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カンラン石の結晶方位定向配列発達の高温高圧下その場観察実験
In-situ observation of crystallographic preferred orientation of olivine aggregates deformed in simple shear

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The characteristics of the seismic anisotropy vary depending on the types of crystallographic preferred orientation (CPO) of olivine . Therefore, the pattern of the seismic anisotropy has been interpreted by taking into account the water-induced olivine fabric transitions in recent studies (Jung and Karato, 2001). The fabric strength of olivine aggregates is also important when we evaluate the magnitude of the seismic anisotropy in the upper mantle. In the actual upper mantle, the steady-state fabric strength of olivine is expected to be achieved due to long time-scales of flows.

The dependency of the fabric strength of olivine aggregates on strain has been evaluated in only limited numbers of experimental studies (e.g., Bystricky et al., 2000). Bystrikcy et al. (2000) showed that total shear strains higher than 4 are needed to achieve the steady-state fabric strength of olivine (D-type fabric) at 0.3 GPa and 1473 K. However, it has been difficult to evaluate the detailed processes of the developments of fabrics because fabrics of recovered samples have been used. Recently, we have developed experimental techniques for in-situ simple-shear deformation experiments using a D-DIA apparatus. In this paper, we briefly show that our recent experimental results on in-situ observations of stress, strain, and fabric developments in olivine samples.

Simple-shear deformation experiments on olivine aggregates at pressures P = 1-2 GPa, temperatures T = 1290-1490 K, and shear strain rates of 3E-4 s-1 were performed using a deformation-DIA apparatus installed at SPring-8. The MA6-6 system (Nishiyama et al., 2008) with a truncated edge length of the second-stage anvils of 5 mm was adopted for the experiments. A sectioned sample of anhydrous olivine aggregates (diameter = 1.5 mm; thickness = 300-500 um) was placed into a nickel capsule and then sandwiched between two alumina pistons. Shear strain (up to 5) was measured by the rotation of a platinum strain-marker, which was initially placed perpendicular to the shear direction. Differential stress, generated pressure, and CPO patterns of olivine samples were determined from two-dimensional X-ray diffraction patterns using software (IPAnalyzer, PDIndexer, and ReciPro: Seto et al., 2010; Seto, 2012). The CPO patterns of olivine in the recovered samples were also evaluated by the indexation of the electron backscattered diffraction (EBSD) patterns using a JEOL JSM-7000F at Ehime University. The CPO patterns determined from two-dimensional X-ray diffraction patterns were consistent with those obtained from the EBSD analyses.

A-type olivine fabric was developed at high temperatures (1490 K). CPO patterns showing A-type fabric were observed at strains higher than 1. The fabric strength increased with strain (< 3). Steady-state fabric strength was achieved at shear strains about 3. Strain softening was observed in most of samples due to the developments of CPO of olivine. Developments of B-type and C-type-like fabric were observed at low temperatures (< 1440 K) in relatively wet samples (about 300-400 ppm H/Si in olivine: caused by absorption of water in olivine during deformation).

It has been reported that the developments of the A-type fabric, which is the most commonly observed olivine fabric in natural peridotites (Ismail and Mainprice, 1998). The threshold shear strain of 3, which is needed for the achievement of steady-state fabric strength, corresponds to 100 Myr of mantle flow (under the assumption of a shear strain rate of 1E-15 s-1). Our results implies that overwriting of an olivine CPO pattern due to a change of the deformation condition requires a long time-scale (i.e., 100 Myr or longer). The seismic anisotropy observed in the upper mantle would reflect the olivine CPOs formed within 100 Myr ago.

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