Kinetics of olivine-modified spinel transformation in Mg2SiO4

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Transformations of olivine Mg2SiO4 (alpha-phase) to modified spinel (beta-phase) and spinel (gamma-phase) are important reactions occurred in the Earth's mantle. It has been suggested that kinetics of these transformation greatly affect on the mantle convection, i.e., dynamics of oceanic plates descending into the deep mantle. We have conducted in situ X-ray diffraction experiments on the alpha-beta transformation kinetics in Mg2SiO4 at 13.2-15.8 GPa and 1123-1373K. We estimated time dependence of the transformed volume fraction from changes of the integrated intensities of diffraction lines in alpha and beta-phase. We analyzed the kinetic data using a grain boundary nucleation and growth model, and determined the nucleation and growth rates, and its temperature dependence.

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In situ X-ray diffraction experiments were carried out using multi-anvil high-pressure apparatus (SPEED-1500) installed in the BL04B beam line. The white X-rays from synchrotron radiation was used as the incident X-ray beam and the diffracted beam was detected by energy dispersive method. The sample assembly consisted of MgO and ZrO2 pressure medium, a graphite tube heater, and a MgO sample capsule. The starting material was a fine grained powder of synthetic Mg2SiO4 forsterite. Temperature was measured by a W25Re-W3Re thermocouple, and pressure was evaluated from the volume of NaCl. Sample was compressed at room temperature to about 10 GPa and then annealed in the stability field of alpha-phase at 1473K for 100 minutes. Following annealing, temperature was reduced to 773K and pressure was increased to the desired value in the stability field of beta-phase. Then, temperature was increased again to the desired value at a heating rate of 773K/min, and X-ray diffraction patterns were taken separately with an interval of every 5-600 seconds. In this way, we observed the alpha-beta transformation at 13.2-15.8 GPa and 1123-1373K.

We estimated time dependence of the transformed volume fraction from changes of the integrated intensities of diffraction lines in alpha and beta-phase. We analyzed the kinetic data using a grain boundary nucleation and growth model, and determined the nucleation and growth rates, and its temperature dependence. Activation energy for growth of beta-phase was estimated to be 430 kJ/mol. The determined growth rates were consistent with the previous study using analogue materials at lower pressures.