing silicon carbide and the sintering additive was enriched with 10, 20, and 30% alumina. The specimens were pressed at a pressure of 100 MPa and roasted at 1400°C. Table 2 presents the results of the determination of the properties of the specimens.

As the alumina content was increased from 10 to 20%, the material compacted considerably. Further increase in the alumina content is inexpedient; the softening seems to be explainable by the fact that the amount of the introduced additive is not sufficient for full bonding of the silicon carbide and alumina grains.

<table>
<thead>
<tr>
<th>Roasting temperature, °C</th>
<th>1300</th>
<th>1350</th>
<th>1400</th>
<th>1450</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean density, g/cm³</td>
<td>1.80</td>
<td>1.83</td>
<td>1.85</td>
<td>1.87</td>
</tr>
<tr>
<td>Open porosity, %</td>
<td>43.8</td>
<td>42.8</td>
<td>42.2</td>
<td>41.6</td>
</tr>
<tr>
<td>Ultimate bending strength, MPa</td>
<td>7</td>
<td>8</td>
<td>11</td>
<td>17</td>
</tr>
</tbody>
</table>

1 D. I. Mendeleev Russian Chemical Engineering University, Moscow, Russia.
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### TABLE 2. Effect of the Amount of Introduced GK Alumina on the Properties of Porous Ceramics

<table>
<thead>
<tr>
<th>Number of composition</th>
<th>Content of alumina, %</th>
<th>Density, g/cm³</th>
<th>Open porosity, %</th>
<th>Ultimate bending strength, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>2.06</td>
<td>35.6</td>
<td>32</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>2.23</td>
<td>30.2</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>30</td>
<td>2.15</td>
<td>32.8</td>
<td>29</td>
</tr>
</tbody>
</table>

In further experiments we used specimens based on composition No. 1 which had the highest porosity. They were roasted at a higher temperature (1450°C), which caused a marked reduction of the porosity (<23%) due to the densification of the material.

In order to study the effect of the grain size of the filler on the strength of the porous ceramics we used commercial powders of silicon carbide with a mean particle size of 100, 120, and 630 μm (black powder No. 10, green powder No. 12, and black powder No. 63, respectively). The specimens of composition 1 were pressed at 50 MPa and roasted at 1350°C and 1430°C. As had been expected, the strength increased regularly with the growth in the size of the silicon carbide grains. At 1430°C the material compacted somewhat and its porosity decreased. Therefore, we chose the temperature of 1350°C for the further study. The properties of the porous ceramics obtained at this temperature are presented in Table 3.

Silicon carbide specimens with a particle size of 100 μm had a more uniform fine-pore structure. Specimens based on the other fillers had a very wide size distribution of the pores.

We used the earlier developed technology to fabricate filtering elements in the form of discs. The filtering elements had a layered structure consisting of fine-pore ceramic layers deposited on a coarse-pore substrate. The coarse-pore structures were created on the base of silicon carbide Nos. 10, 12, and 63. The selective layer was a SiO₂ sol and a suspension of Al₂O₃ powder with a Koral composition deposited by sputtering. Then the specimens were calcinated at 1100°C.

When testing the filtration efficiency we measured the overshoot \( K \) of liquid model particles of turbine oil with a diameter of 0.25 and 0.3 μm by the nephelometric method and the initial resistance of the filtering elements \( \Delta\rho_0 \) at an air flow rate of 1 cm/sec, a temperature of 20°C, a relative moisture content of 32%, and a normal pressure. The efficiency \( E \) of arrest of the model particles was calculated by the formula

\[
E = (1 - K) \times 100\%.
\]  

(1)

At first we tested the properties of specimens of the coarse-pore substrate (Table 4). Silicon carbide with a grain size of 100 μm provided better cleaning than specimens based on SiC with 120-μm grains, because the size distribution of pores in it was narrower and therefore the structure was more homogeneous. The high cleaning parameters provided by specimens with a particle size of 630 μm are explainable by the lower open porosity of these specimens.

Then we deposited selective layers on coarse-grain substrates by sputtering and tested the filtration efficiency. The results are presented in Table 5.