Metal-silicate partitioning of copper during the core formation of Mars

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Seismological observations on Mars revealed that the core of Mars contains substantial amounts of light elements (Samuel et al., 2023; Khan et al., 2023). The major candidate of the light elements in the Martian core is sulfur, considering that Martian meteorites are depleted in chalcophile elements (Dreibus and Wänke 1985), while the presence of other light elements (oxygen, carbon, and hydrogen) is also possible (Khan et al., 2022). Copper, a typical chalcophile element, exhibits significant depletion in the Martian mantle compared to CI-chondrite composition (Yoshizaki & McDonough, 2020), which likely reflects the composition of core-forming metal. Metal-silicate partitioning of copper has been investigated at ~1–10 GPa and ~50–80 GPa through high-pressure experiments (e.g., Righter et al., 2010; Mahan et al., 2018). However, the effects of light elements on the metal-silicate partition coefficient of copper (D_{Cu}) are not well understood at the pressure-temperature conditions of the core formation of Mars. While the presence of sulfur in metal increases D_{Cu} at lower pressures than 10 GPa, differences in D_{Cu} between sulfur-bearing and sulfur-free experiments are small at higher pressures than 50 GPa (Wood et al., 2014; Mahan et al., 2018). The effect of hydrogen on D_{Cu} remains unexplored.
Here, we present the results of the metal-silicate partitioning experiments on copper with sulfur, carbon, and/or hydrogen in metal at ~20–30 GPa and ~3000–4000 K using a laser-heated diamond-anvil cell. Chemical compositions of recovered samples showed that sulfur in metal increases D_{Cu} while carbon decreases D_{Cu}, which is consistent with experiments at pressures lower than ~10 GPa (Righter et al., 2010; Wood et al., 2014). Hydrogen concentration in metal was estimated from in-situ X-ray diffraction patterns, and the effect of hydrogen on D_{Cu} was found to be smaller than that of sulfur and carbon. We will discuss the core formation and the possible core composition of Mars based on pressure- temperature-, and composition-dependence of D_{Cu}.

キーワード：火星、コア
Keywords: Mars, core

