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Determination of melting relation of Fe_3C by in-situ X-ray diffraction experiments

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The carbon cycle in the Earth's interior (Deep Carbon Cycle) is one of the outstanding topics in Earth science. Carbon may be contained in the Earth's core. The Earth's core is regarded as an Fe-Ni alloy but the density of the core is lower than that of pure Fe at pressures and temperatures corresponding to the core conditions. Therefore, the Earth's core is supposed to contain light elements and carbon is one of the candidate of the light elements to explain the density deficit of the Earth's core. Until now, many studies on physical and chemical properties of Fe-carbides have been carried out at high pressure. Especially, the recent studies on melting of Fe_3C were reported by Nakajima et al. (2009) and Lord et al. (2009). Nakajima et al. (2009) reported the melting temperature of Fe_3C up to around 30 GPa based on textual observations, the chemical analysis of the quenched run products, and in situ X-ray diffraction experiments using a Kawai-type multi anvil apparatus. Lord et al. (2009) reported melting temperatures of Fe_3C up to 70 GPa, which was determined by the temperature plateau during increasing laser power using a laser-heated diamond anvil cell. However, there are obvious discrepancies between the melting curves of Fe_3C reported by Nakajima et al. (2009) and Lord et al. (2009). In this study, the melting temperatures of Fe_3C were determined based on in situ X-ray diffraction experiments. This study aims to reveal the uncertainty of the melting temperature of Fe_3C and discuss the behaviours of carbon in the Earth's core.

We have performed experiments using a diamond anvil cell combined in situ X-ray diffraction experiment at BL10XU beamline, SPring-8 synchrotron facility. An NaCl powder and a rhenium foil were used for the insulator and gasket, respectively. Melting of the sample was determined by disappearance of the X-ray diffraction peaks as described in previous works (e.g. Campbell et al., 2007; Morard et al., 2008; Kamada et al., 2010).

We determined the melting relation of Fe_3C up to 70 GPa by in situ X-ray diffraction experiments. The melting temperature (both solidus and liquidus) of Fe_3C is close to Nakajima et al. (2009) up to 30 GPa but becomes close to that reported by Lord et al. (2009) at higher pressure conditions. The present experiments revealed that Fe_3C was stable as a subsolidus phase at least up to 70 GPa. This indicates that Fe_3C is a potential candidate of the Earth's inner core.

Keywords: Deep carbon cycle, Earth's core, Fe-Carbide, in situ X-ray diffraction experiment