

Hidden light carbon in the Earth's core?: Evidence from high pressure high temperature experiments in the Fe-C system. M. Satish-Kumar¹, H. So¹, T. Yoshino², M. Kato³ and Y. Hiroi³, ¹Shizuoka University, ²Okayama University, ³Chiba University.

Carbon is the fourth most abundant element in the solar system. It has a key role in the melting phase relations of mantle rocks and metallic core, and influences the physical properties such as densities and viscosities of silicate melt and metal alloys. Carbon further acts as an agent of mass transfer in the form of mobile carbonate-rich melts or elemental carbon at the core-mantle boundary, and also has significant impact on partitioning of other key elements between minerals and melts or two immiscible melts in both silicate-carbonate and in metal system. The presence of carbon is also critical for siderophile element partitioning between core and mantle and between inner core and outer core. The high carbon content of CI chondrites (3.2 wt.%) compared to bulk Earth estimates, the presence of graphite/diamond and metal carbides in iron meteorites, the high solubility of carbon into iron melts in the Fe-C system at high-pressure conditions suggests the plausible presence of carbon in the Earth's core. However, the distribution of carbon isotopes in the core is not understood.

We present here our recent experimental data in the Fe-C system and results on the equilibrium carbon isotope fractionation between graphite/diamond and iron carbide melt at 5 GPa and 10 GPa at a temperature range of 1200 to 2100°C.

Our results suggest that iron carbide melt will preferentially gather ¹²C than ¹³C, which is temperature dependent and are consistent with the carbon isotope distribution observed between graphite and cohenite (Fe₃C) in iron meteorites. The temperature dependent fractionation between iron carbide melt and graphite/diamond finds potential application in determining the temperature of formation of meteorites and metallic core of planetary materials [1].

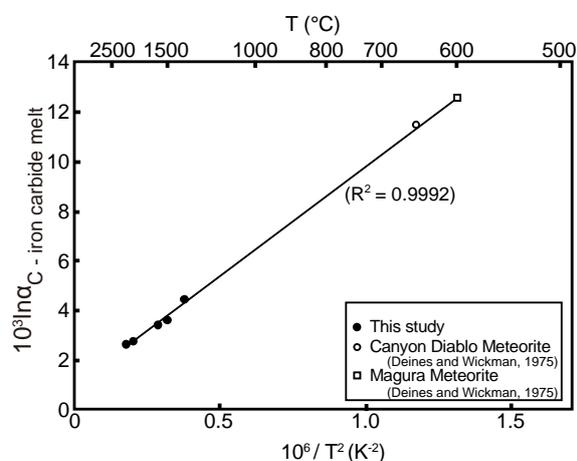


Figure 1. Temperature dependent carbon isotope fractionation in the Fe-C system [1].

Furthermore, we anticipate that the temperature dependent fractionation of carbon isotopes between iron carbide melt and graphite/diamond is an effective mechanism that created a “¹²C enriched core” with large scale differences in the distribution of the carbon isotopes in the metallic core and bulk silicate Earth during the accretion and differentiation of early Earth. An important consequence of ¹²C enriched carbon-bearing Earth's core is that the $\delta^{13}\text{C}$ value of -5.5‰ may not be representative of the bulk silicate Earth. Our findings also have implications on the deep carbon cycle of the Earth, where the light carbon from the core might have transported to the mantle and crust through deep mantle plumes.

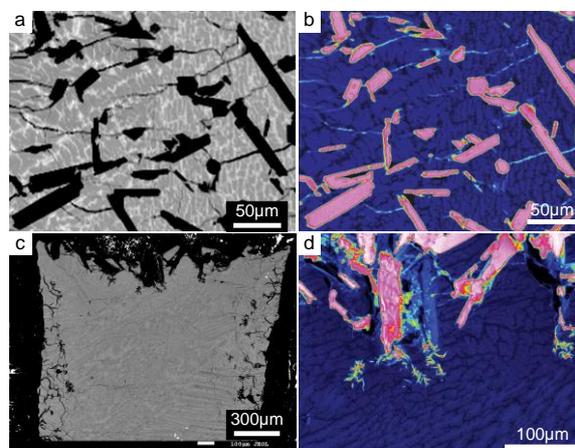


Figure 2. Back scattered electron images and element distribution maps of run products of experiments in the Fe-C system. (a) Back scattered electron image showing Fe₃C (in grey) and euhedral graphite crystals (in black) at 1600 °C and 5 GPa. Note the grain boundaries of Fe₃C have bright thin rinds of metallic iron formed during annealing of iron carbide melt. (b) Carbon elemental distribution map showing the variations in carbon content within the iron carbide phases in the quenched melt. (c) Back scattered electron images showing segregation of iron carbide melt and graphite during the experimental run at 1970 °C and 5 GPa. The iron carbide melt annealed to form Fe₃C and Fe along grain boundaries to form a typical dendritic structure. The iron carbide portion in this run product was mechanically separated for carbon isotope analyses, whereas the graphite-rich portion was treated with HF to dissolve the iron carbide to isolate graphite for carbon isotope analysis. (d) Carbon elemental distribution map showing the uniform carbon content in iron carbide phase.

References:

[1] Satish-Kumar, M., So, H., Yoshino, T., Kato, M. and Hiroi, Y. (2011) *EPSL* (in press).