In situ deformation experiments of coesite

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Since continental crust is chemically rich in SiO_2 and contains a large amount of radioisotope compared with bulk upper mantle, flux of subducting continental crust could affect terrestrial thermal history and chemical evolution. This flux is largely determined by viscosity of continental crust. Based on deformation experiments of quartz, Gleason and Tullis (1995) suggested that behavior of continental crust is controlled by frictional sliding and plastic deformation of quartz up to 90 km depth. Coesite is a stable SiO_2 mineral under P-T conditions from 90 to 270 km depth and expected to play a major role in the mechanical behavior of continental crust at this depth. However only one experimental study on viscosity of coesite has been reported (Renner et al., 2001), and pressure condition in the previous study is limited to 4 GPa (120 km depth) because of the limitation of the Griggs type apparatus.

To study rheology of coesite at higher pressures, in situ uni-axial deformation experiments of coesite was conducted using deformation-DIA apparatus "D-CAP" at the synchrotron beamline NE7A, Photon Factory Advanced Ring (PF-AR), National Laboratory for High Energy Accelerator Research Institute (KEK). Water content and microstructure of starting material and deformed sample were determined by Fourier-transform infrared spectrometer (FTIR) and field-emission scanning electron microscope (FE-SEM), respectively. Two types of starting materials were employed. One is polycrystalline quartz with 20 μm grain size and 460 wt ppm H_2O, the other is polycrystalline coesite 10 μm grain size and 10 wt ppm H_2O. A 7 mm cubic (Mg,-Co)O pressure medium was pressurized by WC and cBN anvils with truncated edge length (TEL) of 5 mm. High temperature was generated by a ϕ3.0/2.5 mm graphite heater and temperature was measured using a WRe thermocouples. To remove the initial stress, annealing was performed for an hour at high pressure (quartz was transformed to coesite at this stage) and then uni-axial deformation was done at constant strain rate. Monochromatic X-ray with 50 keV was used for the in situ observation of sample. Radiograph image was taken by YAG phosphor and CCD camera. Two-dimensional diffraction pattern by incident X-ray with dimension of 0.2 ×0.2 mm^2 was obtained using an imaging plate with exposure time of 3-6 min. Strain was determined from sample length on the radiographic image. Differential stress was calculated using equation by Singh et al. (1998) and shear modulus reported by Chen et al. (2015). Pressure was calculated from thermoelastic parameters reported by Angel et al. (2001) and; Galkin et al. (1987). Deformation conditions were temperature of 800 - 1100 ℃, pressure of 3 - 4 GPa, strain rate of 6.7×10^{-6} - 1.1×10^{-4} s^{-1}. Since, unfortunately, experiments at high pressures were unsuccessful, pressure condition was similar to that in Renner et al. (2001).

Steady state stress was determined for each deformation. Viscosity of coesite in this study shows good agreement with that reported by Renner et al. (2001) except for data at 800℃. The results fitted by constitutive equation, and stress exponent n and activation enthalpy H* were determined to be 2.9±0.5 and 99.5±27.7 kJ/mol, respectively. Renner et al. (2001) reported n and H* of 2.9±0.5 and 261±45 kJ/mol, respectively. The disagreement of these values may be partly due to large errors of the measured stress in both studies.
Ichikawa et al. (2013) reported that 2.2 km^3 /yr of continental crust material can be subducted to 270 km depth based on the numerical simulation using the flow law parameters of Renner et al. (2001). If flow law parameters determined in this study is used, the flux of continental materials would be less because the

smaller n value causes lower viscosity of coesite under natural strain rate of 10^{-12} - 10^{-15} s^{-1}.

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