The interaction between deformation and the olivine-spinel transformation in fayalite

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Abstract

The non-equilibrium olivine-spinel transformation may trigger deep earthquakes and large deformation of deep slab through localized deformation enhanced by significant grain-size reduction. Therefore it is indispensable to investigate the coupling process between the transformation and deformation. In the present study, we examined creep behaviors during the olivine-spinel transformation in fayalite up to _˜14 GPa by in-situ X-ray observations.
Deformation experiments were conducted using a D-DIA apparatus in the beamline of BL04B1 at SPring-8 and NE-7 at Photon Factory. After annealing polycrystalline fayalite at _˜4 GPa and 900◦C for 2 h, we observed the olivine-spinel transformation at _˜6-14 GPa (overpressures dP of _˜1-10 GPa) and 823-1173 K with and without deformation (in uniaxial compression with constant strain rate of 3-8 x 10-5 s-1). Stress-strain and transformation-time curves were simultaneously obtained from 2D-XRD patterns and X-ray radiography images using monochromatic X-ray.
The flow stress in olivine normally increased with decreasing temperature from _˜0.5 GPa at 1173 K to _˜3-4 GPa at 823 K. Stresses in olivine, spinel, and the bulk sample were similar at the initial stage, and then spinel becomes dominant deformation phase at around 70% transformation. Spinel is stiffer than olivine in our experimental conditions. There were almost no signs for weakening and/or stress drop in the flow data. We observed grain boundary nucleation and anisotropic growth of spinel perpendicular to the principal stress direction. Nucleation was enhanced by deformation, but fine-grained reaction rims were not formed even at large dP. Thus, we did not observe clear evidences for the reaction-induced weakening as proposed in previous studies. Large dP of _˜5-6 GPa are needed to initiate transformation at 823-873 K even with deformation, in which we observed faulting across the sample associated with micro fractures. Intracrystalline lamellae in olivine developed almost parallel to the main fault. TEM analysis revealed that the thin lamellae were not composed of spinel grains, but olivine crystal with different orientation. The observed faulting and micro fractures may be caused by the deformation lamellae in olivine, however further studies with AE measurements are needed to understand the detailed process.

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