Strength of Hot-pressed SiC from Al Doped α-SiC Powder

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[Received May 24, 1979]

アルミニウムを含有した α-SiC 粉末加圧焼結体の強度

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(1979年5月24日受付)

Key-words: SiC, Hot-press, Strength, Fracture mode
In our previous works\(^1\)\(^-\)\(^2\), it was found that AlB\(_2\) was an effective densification additive of SiC powder, and that 0.36 wt% AlB\(_2\) and 1 wt% C additives could densify β-SiC powder by hot-pressing. When the amount of AlB\(_2\) additive exceeded the solubility limit of Al\(^3\) and B\(^4\) to SiC, for example 1.2 wt% AlB\(_2\), the exaggerated grain growth occurred and the weak grain boundary was formed in the hot-pressed SiC. The hot-pressed SiC with 1.2 wt% AlB\(_2\) and 1 wt% C had lower strength and showed larger strength degradation at high temperature compared with the hot-pressed SiC with 0.36 wt% AlB\(_2\) and 1 wt% C. Small amount of additions should be desirable to make a high strength SiC by hot-pressing.

Our preliminary investigations had shown that the Al doped α-SiC powder, in which Al was dissolved, was more sinterable than a pure β-SiC powder. For example, the Al doped α-SiC powder was hot-pressed to the density of \(\approx 3.15\) by 0.3 wt% AlB\(_2\) and 0.8 wt% C additions, and under 2000°C, 15 MPa, where the pure β-SiC powder was hot-pressed to the density of \(\approx 3.11\) by 0.36 wt% AlB\(_2\) and 1 wt% C additions. It was possible to reduce the amount of additives by using Al doped α-SiC powder at hot-pressing.

The present work reports the results of the strength measurement of the hot-pressed SiC using Al doped α-SiC powder. Sintering of α-SiC with B or B compounds had been investigated by Y. Murata et al\(^5\). They used α-SiC powder which did not contain Al. The strength of SiC densified by normal pressure sintering of the pure α-SiC was reported as about 550 MN/m\(^2\) at 1400°C to 1650°C\(^6\).

The Al doped SiC powders used here were commercially obtained. Two kinds of starting powder were used. One was an α-SiC powder for abrasion, and the other was that for electric materials (denoted as α-1 and α-2, respectively). Both were made industrially by Taiheiyo-kinzoku Co., Ltd. Al was doped in a making process of SiC powder. The chemical analysis of two powders is listed in Table 1. α-2 powder contains 0.78 wt% Al which exceeds the solubility limit of Al to SiC (0.4 wt% at 2000°C to 2400°C\(^3\)). Some Al or Al compounds may exist on the surface of α-2 powder.

The following treatments of SiC powder were carried out before hot-pressing. The powders were pulverized by jet mill and were hydraulic-elutriated. The grain size of the elutriated powders was under about 2 μm. Then, the powders were acid (HF•HNO\(_3\)) treated to remove Al or Al compounds on the surface and the metal contaminations from jet mill. Three specimens were fabricated. α-1 powder was hot-pressed with 0.3 wt% AlB\(_2\) or 0.2 wt% B, and 0.8 wt% C. α-2 powder was hot-pressed only with 0.8 wt% C. Hot-pressing was performed at 2000°C, 15 MPa and for 30 min. Three point bending strength of hot-pressed SiC was measured at room temperature and at 1300°C by Instron type testing machine. Dimension of the samples was about 3×3.5×40 mm. The span of the three point bending was 20 mm. The surface of the samples was polished using 1 μm diamond powder.

Table 2 shows the results of hot-pressing

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Starting powder</th>
<th>Additives wt%</th>
<th>Bulk density g/cm(^2)</th>
<th>Grain size μm</th>
<th>Polytipe</th>
<th>Bending strength MN/m(^2) Room Temp. 1300°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>α-1</td>
<td>AlB(_2) 0.3</td>
<td>C 0.8</td>
<td>3.15</td>
<td>5-15 4H</td>
<td>623 577</td>
</tr>
<tr>
<td>2</td>
<td>α-1</td>
<td>B 0.2</td>
<td>C 0.8</td>
<td>3.16</td>
<td>5-15 4H</td>
<td>645 704</td>
</tr>
<tr>
<td>3</td>
<td>α-2</td>
<td>C 0.8</td>
<td></td>
<td>3.16</td>
<td>7-10 4H</td>
<td>546 417</td>
</tr>
</tbody>
</table>

\(^*) Fracture mode, TG; transgranular, IG; Intergranular
and the strength measurement. The grain size and the fracture mode were determined by the SEM observation of the fracture surface (Fig. 1).

The bulk density and the grain size are almost the same among three samples. At room temperature, the bending strength of sample 1 and 2 is about 620~650 MN/m², and that of sample 3 is about 550 MN/m². Sample 1 and 2 show transgranular fracture, and the fracture of sample 3 is entirely intergranular. At 1300°C, the fracture of sample 1 becomes mixed trans- and intergranular, and the strength decreases about 10% at high temperature. In sample 2, the fracture is predominantly transgranular, and the strength increases to 700 MN/m². Sample 3, which has the strength of 420 MN/m² at 1300°C, behaves large strength degradation at high temperature. Its fracture is completely intergranular. The most high strength material among the samples investigated here is sample 2. It is likely that the high strength of sample 2 is the result of high strength grain boundary, because the fracture of sample 2 is transgranular at room temperature and also at 1300°C. It is not clear whether the high strength grain boundary of sample 2 was performed by the property of B additive or by the small amount of additive in sinterable Al doped α-SiC. It is, however, considered that the strength is remarkably influenced by the fracture mode, i.e., the nature of the grain boundary in the case of poly-crystalline SiC materials.

References


