博士論文

Melting relations of Fe–Fe_3C system and physical properties of Fe_3C under high pressure and temperature conditions: Implications for carbon in the Earth's core

(高温高圧下における Fe–Fe_3C の融解関係及び

Fe_3C の物性測定：地球核中への応用)

Suguru Takahashi

髙橋　豪

平成 26 年

Contents

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, Fe_3C, 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 Fe_3C (Chapter 4).

First study is about the determination of phase diagrams of Fe_3C and the Fe–Fe_3C 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 Fe_3C to liquid and Fe_7C_3 was determined up to 200 GPa, and Fe_3C was observed as a stable subsolidus phase up to 340 GPa. This result strongly supports that Fe_3C is a potential constituent of the core, contrary to some previous studies. In addition, the Fe–Fe_3C eutectic composition was suggested to move to Fe-rich side with increasing pressure. Therefore, the stable P–T conditions of Fe-carbides, such as Fe_3C and Fe_7C_3, could be expanded to Fe-rich compositions.

Second is focused on the compression behavior of Fe_3C 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 Fe_3C were obtained from 70 GPa up to 180 GPa, and ~2300 K. The equation of state (EOS) of Fe_3C at high temperature conditions was obtained using P–V–T relationship. The density of Fe_3C at 329 GPa and 5000~6000 K calculated from the EOS was compatible with PREM profiles.

Last study is about sound velocity measurements of Fe_3C by the inelastic X-ray scattering (IXS) method at BL35XU and BL43LXU beamline of SPring-8 facility. Sound velocity (V_P) of Fe_3C was determined up to 84 GPa and ~2300 K. Present results indicated that the temperature effects for the sound velocity of Fe_3C was weaker than that of Fe. V_P and V_S of Fe_3C 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 Fe_3C.