Diffusion of hydrogen in wadsleyite and water in the transition zone

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The kinetics of the hydrogen diffusivity in synthesized polycrystalline was measured by FTIR spectroscopy in order to determine the diffusion coefficient of hydrogen in wadsleyite, that is the major constituent of the mantle transition zone. We have measured the diffusivity of FeO bearing wadsleyite $(Mg_{0.89}Fe_{0.11})_2SiO_4$.

We used San Carlos olivine for the starting material to synthesize wadsleyite at 17-18 GPa and 1440-1600C for several hours. The water content of the synthesized wadsleyite before diffusion experiments are measured to be 200-1600wt.ppm depending on the synthesis conditions. The average of the grain size of the wadsleyite starting materials are around 15 microns.

Diffusion experiments were conducted in the pressure and temperature ranges around 15-17 GPa and 800-1200C. The starting wadsleyite was surrounded by a 10:1 mixture of NaCl and $Mg(OH)_2$ by weight which was used as the hydrogen source in a platinum capsule. Ni foil and NiO powder was placed in the capsule to control the oxygen fugacity of the samples. Samples were heated up to the target temperature with the heting rate of 10 degree/ sec at a constant load. The grain size of the wadsleyite sample was the same as that synthesized before the diffusion experiments.

Unpolarized infrared absorption spectra of polycrystalline samples were measured using JASCO FMT-2000 Fourier transform infrared spectrometer (FTIR). The thickness of the samples was about 80-160 microns for the FTIR measurements. In each measurement of diffusion of hydrogen, the aperture size of FTIR was 50x100 microns for the most samples, and the beam positions were scanned by 10-25 microns in each step. The water contents in wadsleyite were determined by Paterson (1982). Determination of the diffusion coefficients was made fitting the solution of the Fick's second law for the one-dimmentional diffusion (e.g., Carslaw and Jaeger, 1959).

According to Kohlstedt and Mackwell (1998) at relatively low temperatures or short durations, incorporation of hydrougen occurs by redox exchange of protons with with electronic defects, i.e., hydrogen diffuses with a couter-flux of polarons, related to Fe^{3+}. In this case, hydrogen diffusion determined here Dex(H) can me experessed as follows; Dex(H)=2D(H) by takng account of D(P) far greater than D(H). The hydrogen diffusion in this process can be related to the electrical conductivity in the mantle transition zone. The diffusion of hydrogen in polycrystalline wadsleyite with a grain size of 15 mm can be expressed as D(H)=1.0x10^(-5)exp[-128(kJ/mol)RT].

On the basis of the water-dependence of the electrical conductivity in minerals (Karato, 1990), the water content in the mantle transition zone can be estimated to be about 0.05 wt. % by using the Nernst-Einstein relation. The electrical conductivity in the transition zone beneath Mariana trench and Phillipine sea trench may be estimated to be 0.03-0.15 (Utada et al, 2003; Fukao et al., 2004).