

博士論文

**Melting relations of Fe–Fe₃C system
and physical properties of Fe₃C
under high pressure and temperature conditions:
Implications for carbon in the Earth's core**
(高温高圧下における Fe–Fe₃C の融解関係及び
Fe₃C の物性測定：地球核中への応用)

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The density and sound velocities of the Earth's interior have been known based on the seismological observations, as well-known as Preliminary Reference Earth Model (PREM). Although the Earth's core is regarded as an Fe(-Ni) alloy, its density is lower than that of Fe, and sound velocities of the core could not be explained by those of pure Fe at the core conditions. Therefore, the Earth's core is supposed to contain light elements to explain the density deficit and differences of sound velocities between Fe and the Earth's core.

Carbon is one of the most important candidates for light elements in the Earth's core. Especially, Fe₃C, which is one of the Fe-carbide, is focused in this study. In order to understand the carbon effect to physical properties of Fe and discuss the carbon in the core, three experiments were carried out about melting relations and a stable phase in Fe-C system (Chapter 2), compression behavior (Chapter 3), and sound velocity measurements of Fe₃C (Chapter 4).

First study is about the determination of phase diagrams of Fe₃C and the Fe-Fe₃C binary system by *in-situ* X-ray diffraction experiments at BL10XU beamline at SPring-8 facility and chemical analysis of recovered samples by EPMA. The incongruent melting temperature of Fe₃C to liquid and Fe₇C₃ was determined up to 200 GPa, and Fe₃C was observed as a stable subsolidus phase up to 340 GPa. This result strongly supports that Fe₃C is a potential constituent of the core, contrary to some previous studies. In addition, the Fe-Fe₃C eutectic composition was suggested to move to Fe-rich side with increasing pressure. Therefore, the stable *P-T* conditions of Fe-carbides, such as Fe₃C and Fe₇C₃, could be expanded to Fe-rich compositions.

Second is focused on the compression behavior of Fe₃C under the high pressure and high temperature conditions based on *in-situ* X-ray diffraction experiments at BL10XU beamline of SPring-8 facility. Pressure and volume relations of Fe₃C were obtained from 70 GPa up to 180 GPa, and ~2300 K. The equation of state (EOS) of Fe₃C at high temperature conditions was obtained using P - V - T relationship. The density of Fe₃C at 329 GPa and 5000~6000 K calculated from the EOS was compatible with PREM profiles.

Last study is about sound velocity measurements of Fe₃C by the inelastic X-ray scattering (IXS) method at BL35XU and BL43LXU beamline of SPring-8 facility. Sound velocity (V_P) of Fe₃C was determined up to 84 GPa and ~2300 K. Present results indicated that the temperature effects for the sound velocity of Fe₃C was weaker than that of Fe. V_P and V_S of Fe₃C were estimated to be 12% and 48% faster than those of PREM at 329 GPa and 5000 K respectively. It should be considered the premelting effect and/or the partial melting to explain the sound velocities of PREM by those of Fe₃C.