Torsional deformation experiments at Mbar pressures toward understanding deep Earth rheology

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The rheological properties of deep Earth materials are key to understanding the dynamics and evolution of the Earth’ s interior. Recent technological developments in deformation experiments under high pressures and temperatures combined with the use of synchrotron X-rays have facilitated a qualitative understanding of the rheological properties. For instance, through the use of the D-DIA and the rotational Drickamer apparatuses, it is possible to determine stress-strain relationships at high pressures (P) and temperatures (T) to those in the uppermost part of the lower mantle[Girard et al., 2016; Tsujino et al., 2016].

In this study, we introduced a rotational diamond anvil cell [Blank et al., 1984] to extend the pressure range of large-strain steady-state deformation experiments. High experimental pressures covering those in the whole of the lower mantle were achieved using nano-polycrystalline diamond as the anvil material with a high experimental success rate [Nomura et al., 2017]. Additionally, pressures up to multi-Mbar were observed using single crystal diamond anvils, although the success rate was not high. A simple detachable external heating system with a vacuum chamber was introduced to generate temperatures greater than 1000 K. The high-pressure in-situ X-ray laminography technique [Nomura and Uesugi, 2016] was introduced to determine the strain state within a sample under high-pressure conditions. The X-ray diffraction measurement system was introduced to determine the stress state of the sample under high-pressure and high-temperature deformation conditions. A combined X-ray diffraction and X-ray imaging measurement system was set up in an identical beamline (BL47XU of SPring-8, Japan). Through this combined measurement technique with the rotational diamond anvil cell, we succeeded in extending the P-T range of the quantitative experimental studies to understand the rheological properties of the deep Earth materials. We present recent technical developments and their relevant applications.

Keywords: high-pressure and high-temperature, rotational diamond anvil cell, Earth's deep interior

