Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

SIT039-14 Room:301A Time:May 24 12:00-12:15

Effect of water on the crystallographic preferred orientation of olivine under the asthenospheric mantle conditions

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Crystallographic preferred orientation (CPO) of olivine, which is developed by dislocation creep, controls the seismic anisotropy in the upper mantle. One of the remarkable observations on the upper mantle near subduction zones is a striking rotation of fast direction of shear-wave splitting across an arc. Trench-normal fast directions are observed in the back-arc side, but trench-parallel ones are observed in the fore-arc side (e.g, Smith et al., 2001; Nakajima and Hasegawa, 2004). The rotation of fast direction of shear-wave splitting has been attributed to the transition of mantle-flow direction from trench-normal flow (in the back-arc side) to trench-parallel flow (in the fore-arc side) under the assumption that the A-type olivine fabric (developed by the (010)[100] slip system), which has a seismic fast-axis orientation subparallel to the shear direction, is assumed to be the unique cause of seismic anisotropy (e.g., Russo and Silver, 1994). However, this model is not fully supported by other observations such as geodetic observations.

Recent laboratory results have shown that the flow-parallel shear wave splitting is caused not only by A-type olivine fabric but also by C- (developed by the (100)[001] slip system) and E-type (by the (001)[100] slip system) olivine fabrics (Jung and Karato, 2001; Katayama et al., 2004). Moreover, flow-perpendicular shear wave splitting is also found to be caused by the B-type olivine fabric (developed by the (010)[001] slip system) (Jung and Karato, 2001). All of newly found olivine fabrics are developed under wet conditions. Based on the seismological properties of various olivine fabrics, it has been proposed that the trench-parallel shear wave splitting and trench-normal shear wave splitting are caused by trench-normal flow associated with B-type olivine fabric (in fore-arc side) and with C- (or E-) type olivine fabrics (in back-arc side), respectively (Karato, 2003; Kneller et al., 2005). However, it has recently been reported that the CPO patterns of anhydrous olivine depend on pressure (Jung et al., 2009; Ohuchi et al., 2011), suggesting the possibility that the fabric boundaries determined at low pressures (0.5?2 GPa: Jung and Karato, 2001; Katayama et al., 2004) cannot be applicable to the asthenospheric mantle wedges ($>$ 60 km depth).

In order to explore the effect of water on CPO of minerals at high pressures, we developed a new cell assembly for the multi-anvil assembly 6-6 (MA6-6) system combined with a deformation-DIA apparatus (Ohuchi et al. 2010). We have initiated a series of experimental studies on the effect of water on the CPO of olivine under the upper mantle conditions. We conducted the experiments of the simple-shear deformation of hydrous olivine at P = 2-7 GPa and T = 1400-1670 K for a range of shear strain rate 1E-5 to 1E-4 /s. Our experimental results showed that the A-type olivine fabric was the dominant under dry and moderately wet conditions. In contrast, B-type-like olivine fabrics were developed under wet conditions. These observations suggest that water content is one of the most important parameter controlling the fabric transition of olivine not only in the lithosphere but also in the asthenosphere. The water-induced fabric transition can be the cause of the rotation of fast direction of shear-wave splitting across an arc.

Keywords: olivine, crystallographic preferred orientation, water, seismic anistropy