

Pressure, temperature, water content, and oxygen fugacity dependence of the Mg grain-boundary diffusion coefficient in forsterite

HONGZHAN FEI^{1,2,*}, SANA E KOIZUMI³, NAOYA SAKAMOTO⁴, MINAKO HASHIGUCHI⁵†, HISAYOSHI YURIMOTO^{4,5}, KATHARINA MARQUARDT¹, NOBUYOSHI MIYAJIMA¹, AND TOMOO KATSURA¹

¹Bayerisches Geoinstitut, University of Bayreuth, Bayreuth D95440, Germany

²Institute for Study of the Earth's Interior, Okayama University, Misasa, Tottori 6820193, Japan

³Earthquake Research Institute, University of Tokyo, 1-1-1 Yayoi, Tokyo, 1130032 Japan

⁴Isotope Imaging Laboratory, Creative Research Institution, Hokkaido University, Sapporo 0010021, Japan

⁵Department of Natural History Sciences, Hokkaido University, Sapporo, 0600810, Japan

ABSTRACT

The Mg grain boundary diffusion coefficients were measured in forsterite aggregates as a function of pressure (1 atm and 13 GPa), temperature (1100–1300 K), water content (<1–350 wt. ppm bulk water), and oxygen fugacity (10^{-18} – $10^{-0.7}$ bar) using a multi-anvil apparatus and a gas-mixing furnace. The diffusion profiles were analyzed by secondary ion mass spectrometer, whereas the water contents in the samples were measured by Fourier transform infrared spectrometer. The activation volume, activation enthalpy, water content exponent, and oxygen fugacity exponent for the Mg grain-boundary diffusion coefficients are found to be 3.9 ± 0.7 cm³/mol, 355 ± 25 kJ/mol, 1.0 ± 0.1 , and -0.02 ± 0.01 , respectively. By comparison with the Mg lattice diffusion data (Fei et al. 2018), the bulk diffusivity of Mg in forsterite is dominated by lattice diffusion if the grain size is larger than ~1 mm under upper mantle conditions, whereas effective grain-boundary and lattice diffusivities are comparable when the grain size is ~1–100 μ m.

Keywords: Mg grain-boundary diffusion, forsterite, upper mantle; Physics and Chemistry of Earth's Deep Mantle and Core