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Metal-silicate partitioning of U, Th, Nd, Sm at high P-T: Implications for heat and chemical budget in the core

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The excess abundance of siderophile elements in the mantle has been proposed that the core was equilibrated with the mantle at ~3500 K, ~30GPa and fO2~$\triangle$IW-1 at the Earth ' s formation (e.g. Righter, 2011 EPSL). Much more severe condition (>6500 K) is supposed immediate aftermath the moon-forming giant impact based on the study of numerical simulation (e.g. Canup, 2012 Science). The occurrence of high-temperature equilibrium between the core and the mantle evoked that the early core had once incorporated heat-genic radionuclides (U, Th) and rare earth elements (e.g. Nd, Sm), which are know as highly lithophile elements, suggesting profound implications for the thermal history (Nimmo, 2007 Treatise on Geophysics) and early-formed geochemical reservoirs (e.g. sub-chondritic 142Nd/144Nd, Boyet and Carlson, 2005 Science).

However, partitioning of these elements between liquid metal and silicate melt has been investigated only up to 20 GPa and 2500 K using multi-anvil apparatus (Malavergne et al., 2007 GCA). Here, we extended pressure and temperature conditions up to 138 GPa and 5200 K at $\triangle$IW-2~-1 using laser-heated diamond cell (LH-DAC) and field emission-type electron probe microanalyzer (FE-EPMA, JXA-8530F, JEOL) and laser-ablation inductively coupled plasma mass spectrometry (LA-ICP-MS, Kimura and Chang, 2012 JAAS). K (4wt%) and trace elements (U, Th, Nd, Sm, Hf, W, Pb) doped pyrolitic gel, and pure iron were used as starting materials. Iron-free pyrolitic gel was used as a thermal insulator. After high P-T experiments using LH-DAC, recovered samples were analyzed by FE-EPMA and LA-ICP-MS for major and trace elements, respectively. Fe and Mg were used as internal standards for metal and silicate, respectively for LA-ICP-MS. The diameter of ablated area was about 10 um, small enough to measure each (silicate melt/liquid metal) phase.

The results are summarized as follows;

(1) Partition coefficient of U and Th are 10-3-10-2 at 3500-4000 K and $\triangle$IW-1 to -1.5, resulting in 0.02-0.2 ppb (<0.03 TW) U and 0.08-0.8 ppb (<0.04 TW) Th into the core assuming that the abundance of U and Th are 22 and 83 ppb in the Earth ′ s mantle (McDonough and Sun, 1995). Total <0.1 TW (present-day) heat flow in the core has negligible effect on the thermal history of the Earth with <50 K change in the initial temperature at core-mantle boundary (Nimmo, 2007 ToG).

(2) The ratio of partition coefficients, D_{Nd}(metal/silicate)/D_{Sm}(metal/silicate), was always unity despite of large temperature dependence for each D, suggesting that the core could not be a candidate for an early-formed (with sub-chondritic 142Nd/144Nd) hidden reservoir.