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高圧化における固体鉄への珪素の固溶量
Solubility of silicon in hcp-iron at high pressure and high temperature

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The Earth's outer core is believed to be composed of liquid iron alloy with one or more light elements (e.g., Birch 1952; Poirier 1994). Although a number of elements lighter than iron, including hydrogen, carbon, oxygen, silicon, and sulfur, have been considered by various researchers as potential light elements in the Earth's core, silicon is one of the most attractive candidates for the light element in the core (e.g., Takafuji et al. 2005; Sakai et al. 2006; Ozawa et al. 2008, 2009, Wood et al., 2008). The Earth's inner core is considered to consist mainly of a solid iron-nickel alloy. However, multiple experimental studies revealed that the inner core is also less dense than pure iron, indicating the presence of light components in the inner core (e.g., Jephcoat and Olson 1987; Mao et al. 1998; Lin et al. 2005; Badro et al. 2007). If silicon is indeed a major light element in the liquid outer core, the maximum amount of silicon that can be incorporated in the solid inner core during inner-core solidification is limited by the solubility of silicon in solid iron at the pressure of the inner core boundary. Therefore the phase relations of iron-silicon alloys, especially the solubility of silicon in solid iron at high pressure and temperature, are the key to understanding the composition, structure, and crystallization of the inner core. The phase relations of iron-silicon alloys at high pressure have been extensively studied using a multi-anvil apparatus (Zhang and Guyot 1999; Dobson et al. 2002; Kuwayama and Hirose 2004) and a diamond-anvil cell with in-situ x-ray diffraction measurements (Lin et al. 2002; Lin et al. 2003; Dubrovinsky et al. 2003; Hirao et al. 2004; Asanuma et al. 2008, Lin et al 2009, Kuwayama et al. 2009). Below 200 GPa, the solubility of silicon in solid hcp-iron has been well studied. Solid hcp-iron can contain at least ˜10 wt% Si at low temperature, but it decomposed to iron-rich hcp phase and silicon-rich bcc phase at high temperature. The positive slope of the dissociation boundary between hcp to hcp + bcc implies that the solubility of silicon into hcp iron increase with increasing pressure. However, the maximum pressure where the studies on the solubility of silicon in hcp iron have been performed so far is ˜200 GPa, quite lower than the Earth's inner-core outer-core boundary conditions. In this study, we performed in-situ x-ray diffraction study on Fe-9.9 wt.% Si using a laser-heated diamond anvil cell up to ˜300 GPa. We observed dissociation into a mixture of hcp and bcc phases at about 230 GPa on heating, consistent with the linear extrapolation of the phase boundary previously reported in Kuwayama et al (2009) and Lin et. al. (2009). In contrast, we did not observe the dissociation at higher pressure, indicating that the more than 9.9 wt% Si can be dissolved in hcp iron at the ICB condition. This implies that the inner core should contain some amount of silicon if the outer core actually conations a substantial amount of silicon.

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