Development of the rotational diamond anvil cell for high-pressure deformation experiments and its measurement systems

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The mechanical properties of lower mantle materials are key to understanding the dynamics and evolution in the Earth' s interior. However, the pressure range of deformation apparatuses which can achieve large strain is limited to ˜30–40 GPa due to a technical reason. We developed a new deformation apparatus named rotational diamond anvil cell (rDAC). This deformation apparatus can apply the torsional deformation to a sample, thus the rDAC can theoretically produces an infinite strain within the sample under ultra-high pressure conditions, corresponding to those of core-mantle boundary [Nomura et al., 2017]. The rDAC is the most suitable deformation apparatus with which to investigate the mechanical properties of deep-Earth materials. In this presentation, we will mainly present the measurement systems, technology and idea which were applied to the rDAC.

Deformation apparatuses used in Earth science need high-pressure and high-temperature techniques, the constant strain rate, and the measurement systems of the stress and strain. The rDAC can apply high pressure and torsional deformation to a sample with constant strain rate by a gearbox and diamond anvils with grooves [Azuma et al., 2018]. *In situ* strain measurements are conducted using X-ray laminography techniques at BL47XU, SPring-8 [Nomura and Uesugi, 2016]. High-temperature conditions and stress measurements have not been achieved in rDAC. Recently, however, the vacuum chamber newly designed for rDAC was installed for high temperature experiments, and stress measurements using X-ray Diffraction (XRD) were applied to deformation experiments in rDAC at SPring-8 (Japan).

To test the high temperature technique and stress measurements using XRD with the new vacuum chamber, the mixture of bridgmanite (Mg,Fe)SiO_3 and ferropericlase (Mg,Fe)O, which was synthesized from San Carlos olivine, was deformed under torsion geometry using the rDAC at BL47XU, SPring-8. The vacuum chamber has a removable Kapton window for incident and diffracted X-ray, and can keep the vacuum state (<˜10 Pa) to prevent the diamond anvils from oxidation during high-temperature deformation experiments. Platinum wires were used as a resistance heater surrounding the sample and Rhenium gasket. Stress was measured by collecting X-ray diffraction pattern at twelve different azimuthal angles, Ψ= 0º, ±30º, ±60º, ±90º, ±120º, ±150º, and 180º.

In heating experiments using new vacuum chamber, temperature was monitored by Pt/Rh thermocouple placed close to the sample and we succeeded in increasing temperature up to ˜1000 K. However, the resistance heater (Pt) was unstable in vacuum. In the future, high-temperature deformation experiments using rDAC will be performed in reducing atmosphere produced by inactive gas (e.g., Argon gas) or internal heating system should be developed for the rDAC .

Stress in bridgmanite was estimated by using diffraction peaks (110) and (112) at P= 50 GPa and T= 673 K. Shear stress in bridgmanite was relatively constant values, whereas uniaxial stress changed during deformation experiments. This preliminary experiment was performed under low-temperature and high-pressure conditions, thus the equivalent stress in bridgmanite was about three times higher than that in previous studies [e.g., Girard et al., 2016].

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