Interstitial Carbon in Solid Fe at High Pressures: Implication to Carbon Content in the Earth's Inner Core

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Carbon has been regarded as one of the light elements to account for the density deficit of the Earth's core based on emerging evidence from cosmological, seismic, geochemical, and mineral physics data. Fe with interstitial carbon can be the candidate solidified products of the Earth's inner core if the bulk carbon content during the core formation stage was less the eutectic carbon content in the Fe-C system. However, the solubility of interstitial carbon in solid Fe as well as the effects of interstitial carbon on the physical properties of Fe, which are essential to understanding the maximum carbon content in the core, have never been studied under high pressure. Here, we synthesized homogeneous Fe-C samples with 0.31 (Fe-0.31), 1.37 wt% (Fe-1.37C) interstitial carbon, that were loaded together with pure Fe into a Diamond Anvil Cell and measured by synchrotron X-ray diffraction to systematically investigate the effect of interstitial carbon on the volume, density, and length of axis for both bcc and hcp-Fe at high pressure up to 45 GP at 300 K. It shows that substitution of interstitial carbon would contract the lattice in bcc-Fe but would expand the lattice in hcp-Fe, resulting hcp-Fe is less dense than that of bcc phase with same carbon content if presented in the core. Axial incompressibility for *a* axis is greater than *c* axis for pure Fe, while *c* axis becomes less compressible than *a* axis for Fe-1.37C, implying a reversal in axial anisotropy with increasing carbon content. We further performed thermoelastic modelling along an adiabatic geotherm for pure Fe, Fe-0.31, and Fe1.37C to interpolate the carbon content that can account for the density deficit. The results show that Fe with 1.1wt% C would best reconcile the seismic observations.