The solubility of carbon in molten iron at high pressure and temperature

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The earth's outer core is 6-10 wt% less dense than pure iron at the core pressure based on seismic observations and shock-wave experiments. Accordingly, the outer core is believed to contain some light element(s) such as H, O, C, S, and Si. Among the light elements, carbon is the 4th abundant in the solar system, presents substantially in C1 carbonaceous chondrites and it dissolves in molten iron easily at low pressure. As studied by Wood (1993), volatility of carbon is very strongly dependent on pressure. In other words, substantial amount of carbon may have trapped in molten iron at high pressures where metal-core and silicate-mantle segregated. The carbon bearing iron melts may sink in the earth's core, because the eutectic temperature in Fe-C system is much lower than the solidus of silicate-mantle (Hirayama et al., 1993). Thus, high-pressure phase relations in the Fe-C system are very important to understand the core formation process in terrestrial planets.

In order to determine the solubility of carbon in molten iron, we have performed experiments up to 14 GPa and 2000 deg C. Powder and rod of pure iron were taken in a graphite capsule, so that molten iron is always saturated with carbon. Graphite capsule was installed in LaCrO3 furnace with pressure medium of Cr2O3-doped MgO octahedron with edge lengths of 14 mm. Recovered run products were polished and analyzed with EPMA. In order to analyze precise carbon concentration, the sample was analyzed without carbon coating. Experimentally synthesized Fe3C (6.7 wt%C) crystal was used as the standard for iron and carbon. At 5 GPa, melts coexist with graphite and they are crystallized into small dendrites of Fe3C and Fe. The melts coexisting with graphite contain about 6-8wt% C in the temperature range of 1600 to 2000 deg C. At high pressures more than 10 GPa, melts coexist with Fe7C3 (8.4 wt%C) at low temperature (ca. 1600deg C) as reported by Shterenberg et al, (1975), and diamond becomes the coexisting carbon rich phase at higher temperatures. At high-pressure experiments (above 10 GPa), the carbon content of the molten iron is about 5.5-7wt%. Our new data suggests that the outer core may contain much larger amount of carbon than the previous estimate (Wood, 1993).