

Element partitioning between mantle minerals and melt under deep lower mantle condition

TATENO, Shigehiko^{1*}; SAKATA, Shuhei²; HIRATA, Takafumi²; HIROSE, Kei³

¹Dept. Earth & Planetary Sciences, Tokyo Institute of Technology, ²Dept. Earth & Planetary Sciences, Kyoto University, ³Earth-Life Science Institute, Tokyo Institute of Technology

Melting is a primary mechanism of chemical evolution of our planet. Earth's mantle would have been completely molten due to moon-forming giant impact, leading to a global magma ocean. Resultant fractional crystallization by secular cooling progressively induced the chemical evolution of the Earth. As a consequence, remnant silicate melt left at the present day at the base of the mantle is a possible explanation for the seismically observed ultralow-velocity zones (ULVZs). The knowledge of melting phase relations and element partitioning between mantle minerals and partial melt is crucial to understand the chemical evolution in the early Earth and the nature of ULVZs. However, melting experiments under the middle to deep lower mantle conditions are quite limited.

Here we carried out the melting experiments on KLB-1 peridotite and basalt to deep lower mantle conditions up to 179 GPa by a combination of laser-heated diamond-anvil cell experiments and chemical analyses of recovered samples. Textural characterization and chemical analysis on major and minor elements were made by a field-emission-type electron microprobe (FE-EPMA). Trace element abundances were determined by a laser-ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). Typical crater diameter was 2 or 5 μm by using ArF Excimer laser.

Results shows that the liquids phase was MgSiO_3 -perovskite at least above 34 GPa and further to post-perovskite in KLB-1 peridotite. The Fe-Mg distribution coefficients (K_D) between perovskite/post-perovskite and melt decreased considerably with increasing pressure, leading to strong Fe-enrichment in partial melts. It supports dense partial melts in a deep lower mantle, which migrate downward to the core mantle boundary (CMB). Furthermore, CaSiO_3 -perovskite (CaPv) was found to be a liquids phase under whole lower mantle condition in MORB bulk composition. We then investigated the minor/trace element partitioning between CaPv and melt in basaltic composition. Partition coefficient of alkali elements such as Na and K increases with increasing pressure. In particular, potassium, known as highly incompatible element, become compatible with pressure, whose partition coefficient exceeded the unity at 90 GPa. Although pressure effect on D_{Sm} and D_{Nd} was not found even to 80 GPa, D_{Sm}/D_{Nd} decreases with increasing pressure and will reach to the unity at around 100 GPa. Our results shows that Sm and Nd was equally partitioned to partial melt and residual solids upon fractionation of CaPv from primordial deep magma ocean. This has profound implications for the origin of the super-chondritic $^{142}\text{Nd}/^{144}\text{Nd}$ for all terrestrial rocks.