

Grain-growth kinetics of ferropericlase at high-pressure

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Rheology is one of the most important mineral properties which play a major role in controlling dynamic processes in the Earth's mantle. Ferropericlase, (Mg,Fe)O, is the second most abundant mineral in the Earth's lower mantle following silicate-perovskite. Although volume fraction of ferropericlase is not very large (~20 vol% in pyrolite mantle; Irifune, 1994), rheology in the lower mantle can be dominated by this mineral since ferropericlase is considered to be significantly softer than Mg-perovskite (e.g. Yamazaki and Karato, 2001). Since the dominant deformation mechanism of ferropericlase at lower mantle conditions is most probably diffusion creep, and diffusion creep rate depends on the grain-size of mineral, knowledge of grain growth kinetics this mineral is important for understanding of rheology in the deep mantle. Grain-growth kinetics of pure-MgO at 1 atm was investigated by Spriggs et al. (1964) and Heuer et al. (1966). However, at high-pressure grain-growth kinetics of single phase (Mg,Fe)O-ferropericlase has not been known. Therefore, in this study, we have investigated effect of pressure on grain-growth kinetics of (Mg,Fe)O-ferropericlase.

Ferropericlase aggregates with a composition of $(\text{Mg}_{0.85}, \text{Fe}_{0.15})\text{O}$ have been annealed under dry conditions at 5 and 10 GPa, 1400-1600 degree C and the oxygen fugacity of Ni-NiO buffer using a Kawai-type multi-anvil apparatus (SPI-1000) at Tokyo Institute of Technology. Starting material is an aggregate sintered using piston-cylinder apparatus with average grain size of 4.0 μm . The annealed run products were polished using diamond paste and subsequently with colloidal silica suspension, and etched by acetic acid. Average grain sizes of sample were measured by linear intercept method (Mendelson, 1969).

The grain-growth kinetics of ferropericlase is described by $G^n - G_0^n = k_0 \exp(-(E^\Lambda + PV^\Lambda)/RT)t$ where G is the average grain-size at annealing time t ; G_0 , the initial average grain-size; k_0 is the pre-exponential constant, E^Λ is activation energy, P is pressure, V^Λ is activation volume, R is the gas constant and T is absolute temperature, with $n = 2.6 \pm 0.4$, $\log_{10} k_0 = -7.5 \pm 1.7 \text{ m}^{2.6}/\text{s}$, $E^\Lambda = 262 \pm 30 \text{ kJ/mol}$, $V^\Lambda = 4.7 \pm 0.7 \text{ cm}^3/\text{mol}$. Both activation energy and activation volume of grain-growth are similar to those of grain-boundary diffusion of Mg ($V^\Lambda = 5.0 \text{ cm}^3/\text{mol}$; Van Orman et al., 2003) or O ($E^\Lambda = 230 \text{ kJ/mol}$, $V^\Lambda = 4.5 \text{ cm}^3/\text{mol}$; Forst and Ashby, 1982, Van Orman et al., 2003). Thus, in terms of activation parameters, atomic process of grain-growth would be similar to that of grain-boundary diffusion rather than lattice diffusion.

Compared at same pressure and temperature, grain-growth rate of ferropericlase is similar to olivine (Karato 1989) and MgO (Spriggs et al., 1964 and Heuer et al., 1966) and faster than those of wadsleyite (Nishihara et al., 2006) and ringwoodite (Yamazaki et al., 2005), respectively. The present results show that, at the top of the lower mantle ($P = 25 \text{ GPa}$ and $T = 1500 \text{ degree C}$) grain-size of ferropericlase in single phase system evolves to $\sim 2 \times 10^{-2} \text{ m}$ after significant geological time (10 My) while a previous study predicts that grain-size of MgO in two-phase system (Yamazaki et al., 1996) is as small as $\sim 8 \times 10^{-6} \text{ m}$ at same condition.