Development of rotational diamond anvil cell for deformation experiments under ultra-high pressure corresponding to Earth's core

*Shintaro Azuma[1], Ryuichi Nomura[2], Yuki Nakashima[3], Kentaro Uesugi[4], Toru Shinmei[2], Tetsuo Irifune[2]

1. Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University, 2. Ehime University, Geodynamics Research Center, 3. Tokyo Institute of Technology, 4. Japan Synchrotron Radiation Research Institute

Development of high-pressure (static compression) experiments enabled to increase pressure up to ~360 GPa, corresponding conditions to inner core of the Earth (e.g., Tateno et al., 2010). On the other hand, pressure is limited for a technical reason in high-pressure deformation experiments. Earth’s interior is dominated by ‘dynamic’ processes. Therefore, expansion of pressure range in deformation experiments is necessary to understanding the evolution of Earth’s deep interior. We developed rotational diamond anvil cell (R-DAC) to conduct deformation experiments with large strain under ultra-high pressure conditions, corresponding to those of Earth’s core.
In this study, existing diamond anvil cell (DAC) is modified to give torsional deformation to sample under ultra-high pressure conditions. In the developed R-DAC, lower anvil is fixed and upper anvil can rotate to relative to the lower anvil. We deformed periclase (one phase), and mixture of bridgmanite and ferropericlase to test this apparatus. The experimental conditions are ranging 35–150 GPa, room temperature and strain-rate of 5.6×10^{-5}–1.7×10^{-4} s^{-1}. Starting material was grooved by FIB and the groove was deposited by Pt as strain-marker. Recovered samples were cut by FIB to observe the rotation angle of strain-marker, sample thickness, and shape of strain-marker in each cross-section. Deformation experiments were conducted also in Japan Synchrotron Radiation Research Institute (SPring-8) and 3D visualization of the internal structure of samples were performed using X-ray laminography (Nomura and Uesugi, 2016).
The geometry of strain-marker in recovered samples show nearly simple shear, indicating that this apparatus allows us to investigate the deformation with large strain under ultra-high pressure conditions, corresponding to those of core-mantle boundary (CMB). The rotation angle of strain-marker in recovered samples were compared to that expected from rotation angle of upper anvil. The results indicated that slip occurred between upper anvil and samples. Therefore, the combination of R-DAC and X-ray laminography, which can perform in-situ 3D observation of strain marker, is a valid and feasible way.
Recovered sample was observed using FE-SEM. Microstructure of mixture of bridgmanite and ferropericlase showed that ferropericlase highly deformed and connected each other. Although this prototype of R-DAC has some points that should be improved, we present preliminary results and potential of R-DAC to conduct ultra-high pressure deformation experiments.

Keywords: Deformation experiment, Diamond anvil cell (DAC), Lower mantle, Core

