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Experimental investigation of Mercury's core using phase equilibria experiments on Fe-Ni-Si-S-C alloys at high pressures and high temperatures

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The large metallic core of planet Mercury plays a crucial role in the thermal and magnetic evolution of the planet. Primarily composed of iron and nickel, the core is thought to contain a substantial amount of silicon and small amounts of sulfur and carbon, as a result of core-mantle differentiation in a highly reducing environment. Although some studies have explored core analogs in binary and ternary iron-alloy systems, fundamental properties of an Fe-Ni-Si-S-C core, such as the liquidus curve and the partitioning of light elements between liquid and solid phases, are still poorly constrained at pressure and temperature conditions relevant to Mercury's core.

Here, we report results of Mercury's core crystallization. High-pressure and high-temperature experiments were conducted using a multi-anvil press at pressures of 5, 10, and 15 GPa and at temperatures from 1373 to 1873 K. Retrieved samples were analyzed using electron microscopy and Raman spectroscopy. The Fe-Ni-Si-S-C starting materials are powders that contain up to 7 wt.% Ni, up to 8 wt.% Si, up to 4 wt.% S, and up to 4 wt.% C, to explore the effects of these elements on Mercury's core. Our experimental results show that solidus temperatures are strongly influenced by sulfur and carbon contents. We observe diamonds in high-carbon content (~4 wt.%) experiments at 10 GPa, and graphite at 5 GPa. No graphite or diamond was found in the recovered samples with a lower carbon content (≤ 2 wt.%). Our findings suggest that diamonds can only form if the core is C-saturated, with a bulk C content > 4 wt.% in a multi-component system. Carbon-poor solid phases, $(Fe, Ni)_4(Si, C)$ and $(Fe, Ni)_7(Si, C)_3$ are observed in most recovered samples, suggesting that these solids are stable at Mercury's solid inner core conditions. Based on our new findings, we develop a compositional model of Mercury's core, highlighting the effect of carbon in shaping Mercury's interior and surface.