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135 GPa までの Fe-Ni-Si および Fe-Ni 合金の融解関係
Melting relations of Fe-Ni-Si and Fe-Ni alloys up to 135 GPa

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The density deficit of the Earth's core was proposed based on the comparison between seismic study and high-pressure experiments. Therefore, the Earth's core consists of not only Fe-Ni alloys but also light elements, such as H, C, O, Si, and S (e.g., Birch, 1952). Therefore, densities and phase relationships in the Fe-light element(s) have been studied well. Silicon, in particular, is one of the most abundant elements in the Earth (e.g., Ringwood, 1959; Birch, 1964). In addition, the solubility of silicon into liquid iron increases with increasing pressure and temperature, and hence there is a possibility that the silicon can solve into outer core by reaction with the lower most silicate mantle (Takafuji et al., 2005; Sakai et al., 2006). Lin et al. (2003) reported that the outer core contains about 8-10 wt% Si and the inner core contains about 4 wt% Si. However, there are some discrepancies in the melting relationships of Fe.

Therefore, the thermal structure of the Earth's core has not been known well yet. For better understandings of the thermal structure of the core, a key point is that the core is composed of the solid inner core and the liquid outer core, suggesting that the temperature at the ICB is the melting temperature of the core material. We focused on the melting relationships of the core materials to constrain the thermal structure of the core. In this study, melting temperature of the Fe-Ni alloy and the Fe-Ni-Si alloy were measured under high pressure conditions to estimate the thermal structure of the Earth's core.

Starting material are Fe-4.8 wt%Ni-4.0 wt% Si alloys and Fe-5.2 wt% Ni alloys. Pressure medium is powdered Al_2O_3. A high pressure device is a symmetric diamond anvil cell. A foil of the starting material was sandwiched by Al_2O_3 powder. The sample was compressed to a desire pressure first. Then, the sample was heated by a double-sided laser technique by employing Nd:YAG laser or fiber laser. Temperature was measured using the radiation from the sample. Pressure measurement was conducted by using Raman T_{2g} mode at the culet of diamond anvil (Akahama and Kawamura, 2004).

Determination of the melting temperature is based on the change in the temperature generation efficiency (e.g., Asanuma et al., 2010; Lorad et al., 2010), the observation of the dendritic quench texture of the recovered sample at 135 GPa using FE-SEM/STEM, and monitoring the in-situ radiation from the sample. The melting experiments of Fe-4.8 wt%Ni-4.0 wt% Si were performed in the P-T ranges of 20-135 GPa and 1000-4000 K. The melting experiments of Fe-5.2wt% Ni were performed in the P-T ranges of 20-135 GPa and 1000-5000 K.

The melting temperature of Fe-Ni-Si alloy was 3720 K at 135 GPa (CMB pressure), and that of Fe-Ni alloy was 4330 K. The effect of silicon on the melting temperature of Fe-Ni alloy is large and decreases 600 K at the CMB condition. The effect of silicon on the melting temperature of Fe-Ni alloy is large and decreases by 600 K at the CMB condition. Based on the melting curve of Fe-4.8 wt%Ni-4.0 wt% Si, we estimated the temperature at the ICB and CMB to be 4980 K and 3820 K assuming that the composition of the inner core is Fe-4.8 wt%Ni-4.0 wt% Si.

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