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Effect of pressure and water on the lattice-preferred orientation of olivine

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Plastic deformation of olivine plays an important role in controlling the dynamics in the upper mantle. The lattice-preferred orientation (LPO) of olivine developed by dislocation creep is known to be the cause of the anisotropic elastic properties of upper mantle materials. Simple shear deformation experiments have been conducted to investigate relationship between LPO of minerals and deformation conditions (such as pressure, temperature, dissolved water content in minerals). It has been reported that water has significant effects on the LPO of olivine (e.g., Jung and Karato, 2001). The fabric transition is controlled by the relative strength of slip systems, and the relative strength of slip systems of olivine is changed by the presence of small amount of dissolved water (Mackwell et al., 1985). The effects of water on the LPO of olivine have been evaluated at the pressures of < 2 GPa, which are the range of generated pressures using a conventional Griggs apparatus. It is known that the amount of dissolved water in olivine and other mantle minerals increases with pressure (e.g., Kohlstedt et al., 1996). Thus, the effects of water on LPO of minerals are expected to be important under high pressure conditions. Recently, Raterron et al. (2007) conducted a series of deformation experiments on forsterite single crystals at pressures of 2.1-7.5 GPa and temperatures of 1373-1677 K using a deformation-DIA apparatus, and reported that the dominant slip direction changes from b = [100] to [001] at > 5 GPa. Their results suggest the possibility of pressure-induced fabric transition of olivine. However, the influence of pressure on LPO of olivine and other minerals has been evaluated at the pressures of < 4 GPa, which are the range of generated pressures using a Griggs apparatus (or a modified Griggs-type apparatus).
In order to explore the pressure-induced fabric transition of minerals and the effect of water on LPO 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 (Nihsiyama et al. 2008). We have initiated a series of experimental studies on the effect of pressure and water on the LPO of olivine under the upper mantle conditions. We conducted the experiments of the simple-shear deformation of anhydrous and hydrous olivine at P = 3-7 GPa and T = 1473-1573 K for a range of shear strain rate 1E-5 to 1E-4 /s. In this paper, we report the preliminary results on the deformation experiments.
Our experimental results showed that the type-A LPO of olivine, where the olivine [100] axis is subparallel to the shear direction and the (010) plane is subparallel to the shear plane, was the dominant under the anhydrous conditions. A new-type LPO of olivine, which is characterized by the olivine [100] axis perpendicular to shear direction and the (010) plane subparallel to the shear plane, was the dominant under the hydrous conditions. The new-type LPO is similar to the type-B LPO of olivine, where the olivine [001] axis is subparallel to the shear direction and the (010) plane is subparallel to the shear plane. These observations suggest that water content is one of the most important parameter controlling the fabric transition of olivine not only in the uppermost mantle but also in the deeper part of the upper mantle.

Keywords: olivine, LPO, simple-shear deformation, D-DIA