B2 phase in the inner core: constraints from high pressure experiments

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The Earth inner core is considered to be composed of hcp-iron alloy with small amounts of light elements, and intensive efforts have been made to clarify the physical properties of hcp-iron. On the other hand, there are many seismological observations on existence of heterogeneities, layering, and anisotropy in the inner core, which cannot be accounted for only by hcp-iron.

It has been suggested that B2 or bcc phase can exit in the inner core mainly by theoretical calculations (e.g., Belonoshko et al., 2003). Therefore, it has been a debated matter on the existence of a stable B2 structure of iron alloys in the inner core. There is experimental reports suggesting existence of B2 phase in Fe-Si alloy (Fischer et al., 2013). Coexistence of hcp+B2 is observed by Fishcer et al. (2013) in the Fe-Si system with silicon greater than 6 wt. %.

Nickel is an important metallic component in meteorites, and it can modify the phase relations of iron alloy systems significantly. In order to clarify the stability of B2 phase in the inner core, we studied the phase relations of the Fe-Ni-Si system at high pressure and temperature relevant in the core. The in-situ X-ray observations of the Fe-Ni-Si alloys at high pressure and temperature were conducted at BL10XU of SPring-8 by using the double sided laser heating diamond anvil cell. We observed a wide stability field of coexistence of B2 phase and hcp at high pressure and temperature above 100 GPa and 2500 K in the composition of Fe7wt%Ni5wt%Si alloy.

The nickel and silicon contents in the inner core were estimated to be 0~8 wt% and 3-6 wt% respectively in order to account for the PREM inner core based on the equation of state of hcpFe-Ni-Si alloy (Asanuma et al., 2013) and the sound velocity of hcpFe-Si alloy (Sakairi et al., 2018). Combined with the phase relations together with the sound velocity measurements, we can suggest that the inner core is mainly composed of hcp-iron with a small amount of B2 phase. Coexistence of B2 phase with hcp-Fe alloy in the inner core can explain the heterogeneity and fine structure of the inner core reported in seismology.

Reference: Belonoshki et al. (2003) Nature, 466, 744-747. Fischer et al. (2015) Am Min, 100, 2718-2724. Asanuma et al. (2011) EPSL, 310, 113-118. Sakairi et al. (2018), Am Min., 102, 85-90.

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