Melting in the Fe-FeO system to 214 GPa

*Kenta Oka[1], Yuto Kidokoro, Kei Hirose[1], Yoichi Nakajima[2], Guillaume Morard[3], Guillaume Fiquet [3], Nicolas Coudurier[3]

1. Department of Earth and Planetary Science, The University of Tokyo, 2. Priority Organization for Innobation and Excellence, 3. Sorbonne Université

Oxygen is one of the likely candidates as the light elements in the Earth's core. If oxygen is the primary one, the oxygen content in the outer core should be less than that of the eutectic liquid composition in the Fe-FeO system, which is required to explain the dense solid inner core compared to the liquid outer core. The eutectic liquid composition in the Fe-FeO system has been estimated under high pressures, on the basis of thermodynamic calculations and high-pressure experiments. However, large inconsistency is found among these previous studies, especially below 100 GPa.

In this study, we have conducted high-temperature and high-pressure experiments up to 214 GPa and 3650 K. Liquidus phase relations were determined from textural and chemical characterizations of recovered samples using FIB/FE-EDS/FE-EPMA. Liquid-liquid immiscibility reported below 21 GPa in previous multi-anvil studies (Tsuno et al., 2007) was not observed above 42 GPa in the present DAC experiments. Our results demonstrate that the eutectic liquid composition in the Fe-FeO binary system changed largely from Fe+1.3wt.%O at 15 GPa (Tsuno et al., 2007) to >8 wt.% O at 42 GPa. It then further increased gradually to ~13 wt.% O with increasing pressure to 214 GPa.

These results are in reasonably good agreement with the previous DAC experiments by Seagle et al. (2008) based on XRD measurements and the earlier thermodynamic model by Komabayashi (2014) that considered non-ideal mixing between liquid Fe and FeO. Our data also showed contamination by variable amounts of carbon in liquid, which may explain the difference from the results by Morard et al. (2017) below 80 GPa. The large change in the liquidus phase relations in the Fe-FeO system observed between 15 and 42 GPa is likely related to the disappearance of liquid-liquid immiscibility.

The outer core may include 5.5 wt.% O if oxygen is a sole light element (Badro et al., 2014). When extrapolating our data to 330 GPa, the eutectic liquid in the Fe-FeO binary system includes about 15 wt.% O, which is much higher than the 5.5 wt.% O and therefore allows the outer core liquid containing oxygen as one of important light elements to crystallize solid Fe at the ICB. These results support the presence of oxygen in the core.

Keywords: outer core, light elements, melting experiment, Fe-FeO System

