Mineralogy of the pyrolitic mantle and subducting MORB crust in the deep lower mantle conditions

Kei Hirose[1]; Motohiko Murakami[2]; Naoto Takafuji[3]; Nagayoshi SATA[4]; Yasuo Ohishi[5]

[1] Dept. Earth & Planet. Sci., Tokyo Tech.; [2] Earth and Planetary Sci., Titech; [3] Earth and Planetary Sci., Hokudai Univ ; [4] IFREE, JAMSTEC; [5] JASRI/SPring-8

Recent progress in X-ray diffraction (XRD) measurement in situ at high-pressure and -temperature in a laser-heated diamond-anvil cell (LHDAC) enables us to do a search for new high-pressure phases to the core-mantle boundary condition. $MgSiO_3$-rich perovskite is a major mineral in both pyrolite and MORB compositions in the lower mantle. The discovery of post-perovskite phase in Mg-end-member composition suggests that phase transition of $MgSiO_3$-rich perovskite may occur also in these natural compositions (Murakami, Hirose & others, 2004, Science).

Phase relations of a natural pyrolitic mantle composition (KLB-1) were determined up to 126 GPa and 2450 K (Murakami, Hirose & others, 2005, GRL). Mg-perovskite transforms to a post-perovskite phase at about 113 GPa and 2500 K (400-km above the core-mantle boundary). The depth of phase transition is shallower than the 2600-2700-km depth where the D" seismic discontinuity is observed. This could be due to the uncertainty of P-V-T equation of state of gold used to determine pressure in the experiments. It is also possible that the D" discontinuity is not a phase transition boundary but is caused by the onset of strong preferred orientation of the post-perovskite phase. Results indicate that the lowermost mantle consists of $MgSiO_3$-rich post-perovskite phase, (Mg,Fe)O magnesiowustite, and $CaSiO_3$-rich perovskite. Chemical analyses on recovered samples using transmission electron microscope (TEM) show that the distribution of iron significantly changes at the post-perovskite phase transition. A strong enrichment of iron in magnesiowustite leads to the unique geophysical and geochemical properties of the lowermost mantle.

Phase relations of a natural mid-oceanic ridge basalt (MORB) composition were also determined in the lower mantle conditions up to 134 GPa and 2300 K. The basaltic composition consists of $MgSiO_3$-rich perovskite, rutile-type SiO_2 phase (stishovite), $CaSiO_3$ perovskite, and $CaFe_2O_4$-type Al-phase in the upper part of the lower mantle. Mg-perovskite transforms to a post-perovskite phase at about 110 GPa and 2500 K. SiO_2 phase undergoes phase transition twice in the lower mantle; stishovite transforms to $CaCl_2$-type phase at 64 GPa and 2000 K, and further to _-PbO_2-type phase around 110 GPa. $CaSiO_3$ perovskite also shows phase transition from tetragonal to cubic with increasing temperature. These phase transitions contribute to the seismic heterogeneities observed in a wide depth range in the lower mantle, especially the ferroelastic-type of post-stishovite phase transition in SiO_2. The tetragonal to cubic transition in Ca-perovskite may also be ferroelastic-type. Chemical compositions of coexisting phases were determined by using transmission electron microscope (TEM). The density of bulk MORB composition was calculated using X-ray diffraction data, combining with measured chemical composition and the calculated mineral proportions. Results demonstrate that MORB is denser than the surrounding mantle throughout the lower mantle contrary to the earlier predictions. The subducted basaltic crust may have accumulated at the bottom of the mantle.