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Electrical conductivity of synthetic mullite single crystals

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Abstract

The electrical conductivity of 2/1-mullite (approximate composition $2Al_2O_3 \cdot SiO_2$) was measured using plane parallel, polished plates cut perpendicular to [100], [010], and [001] from a large single crystal grown by the Czochralski method. Impedance spectra were recorded in the 1 Hz to 1 MHz frequency range at temperatures from 550 to 1400 °C in air. The conductivity vs. temperature curves display changes of their slope between 850 and 950 °C depending on the crystallographical direction. The low-temperature region (T < 850 °C) of conductivity is characterized by low-electrical conductivities ($\sigma_{av} \approx 5.4 \times 10^{-9}$ $\Omega^{-1}cm^{-1}$, average conductivity at 550 °C) with $\sigma_{[010]} > \sigma_{[100]} > \sigma_{[001]}$ and low-activation energies (≈0.66 eV, average value). In the high-temperature region (T > 950 °C) the electrical conductivity is significantly higher ($\sigma_{av} \approx 1.1 \times 10^{-5}$ $\Omega^{-1}cm^{-1}$, average conductivity at 1400 °C) with $\sigma_{[001]} > \sigma_{[100]} \approx \sigma_{[010]}$, and with higher activation energies (≈1.6 eV). While the conductivity in the low-temperature region essentially is electronic, ion conductivity dominates the conductivity in the high-temperature region. We believe that the ionic conductivity is essentially due to hopping of O atoms from structural sites linking the tetrahedral double chains in mullite toward adjacent oxygen vacancies especially in **c**-axis direction. These oxygen hoppings are associated with complex structural re-arrangements, which control and slow down the velocity of the processes. Thus the electrical conductivity of mullite at high temperature is much lower than, e.g., that of Y-doped zirconia, but is significantly higher than that of α-alumina.

Keywords: Mullite, single crystals, electrical conductivity, high temperature