14C2/2008G641

Time-resolved 2D-XRD observations of the olivine-wadsleyite transformation

Tomoaki KUBO*[1], Akira SHIMOJUKU[1], Masayuki NISHI[1], Takumi KATO[1], Takumi KIKEGAWA[2]
[1] Department of Earth and Planetary Sciences, Kyushu University, Fukuoka, 812-8581, Japan
[2] KEK-PF, Tsukuba, Ibaraki 305-0801, Japan

Introduction

The olivine-wadsleyite transformation, that is the origin of the 410 km seismic discontinuity in Earth's mantle, occurs by nucleation and growth processes involving about 8% density increase. Kinetics of this transformation greatly affects dynamics of cold current of the mantle convection by changing density and rheological properties. We have developed the experimental method to observe nucleation and growth of individual grains during phase transformation at high pressures based on time-resolved two-dimensional X-ray diffraction (2D-XRD) measurements using Kawai-type apparatus. Here we report preliminary results on kinetics of the olivine-wadsleyite transformation obtained using this method.

Experimental method

The experiments were carried out using the double-stage multi-anvil high-pressure apparatus MAX-III at BL14C2 of Photon Factory, Tsukuba, Japan. We used monochromatic X-ray (40 keV, collimated to 300x500 μm) from synchrotron radiation and obtained time-resolved 2D-XRD patterns every 15 minutes using imaging plate. Two sintered diamond anvils were used as the second-stage anvil to obtain the Debye ring pattern within 2 theta of 10° (Fig. 1). The starting material of $(Mg_{0.9}Fe_{0.1})_2SiO_4$ olivine powder was first annealed at around 11-12 GPa and 1473 K for 60 min in the stability field of olivine. Following the annealing, we observed kinetics of the olivine- wadsleyite transformation at two conditions, 13.9-14.4 GPa and 1473 K, and 14.9-15.2 GPa and 1673 K.

Results and discussion

The number of diffraction spots N on 2D detector that fulfill the Bragg condition is proportional to the number of grains per radiated volume N', and the intensity of each spot is proportional to the volume of the grain. We expect to observe nucleation and growth kinetics of individual grains from the evolution of numbers and intensities of diffraction spots as a function of time. We preliminary examined relationships between N and N' at the BL14C2 beamline using the standard polycrystalline materials based on the following equation: $N = N' p \Delta\theta \cos\theta_B / 2$, where p is multiplicity factor, $\Delta\theta$ is angle over which crystal reflects due to various factors such as lattice distortion and divergence of beam, and θ_B is the Bragg angle. The $\Delta\theta$ values for the BL14C2 beamline was estimated to be 2.2×10^{-2} radian.

We obtained the transformation-time curves from changes of integrated intensities of olivine and wadsleyite in 1D-XRD patterns. The n-value in the Avrami rate equation is about 1 in both experiments, suggesting that many wadsleyite grains nucleate at the initial stage of the transformation. This is consistent with the fact that ring patterns of wadsleyite were observed at the lower temperature of 1473 K (Fig. 2a). At the temperature of 1673 K, we observed relatively spotty patterns (Fig. 2b), which implies larger wadsleyite grains are produced due to the faster growth rate at the higher temperature. In order to evaluate nucleation kinetics, we have to carry out transformation experiments at lower overpressure conditions.

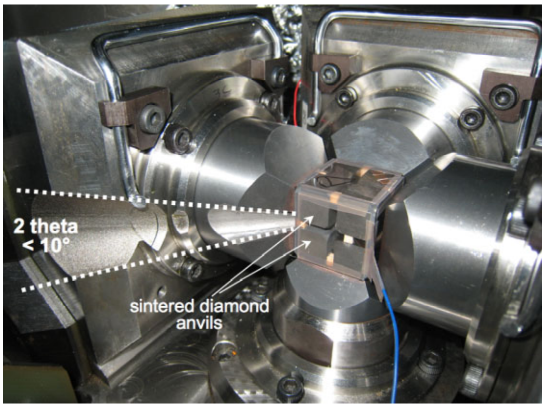

Fig. 1 The double-stage multi-anvil system for 2D-XRD measurements.

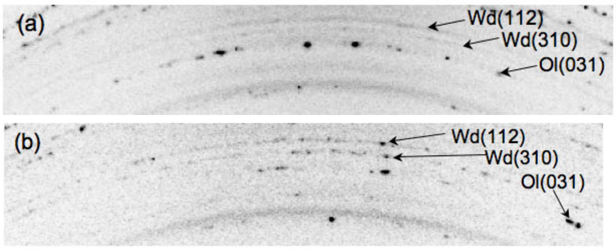

Fig. 2 Snapshots of 2D-XRD patterns during the olivine-wadsleyite transformation at (a) 14.4 GPa and 1473 K (t=69 min), and (b) 15.0 GPa and 1673 K (t=53min).

* kubotomo@geo.kyushu-u.ac.jp