High Temperature Sintering Kinetics of $\alpha$-Al$_2$O$_3$ Powder

M. R. Ivanović$^{1*}$, M. Nenezić$^2$, V. Jokanović$^3$

$^1$Faculty of Matalurgy-Technology, Podgorica, Serbia and Montenegro
$^2$KAP Podgorica, Podgorica, Serbia and Montenegro
$^3$Institute of Technical Sciences of the SANU, Belgrade, Serbia and Montenegro

Abstract: The sintering kinetics of $\alpha$-Al$_2$O$_3$ powder is investigated in this paper. Commercial $\alpha$-Al$_2$O$_3$ powdered compacts were sintered close to 95% of the theoretical density. The characteristic parameters of sintering kinetics were also determined.

Keywords: Alumina; Sintering.

1. Introduction

Alumina ($\alpha$-Al$_2$O$_3$) is one of the most examined materials [1]. Generally, fundamental investigations of sintering kinetics and mechanism of $\alpha$-Al$_2$O$_3$ powder are most important in the physics of sintering.

The results recorded by measuring the shrinkage rate of the pressed samples of $\alpha$-Al$_2$O$_3$ powder are frequently used in examinations of the sintering kinetics of this material [2-5]. These results showed that sintering of $\alpha$-Al$_2$O$_3$ is controlled by grain-boundary diffusion in the initial stage. The change of activation energy during non-isothermal sintering of $\alpha$-Al$_2$O$_3$ is in detail examined using the data obtained, which is used to calculate the apparent diffusion coefficient [6]. Experimental results of sintering highly sinterable $\alpha$-Al$_2$O$_3$ showed that grain-boundary diffusion is the predominant mechanism [7].

In this work we examined the kinetics of high-temperature sintering of $\alpha$-Al$_2$O$_3$ using the relationship between linear shrinkage and the sintering time. The characteristic parameters of this process were defined, too.

* Corresponding author
2. Experimental Procedure

Commercial $\alpha$-Al₂O₃ was used in this work. The powder contained 0.78 % impurities including 0.42 % SiO₂, 0.21 % MgO and 0.15 % CaO. The average size of particle was 1.2 μm. The powder was pressed under the high pressure of 1 t/cm² and we obtained compacts whose density was 1.73 g/cm³. Sintering was carried out in the temperature interval between 1823-1973 K for 15-480 min. The density of sintered samples is shown in Tab. I.

**Tab. I** The density of sintered $\alpha$-Al₂O₃ samples

<table>
<thead>
<tr>
<th>t (min)</th>
<th>1823 K</th>
<th>1873 K</th>
<th>1923 K</th>
<th>1973 K</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>3.01</td>
<td>3.11</td>
<td>3.40</td>
<td>3.53</td>
</tr>
<tr>
<td>60</td>
<td>3.13</td>
<td>3.27</td>
<td>3.47</td>
<td>3.55</td>
</tr>
<tr>
<td>120</td>
<td>3.20</td>
<td>3.38</td>
<td>3.50</td>
<td>3.61</td>
</tr>
<tr>
<td>240</td>
<td>3.31</td>
<td>3.45</td>
<td>3.56</td>
<td>3.65</td>
</tr>
<tr>
<td>480</td>
<td>3.51</td>
<td>3.59</td>
<td>3.64</td>
<td>3.70</td>
</tr>
</tbody>
</table>

The density of the green compact ($\rho_0$) and those of isothermally sintered compacts ($\rho_s$) were calculated from dimensions and weights.

3. Discussion

In this work examinations of sintering kinetics of $\alpha$-Al₂O₃ were performed in the temperature range typical for the final sintering stage. A logistic curve was obtained after 15 min. of sintering, while a practically linear dependence was obtained after 480 min. (Fig. 1). According to the results obtained we can see that maximal densities of the compacts are approached after 480 min.

**Fig. 1** Relative density as a function of the sintering temperature.

Lee et al. [8] determined the relationship between linear shrinkage $\alpha$-Al₂O₃ and sintering temperature under conventional sintering conditions. They concluded that below 1673 K linear shrinkage is very small. Our results indicate that shrinkage, in the temperature interval of 1823-1973 K, is 17-22 %.
For sintering time less than 60 min. (Fig. 2), the kinetics of that process can be described by the following equation:

\[ n = \frac{dt}{t} \left( \frac{\Delta L}{L_0} \right) \]

where \( t \) is the sintering time and \( \Delta L/L_0 \) is the relative linear shrinkage. For our conditions \( n = 1 \).

**Fig. 2** Linear shrinkage of the specimen as a function of the sintering time.

Using the formal sintering rate, the activation energy of the high-temperature process of sintering \( \alpha\)-Al\(_2\)O\(_3\) samples (Fig. 3) was calculated and its value is 240 kJmol\(^{-1}\)K\(^{-1}\).

**Fig. 3** The sintering rate constant as a function of the sintering temperature.

4. **Summary**

A study of conventional sintering of \( \alpha\)-Al\(_2\)O\(_3\) powder compacts (1823-1973 K) showed that the samples could reach approximately 95% of the theoretical density at the temperature of 1973 K. At all used temperatures, for sintering times below 60 min., a linear dependence quantitatively describes the linear process of sintering. In this case, the activation energy of the sintering process is 240 kJmol\(^{-1}\)K\(^{-1}\).
References