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Equation of state of Fe_3C under high pressure and temperature with implications for carbon in the Earth's core.

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The densities 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. In this study, we focused on the compression behavior of Fe_3C, which is one of the Fe-carbide. We aimed to discuss the possibility of Fe_3C as the constituent of the Earth's inner core.

We performed in-situ X-ray diffraction experiments using the diamond anvil cell at BL10XU beamline of SPring-8 facility to obtain pressure and volume relations of Fe_3C. We obtained P-V profiles of Fe_3C at 70˜180 GPa, and ˜2300 K. The equation of state (EOS) of Fe_3C at high temperature conditions was determined using P-V-T relationships. Compressional data were fitted by the 3rd-order Birch-Murnaghan EOS at 300 K and the Mie-Gruneisen-Debye EOS at high temperature conditions. The parameters of V_0 = 152.13(8), K_0 = 265.1(6), K'_0 = 3.66(1), θ_0 = 246(84), γ_0 = 1.06(7) and q = 1.5(2) were obtained. The density of Fe_3C at inner core condition (assuming 329 GPa and 5000 K) calculated from the EOS was compatible with PREM profiles. Our results indicate that Fe_3C could be dominant in the Earth's inner core.
Keywords: Earth's core, Fe_3C, Equation of state, PREM, Density