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High-pressure phase transition of olivine in shear stress condition

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High-pressure phase transition has been considered to be a possible trigger of deep focused earthquakes which were observed in subducting slab. In the deep slab condition, considerable shear stress was expected due to the sinking force by own weight. However, phase transition in a non-hydrostatic condition was not fully understood at the condition of deep transition zone. In this study, we tried to develop a new method for deformation experiment in a high-confine pressure corresponding to the lower mantle condition and investigated its effect to high pressure phase transition in olivine. High- pressure experiments were conducted using laser-heted diamond anvil cell (LHDAC). Starting materials are single crystals of natural olivine (San Carlos, USA) and pyrope garnet (Czecho). They were thinned to have a wedge-shaped plate and single-sided coated with metaric iron to stabilize laser heating. Then a set of two plates are confined in a sample hole of rhenium gasket with surrounding pressure medium of sodium chloride to make a direct contact on tilt boundary to compression axis. The shear stress at the contact surface was estimated by major pressure difference between sample center and edge of the sample and was to be around 0.4-0.6 GPa. In-situ X-ray diffraction experiments to evaluate stress evolution in the sample under pressures and temperatures using a LHDAC were performed at KEK-AR-NE1A station, Tsukuba, Japan. After the sample was compressed to the nominal pressure at room temperature, it was heated to the temperature around high-pressure phase boundary. Pressures were determined using the equation of state of sodium chloride (Brown, 1998). The X-ray diffraction pattern at each condition was collected on an imaging plate. High temperatures generate by a Nd:YAG laser driven in multimode were measured based on the emission spectra from the heated area of about 50-70 microns in diameter. We observed high pressure phase of wasleyite and/or ringwoodite in the laser-scanned area up to 23GPa and 1600K. The result of Hall-Williamson analysys (Hall, 1949) from the X-ray diffraction pattern for high pressure phase indicated a significant non-homogeneous strain or shear stress in the high pressure phase than that in single plate experiments, which suggest this method can generate appropriate stress in the sample. The quenched samples were recovered to ambient condition to make thin sections for observation by a scaning electron microscope. High-pressure phase in the heated sample was localized on the contact region between two plates. No significant texual evolution was observed in the outer rim of the same sample. This result is contrasted to the report by Kubo et al. (1998) in which nucleation starts from outer rim of the single crystal sample in a hydrostatic condition. Planner shear bands without phase transition were also observed in the low temperature less than 1000K and 34GPa. Our results indicate that shear stress promotes the transition to high pressure phase and also induces a possible shear instability in the deep slab.

Keywords: phase transition, shear stress deformation, high pressure and high temperature