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Fate of Carbon During the Formation of Earth's Core

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Carbon is an element of great importance in the Earth, because it is intimately linked to the presence of life at the surface, and, as a light element, it may contribute to the density deficit of the Earth's iron-rich core. Carbon is strongly siderophile at low pressures and temperatures (1), hence it should be stored mainly in the Earth's core. Nevertheless, we still observe the existence of carbon at the surface, stored in crustal rocks, and in the mantle, as shown by the exhumation of diamonds. The presence of carbon in the crust and mantle could be the result of the arrival of carbon during late accretion, after the process of core formation ceased, or because of a change in its metal–silicate partitioning behavior at the conditions of core formation (P >40 GPa – T >3500 K). Previous studies reported metal–silicate partitioning of carbon based on experiments using large volume presses up to 8 GPa and 2200°C (2). Here, we performed laser-heated diamond anvil cell experiments in order to determine carbon partitioning between liquid metal and silicate at the extreme conditions of Earth's core–mantle differentiation. We recovered our samples using the Focused Ion Beam technique and welded a 3 μm thick slice of each sample onto a TEM grid. Major elements were analyzed by electron microprobe, whereas the concentrations of carbon in the silicate were analyzed by nanoSIMS. We thus have obtained metal–silicate partitioning results for carbon at PT conditions relevant to planetary core formation, where C remains siderophile in all experiments, but partition coefficients are up to two orders of magnitude lower than in low PTexperiments. We derive a new parameterization of the pressure–temperature dependence of the metal–silicate partitioning of carbon and apply this in a state-of-the-art model of planet formation and differentiation (3,4) that is based on astrophysical N-body accretion simulations. Results show that BSE carbon concentrations increase strongly starting at a very early stage of Earth's accretion and, depending on the concentration of carbon in accreting bodies, can easily reach or exceed estimated BSE values.

(1) Dasgupta et al., 2013. Geochimica et Cosmochimica Acta 102, 191-212

(2) Li et al., 2016. Nature Geoscience 9, 781–785

(3) Rubie et al., 2015. Icarus 248, 89–108

(4) Rubie et al., 2016. Science 353, 1141–1144