Observations of stress-strain curves of Mg2SiO4 ringwoodite at high pressure using a deformation-DIA

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Recent development of global seismic tomography has revealed that, at the most of the subduction zones, subducting slabs start to deform in the mantle transition zone and are stagnant in the lower part of the mantle transition zone. The driving force of the subducting slabs is density contrast between the slabs and the surrounding mantle, which has been studied well in the last two decades. On the other hand, rheological property of minerals that constitutes the mantle transition zone has not been studied well because of experimental difficulty even though it is indispensable to understand how the subducting slabs deform and are stagnant in the mantle transition zone. Thus in the present study, we carried out deformation experiments of ringwoodite. Experiments were performed at 13-BM-D, GSECARS, Advanced Photon Source. We used a deformation-DIA as a deformation apparatus. This apparatus has a DIA-type guide block and the top and bottom anvils can be moved independently. Thus, this apparatus enable us to decouple differential stress from hydrostatic pressure. The truncated edge length of the anvil is 3 mm and four sintered cubic-BN (cBN) anvils are used for side anvils. Pressure medium is a mixture of amorphous boron and epoxy. For the starting material, a pre-sintered, fully densified polycrystalline cylindrical ringwoodite (0.8 mm in diameter and 1.2 mm in length) was used. Two alumina pistons are placed just above and below the sample as deformation pistons. Two gold foils are put in between the sample and the piston and are used as strain markers. In the present study, monochromatized X-rays (65 keV) were used as incident beam. When the X-ray diffraction patterns were collected, incident slits were on the beam path to make a fine beam, and it was directed to the sample. Diffracted X-rays (the whole Debye rings) which go through an anvil gap and cBN anvils were collected using 2-D X-ray CCD detector. When the images of the transmitted X-rays were collected, broad X-ray beam was used. The transmitted X-rays were converted to visible lights using a YAG crystal and the converted lights were recorded by CCD camera. Using these X-ray diffraction patterns and single crystal elastic moduli of ringwoodite, we can calculate pressure and differential stress. On the other hand, the total strain and the strain rate can be calculated using the image data. During the deformation of the sample, the diffraction and the image data collection were repeated, one after another, and stress-strain curves were obtained by analyzing these data. We performed five and four deformation cycles at fixed loads of 30 and 50 tons, respectively. In these deformation cycles, axial strains exceed 20% and strain rates are between 5*10^(-5) and 4*10^(-6) 1/s. The average pressures at 30 and 50 tons are 5 and 8 GPa, respectively. At these pressures, the sample is readily deformed in ductile regime even at room temperature. There is no evidence for fracture, such as a sudden trop of differential stress and sample length, during the deformations. All the stress-strain curves exhibit a consistent trend. Stresses vary linearly with strain until strain reaches about 1.5%, where curves start deviating from linearity. We can define this point as the yield point. Beyond the yield point, relation between stress and strain exhibits a strong non-linearity, indicating strain-hardening. Eventually, stresses are saturated when strain exceeds 8% (steady-state flow). According to the present results, stresses at steady-state flow increase with pressure, and are insensitive to strain rate, which indicates the dominant deformation mechanism at high pressures and room temperature is low-temperature plasticity. Our data can reconcile large discrepancies of results of differential stress measurements by previous studies where no strain information could be obtained.