Crystallographic-preferred orientation of MnGeO$_3$ perovskite

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Efficiency of material and heat transport in the Earth is largely influenced by flow pattern in the mantle. Flow direction at around the 660 km discontinuity is one of the key to understand the flow pattern of the whole mantle. Recently, Tsujino et al. (2016) determined shear induced crystallographic-preferred orientation (CPO) of (Mg,Fe)SiO$_3$ bridgmanite (Brd), which is the most abundant mineral in the lower mantle, based on high-pressure and high-temperature deformation experiments. They showed that seismic anisotropy in the uppermost lower mantle near subducting slab is reasonably explained by horizontal flow of mantle material. However, Tsujino et al.'s (2016) study consists of very limited number of experimental data due to difficulty in conducting experiments under the lower mantle pressure and temperature condition, and further studies are desirable to assess their conclusion. In this study, we have conducted high-pressure and high-temperature deformation experiments on MnGeO$_3$-perovskite (Pv) which is an analog material of Brd and determined its deformation-induced CPO.

A sintered aggregate of MnGeO$_3$-Pv was synthesized from MnGeO$_3$-Opx and adopted as a starting material of deformation experiments. Deformation experiments were conducted using D111-type deformation device installed at PF-AR, KEK and DT-Cup at UCL. The DT-Cup, developed by Hunt et al. (2014), is a modified Kawai-type multi-anvil apparatus by which well-controlled deformation experiments at pressures higher than 15 GPa can be conducted by driving two second-stage anvils using differential actuators. The D111-type apparatus is an improved version of DT-Cup which can be used under higher press load. Pressure and temperature conditions of experiments were 16 GPa and 1200-1300°C, and strain rates were 4.5-13.9 x 10$^{-5}$ s$^{-1}$ in shear deformation and 3.7 x 10$^{-5}$ s$^{-1}$ in uniaxial compression. The CPO of recovered samples were determined using MAUD software by analyzing 2-dimensional diffraction pattern taken with monochromatic X-ray (50 keV) at BL04B1, SPring-8.

Three recovered samples from shear deformation experiments consistently showed CPO pattern with [010] aligned parallel to shear direction, and [100] and [001] weakly aligned sub-parallel to shear plane normal. In a uniaxial compression experiment, [100] strongly aligned parallel to compression direction. These results suggest that dominant slip system of MnGeO$_3$-Pv is [010](100) under the studied conditions. This slip system differs from the dominant slip system of Brd reported by Tsujino et al. (2016), [001](100), whereas Ferre et al. (2007) reported that [010](100) is one of the easiest slip system in MgSiO$_3$-Pv based on first principles calculation. If [010](100) is assumed to be the dominant slip system in Brd, the resultant seismic anisotropy for $V_p$ and $V_s$ is almost identical to that for the [001](100) dominant case. Therefore, present results also suggest predominance of horizontal flow in the uppermost lower mantle near subducting slab as Tsujino et al. (2016) discussed.


Keywords: lower mantle, bridgmanite, MnGeO3-perovskite, crystallographic-preferred orientation, deformation experiments