

Melting relations and stability of Fe₃C up to 230 GPa: Implication for the carbon in the Earth's inner core

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The carbon cycle in the interior of the Earth (Deep Carbon Cycle) is one of the outstanding topics in the Earth science. The Earth's core is considered a carbon reservoir as a part of Deep Carbon Cycle. The Earth's core is regarded as an Fe-Ni alloy but the density of the core is lower than the pure Fe density at pressures and temperatures corresponding to the core conditions. Therefore, the Earth's core is supposed to contain light elements and carbon is one candidate of the light elements to explain the density deficit of the Earth's core. Until present day, many studies on physical and chemical properties of Fe-carbides have been carried out at high pressure. Especially, the recent studies about melting of Fe₃C were reported by Nakajima et al. (2009) and Lord et al. (2009). Nakajima et al. (2009) reported melting temperatures of Fe₃C up to around 30 GPa based on the textual observation, the chemical analysis, and in situ X-ray diffraction experiments using a Kawai-type multi anvil apparatus. Lord et al. (2009) reported melting temperatures of Fe₃C up to 70 GPa was determined by the temperature plateau during heating against increasing laser power using a laser-heated diamond anvil cell. However, there are obvious discrepancies between the melting curves of Fe₃C reported by Nakajima et al. (2009) and Lord et al. (2009). In this study, the melting temperatures of Fe₃C were determined based on in situ X-ray diffraction experiments. This study aims to reveal the uncertainty of the melting temperature of Fe₃C and discuss the behaviours of carbon in the Earth's core.

We have performed experiments using a laser-heated diamond anvil cell combined in situ X-ray diffraction experiment at BL10XU beamline, SPring-8 synchrotron facility. The melting of the sample was determined by a disappearance of the X-ray diffraction peaks as described in previous works. We determined the melting relations of Fe₃C up to 200 GPa by in situ X-ray diffraction experiments. We also confirmed that Fe₃C is stable as a subsolidus phase at least up to 237 GPa and 4100 K. Incongruent melting (Fe₃C => Fe₇C₃ + liquid) temperatures agree with Nakajima et al. (2009) below 30 GPa and Lord et al. (2009) from 50 to 70 GPa. The solidus temperature extrapolated to the ICB pressure, 330 GPa, is 5500 K. Our results suggest that Fe₃C is a potential candidate of the carbon reservoir in the Earth's inner core. However, if the core has a carbon-rich composition and the inner core crystalized by cooling of the outer core from above 5500 K, the inner core is indicated to be composed of Fe₇C₃.

Keywords: Deep carbon cycle, Earth's inner core, Fe-Carbide, In situ X-ray diffraction experiment, Diamond anvil cell