Temperature dependency of the electrical grain boundary transport in forsterite aggregates

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The grain-size-dependency on the electrical conductivity of fine-grained forsterite aggregate was found and attributed to grain boundary diffusion of charge carriers as a main conduction mechanism in the aggregate (ten Grotenhuis et al., 2004). Such result indicates that the electrical conductivity measurement can be used to detect physicochemical changes of grain boundaries with changing temperature and bulk chemistry. We conducted impedance measurements on forsterite aggregates with different grain sizes and secondary phases (e.g., forsterite + enstatite and forsterite + diopside) under a gradual change in temperature in order to obtain temperature (*T*) and grain size (*d*) dependency of the electrical conductivity (*s*).
Synthetic samples of forsterite + enstatite (solidus temperature T_m = 1557 C) and forsterite + diopside system (T_m ~ 1350 C) were prepared from the powders of $Mg(OH)_2$, SiO_2 and $CaCO_3$ (50 nm). Impedance measurements were carried out every 2 ~ 5 minutes during annealing at the highest temperature (1300 ~ 1400 C) for 50 hours and during subsequent gradual cooling down to 1000 C.
Impedance measurements of both forsterite + enstatite and forsterite + diopside during their annealing show grain-size-dependency of their electrical conductivities as $s \propto 1/d$, indicating that the electrical conduction mechanisms are grain boundary transport of the charge carriers in both aggregates.
Impedance measurement during the cooling of forsterite + enstatite shows Arrhenius type of temperature dependency of electrical conductivity which changes with temperature ranges such as the dependency well described by activation energy of 240 kJ/mol at 1000 ~ 1150 C, 290 kJ/mol at 1150 ~ 1350 C and 320 kJ/mol at 1350 ~ 1400 C. Forsterite + diopside exhibits stronger temperature dependency than a simple Arrhenius type dependency providing apparent activation energy ranging from 180 kJ/mol to 1000 kJ/mol at temperature from 1000 C to 1350 C (= sample solidus). We will discuss such temperature dependencies based on structural and/or chemical changes of grain boundaries in these systems.

Keywords: Electrical conductivity, Grain boundary, Grain size dependence

