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The incorporation of Mg into core-forming melts during the accretion of terrestrial planets.

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Energetic impacts during terrestrial planet-formation, such as the Moon-forming giant impact, released enormous quantities of energy which caused large-scale (or even global) melting. Under such extreme pressure and temperature conditions, interaction between metallic iron and silicate melts occurred during the multiple magma ocean events before the metallic melts gravitationally separated into the core. It has been widely accepted that light elements, such as O, S, C, H, and Si may have dissolved into core-forming metallic melts during this phase of differentiation, which is consistent with the geophysical/geochemical observations and experimental results. In addition, recent experimental and theoretical studies showed that even the least siderophile major element, Mg, could substantially partition into the core at very high temperatures (e.g. [1],[2]). It has been proposed that subsequent exsolution of MgO as the core cooled may have contributed to thermochemical convection in the core that might explain the occurrence of an ancient terrestrial magnetic field before the inner core is projected to have formed. However, detailed melting phase relations of the Mg-bearing iron alloy have not been investigated by experiments, and large discrepancies exist concerning the influence of temperature and oxygen concentration on Mg solubility among previous studies.

In this work, we performed multi-anvil experiments in the Fe-FeO-MgO system from 2500 to 3300 K at 23 GPa. Starting materials with varied O and Mg concentration were used to represent the early planets with different redox conditions. The chemical compositions of each phase in the quenched samples were measured by EPMA. Our results show that significant amounts of MgO (up to several mol.%) can dissolve into the Fe-FeO melts when the O concentration in the melts is sufficiently high. At certain temperatures, the solubilities of MgO in the iron-rich melt are dominated by the O content. The melting phase relations of Fe-FeO-MgO determined in this study will be used to constrain the energy sources of the early geodynamo and the light element budgets in terrestrial planetary cores.

[1] Badro, J., Siebert, J. & Nimmo, F. (2016), Nature 536, 326-328.

[2] O'Rourke, J. G. & Stevenson, D. J. (2016), Nature 529, 387–389 (2016).