Effects of water on kinetics of the olivine-modified spinel transformation in Mg2SiO4

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The behavior of subducting slabs is most important for understanding mantle dynamics and the previous studies have suggested that the olivine-(modified) spinel transformation affects on dynamics of the slabs. In addition, the transformation from metastable olivine under large overpressure conditions may cause deep earthquakes (Kirby et al., 1991) and slab weakening due to the grain-size reduction after the transformation (Riedel and Karato, 1997). Recently, it is shown that water affects the physical properties of Earth's minerals. Although olivine can only contain water less than 0.1 wt%, the modified spinel can contain water up to about 3 wt% (Inoue, 1993; Kohlstedt et al., 1996). Therefore water possibly has great influences on the transformation kinetics of olivine. Kubo et al. (1998) examined the kinetics of olivine-spinel transformation in San Carlos Olivine under wet conditions by conventional quenching method, but it was difficult to discuss effects of water on the transformation kinetics quantitatively. In order to clarify the effect of water on the kinetics of the olivine-modified spinel transformation quantitatively, we performed high-pressure in-situ X-ray diffraction experiments under wet conditions.

High-pressure in-situ X-ray diffraction experiments were carried out at SPring-8 using KAWAI type multi-anvil apparatus (SPEED-1500). Starting material, whose composition is Mg2SiO4+0.5wt%H2O, were prepared as the mixtures of MgO, SiO2, and Mg(OH)2. The sample was enclosed with AgPd capsule and sealed by welding to avoid water loss during the experiments. NaCl was used as the pressure marker (Decker, 1971) and temperature was measured by W3%Re-W25%Re thermocouple. We observed transformation kinetics from olivine to modified spinel at 14.2-15.2 GPa and 1003-1173K.

At 14.2 GPa and 1083K, olivine-modified spinel transformation started in 60 seconds and the transformation proceeded about 90% in 800 seconds. At 15.2 GPa and 1173K, the transformation started in 50 seconds and completed in 400 seconds. We analyzed obtained kinetic data using the rate equation (V=1-exp(-kt^n), V: transformed volume fraction, k, n: rate constant, t: time) by Cahn (1956). The n-value was estimated to be 1.0 and 1.3 at 14.2 GPa and 1083K and 15.2 GPa and 1173K. These results indicate that the overall transformation rates were controlled by only growth process. Brearley et al. (1992) reported olivine-modified spinel transformation occur by grain-boundary nucleation and growth processes. Therefore we estimated growth rates based on these mechanisms. Comparison of the results in this study under wet condition and those of the previous study (Kubo et al., 2002) under dry condition suggests that the growth rate is enhanced by 3 and 2 orders of magnitude with 0.5 wt% H2O at 1083K and 1173K, respectively.