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Si diffusivity in Mg_2SiO_4 wadsleyite under nominally dry conditions

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Wadsleyite is one of the major constituent minerals in the mantle transition zone and subducting slabs. In order to understand the rheological behavior of the mantle transition zone, it is essential to determine the diffusion rate of the slowest diffusing species which may control the plastic deformation in silicate minerals undergoing diffusion creep or dislocation climb. In this study, we carried out Si diffusion experiments in Mg_2SiO_4 wadsleyite to discuss the rheological properties in the mantle transition zone and subducting slabs. High-pressure experiments were carried out using a Kawai-type multi-anvil apparatus installed at Tohoku University. Starting material of polycrystalline wadsleyite was synthesized from powdered forsterite at 18 GPa and 2073 K. Surface of the polycrystalline wadsleyite was polished and then coated with a $^{29}SiO_2$ thin film. Diffusion annealing was conducted at 18 GPa and 1723-1873 K. After the diffusion annealing, concentration profiles of ^{29}Si were obtained by the depth profiling method using secondary ion mass spectrometry (SIMS) installed at Kyusyu University.

The water contents of the starting material of polycrystalline wadsleyite were estimated to be 16-35 wt. ppm H2O. The obtained all diffusion profiles were composed of volume diffusion and grain-boundary diffusion regimes. The volume diffusion coefficients (Dv) and grain-boundary diffusion coefficients (Dgb) were determined to be Dv= 6.71 x 10 $^{-11}$ [m^2/s] exp (-323 [kJ/mol]/RT), and deltaDgb = 6.91 x 10^{-20} [m^3 /s] exp (-186 [kJ/mol]/RT), respectively. Si diffusion rates in Mg_2SiO_4 wadsleyite obtained in this study is about three times slower than those having 507 wt. ppm H_2O (Shimojuku et al., 2004).

Because Si is likely to be the slowest diffusing element in wadsleyite, Si may be rate-controlling species in high-temperature creep processes involving diffusion creep and climb-controlled dislocation creep. Some portions in cold subducting slabs may become softer than the surrounding mantle when grain size of spinel decreases to be below 1 micron after the olivine-spinel transformation.

Reference

A. Shimojuku et al. (2004) Geophys. Res. Lett., 31(10), 1029/2004GL020002