Density and Fe-Mg partitioning changes in pyrolite to 50 GPa

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Pyrolite has been considered to present the Earth's mantle composition. Therefore, detailed studies of the phase relations and mineral physics properties in pyrolite over a wide pressure and temperature condition are required in order to understand the mineralogy and dynamics of the entire mantle. Many experimental investigations for pyrolite have been performed so far, however, the pressure conditions are limited up to 30 GPa. In this study, we have conducted in situ X-ray diffraction experiments to clarify the phase relations, Fe-Mg partitioning and density changes in pyrolite under the lower mantle conditions by using a combination of a multianvil apparatus and synchrotron radiation.

High pressure and high temperature in situ X-ray diffraction experiments were performed using a Kawai-type apparatus (SPEED-Mk.II) at SPring-8. In order to generate higher pressures equivalent to the lower mantle conditions, sintered-diamond cubes with truncated edge length of 1.5 mm were used as second stage anvils. A glass of pyrolite composition was used as a starting material for the present X-ray diffraction measurements. Pressure was determined from the gold using the equations of state for gold. Starting material and pressure marker were directly put into semi-sintered MgO or graphite capsule. WC plus diamond powder cemented by epoxy resin or $LaCrO_3$ sleeve were used as heater, and temperature was measured by a $W_{97}Re_3$-$W_{75}Re_{25}$ thermocouple. The incident X-ray beam was directed to the sample via incident slits of 0.05 mm in horizontal width and 0.1 mm in vertical width. The diffracted X-ray was collected through receiving slits of 0.3 mm in horizontal width and 2.0 mm in vertical width. A collimator with 0.05 mm in horizontal slit was also used to acquire the diffracted X-ray. Experiments were conducted by the energy dispersive method using a white X-ray source and diffracted X-ray was detected by a Ge solid-state detector with a fixed 2 theta angle of 6.0 degrees. The pressure conditions were 28 to 47 GPa and temperatures were 1873 to 2073 K, and run durations at constant temperature were 2 to 4 hours.

In this study, the presence of $MgSiO_3$-rich perovskite (MgPv), $CaSiO_3$-rich perovskite (CaPv) and ferropericlase (Fp) were confirmed from the X-ray diffraction profile. This mineral assemblage is consistent with previous studies, and the calculated bulk densities of pyrolite are close to those in PREM. We also observed the Fe-Mg partition coefficient between MgPv and Fp, K_D=$(Fe/Mg)_{MgPv}/(Fe/Mg)_{Fp}$, significantly decrease from 0.8 to 0.5 with increasing pressure in this above range.