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Density measurements of liquid Fe-Si at high pressure using sink-float method

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Introduction

Density of liquid Fe alloys is a fundamental physical property to understand properties and the composition of the Earth's core. Compositional dependence of the density of liquid Fe-alloy at high pressure is essential to estimate the composition of the outer core. Silicon is one of the most plausible candidates of the light elements in the core due to its high cosmic abundance and depletion in the mantle compared to the chondritic abundance. In this study, we performed the density measurement of Fe-Si liquid at 4 GPa and 1650 °C using in situ sink/float method and investigated the effect of Si content on the density of Fe-Si liquid.

Experimental

High-pressure experiments were performed using a KAWAI-type apparatus driven by the cubic presses, MAX-III at the BL14C2 beamline at the Photon Factory. Tungsten carbide anvil cubes with a 12 mm truncated edge length were used as the second stage anvils. Boron nitride was used as a sample container and graphite was used as a heating substance. Temperature was monitored using a $W_{97}Re_3$-$W_{75}Re_{25}$ thermocouple. Pressure was calculated from the volume of the unit cell based on the equation of state of BN. Starting material was Fe-Si powder.

Density was measured with the sink/float method. The sink/float method was used to constrain the density of the sample. It is the method by bracketing the density of the liquid sample based on the movement of the density marker, which is observed by X-ray imaging in situ. Density marker was composed of Pt disk core and alumina tube mantle. Details of the fabrication and use of the composite spheres were given in ref. [1]. This is the first experiment in the world in which, the in situ X-ray imaging was applied for observation of the density marker for the sink-float experiment.

Results and Discussion

Fig.2 shows the increase of Si to liquid Fe decreases its density. The molar volume calculated from the measured density gradually decreases with increasing the Si content. It is noted that the estimated molar volume is different from the ideal mixing between Fe and Si. This behaviour is similar to the Fe-S liquid [1]. The results of this study indicate that amount of Si in the Earth's core could be larger than the previously estimated value.

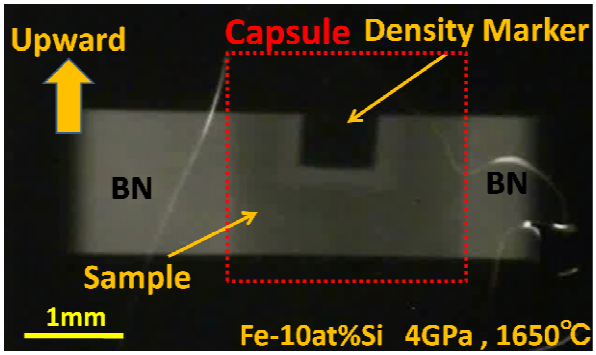

Fig.1 An X-ray absorption image at 4 GPa and 1650ºC.

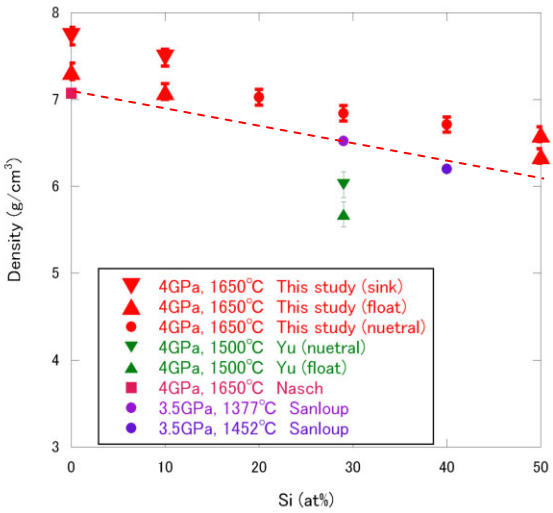

Fig.2 Silicon content versus density of Fe-Si liquids. *Red upward and downward-pointing triangles and circles* represent densities of the sinking, floating and neutral of the density markers, respectively. The density is restricted between these triangles. The dotted bold line in this area shows that the density of Fe–Si liquids decreases with increasing the silicon contents. *Green upward and downward-pointing triangles* and *Blue circles* are previous experiments of density measurement of liquid Fe-Si, respectively. [2, 3]

References

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