In-situ stress-strain measurement of bridgmanite

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In order to understand mantle dynamics in the Earth’s interior, it is important to know the viscosity of the Earth’s lower mantle. One dimensional viscosity models of the Earth’s mantle were proposed by geophysical observations while there are large inconsistencies of viscosity (2~3 order magnitude) in the lower mantle between suggested models. Therefore it is important to determine viscosity of lower mantle minerals by high pressure experiments in order to understand mantle dynamics. In this study, we conducted in-situ stress-strain measurements of bridgmanite aggregate using Deformation-DIA type apparatus as Kawai-type.

In-situ measurements were conducted using SPEED-Mk.II, which is D-DIA apparatus, as Kawai-type apparatus at SPring-8 BL04B1. Mg-pure bridgmanite aggregates were used as starting material. Experimental conditions are 1473-1673 K and 27-28 GPa. Pressures were estimated by equation of state on bridgmanite (Katsura et al., 2009). WC second cubic anvils with slit or cone (5°) to take tomography and 2D X-ray diffraction, was used along X-ray path. X-ray radiographies of the strain markers were taken using an imaging system composed of a YAG crystal and a CCD camera. Two-dimensional X-ray diffraction patterns were corrected for 180-300 s using CCD detector. To calculate pressure and the stress magnitude of bridgmanite, (111) (112) (200) X-ray diffraction peaks were used.

Measured uniaxial stress and strain of bridgmanite during deformation experiments were 0.3-1.3 GPa and < 6 %. Flow law in dislocation creep is described by,

$d\varepsilon/dt = A\sigma^3 \exp(-E^*/RT)$ (1)

where $d\varepsilon/dt$ is strain rate, A is pre-exponent, σ is stress, E^* is activation energy, R is gas constant and T is temperature. Least squares fit of Eq. (1) to these viscosity data yielded $A = 10^{7.6\pm1.5}$ and $E^* = 372 \pm 40$ kJ/mol. This activation energy of flow low is similar to that of atomic diffusion of bridgmanite by Xu et al. (2011). This fact supported deformation mechanism could be dislocation creep controlled by dislocation clime.

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