Creep behavior and high-pressure faulting during the olivine-spinel transformation in fayalite

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Transformations from metastable olivine at large overpressures in cold subducting slabs may cause significant grain-size reduction and lead to the slab weakening and deep earthquakes. It is indispensable to investigate the coupling process between transformation and deformation under pressures of mantle transition zone. In the present study, we examined creep behaviors during the olivine-spinel transformation in fayalite (Fe_2SiO_4) up to ~14 GPa and observed some evidences for transformational faulting. Deformation experiments were conducted using a Deformation-DIA apparatus in the beamline of BL04B1 at SPring-8. After annealing polycrystalline fayalite at ~3.5 GPa and 900°C for 2 h, we observed the olivine-spinel transformation at ~6-14 GPa and 873-1173 K with and without deformation (in uniaxial compression with constant strain rate of 3-5 x 10^{-5} s^{-1}). Stress-strain and transformation-time (strain) curves were simultaneously obtained from time-resolved measurements of two-dimensional X-ray diffraction patterns and X-ray radiography images using monochromatic X-ray (energy 50-60 keV). Overpressures needed for initiating the transformation increased with decreasing temperature from 1.5 GPa and 1173 K to 3.8 GPa at 973 K in the case of no deformation. When the sample was deformed, the overpressures decreased by ~0.5-1 GPa, suggesting the enhancement of spinel nucleation by stress and/or deformation. Stresses in olivine, spinel, and the bulk sample (from stress marker arranged in tandem) were similar at the initial stage, and then spinel becomes dominant deformation phase at around 70% transformation. In these runs conducted at more than 973 K, transformation occurred at grain boundaries of parental phase, and the reaction rims were not formed. On the contrary, larger overpressures than ~5 GPa are needed to cause transformation at lower temperature of 873 K even with deformation, in which we observed faulting across the sample associated with lamellar intracrystalline transformations and micro fracture. The thin intracrysatlline lamellae in olivine crystal developed almost parallel to the main fault and consisted of sub-micron fine-grained materials. This may correspond to transformational faulting as previously observed in germanate olivine at lower pressure conditions of ~5 GPa (Schubnel+, SCI13), however further studies with AE measurements and TEM analysis are needed to understand the detailed process. We did not observe clear evidence for the weakening of bulk sample due to the grain-size reduction as proposed in previous studies.

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