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Density measurements of liquid Fe-S at high pressure using in-situ synchrotron sink/float method

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Introduction

Density of liquid Fe-S is a fundamental physical property in order to estimate the sulfur content in the Earth's outer core based on the density deficit in the core. Previous works (e.g. [1]) estimated the light element content in the core assuming ideal-mixing behavior between iron and light element, i.e., neglecting their excess volumes. The excess molar volume (V_{ex}), which is defined as the difference volume subtracting ideal volume from actual volume, of liquid Fe-S at 4 GPa was reported to be large and to have a negative value [2], suggesting that the Earth's outer core may contain more sulfur than the previous estimates. However, pressure effect on the V_{ex} of liquid Fe-S has never been reported. In order to investigate the pressure effect on V_{ex}, we measured the density of liquid Fe-S at 0.5 GPa and 1650 °C using in-situ synchrotron X-ray sink/float method.

Experimental

Pressure was generated by the KAWAI-type multi anvil press (MAX-III) installed at beamline AR-NE7. Starting materials were mixtures of Fe and FeS powders. We used composite density markers, which is composed of a Pt core and Al_2O_3 tube and rids [2]. The composite marker can be made with different densities by selecting different volumetric ratios between the Al_2O_3 mantle and the Pt core. We monitored the movement of the composite marker using X-ray radiography system [3] in situ. Pressure was evaluated by the unit cell volume of h-BN capsule [4]. Therefore, in-situ synchrotron X-ray sink/float method can provide more accurate density than ex-situ sink/float method.

Results and Discussion

Figure 1 shows a typical successive X-ray radiographic image of sinking density marker. When the sample started melting, the marker was sinking down into the bottom of the capsule, indicating the sample density is lower than that of the marker. Figure 2 shows the density of liquid Fe-S as a function of sulfur content. Downward and upward triangles denote the density of the sinking and floating markers. The sample density is in the range between upward and downward triangles. The dashed curves represent the fitted curve assuming regular solution. Considering pressure effect, this trend is consistent with that at 4 GPa [2] and 0.1 MPa [5]. Figure 3 shows the V_{ex} as a function of Sulfur content. The negative V_{ex} of liquid Fe-S decreases with increasing pressure. This result may suggest the excess molar volume of liquid Fe-S at the pressure of the Earth's outer core might be small and negligible.

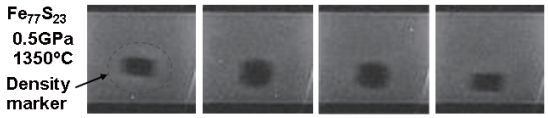

Fig. 1 Typical successive X-ray radiographic image of sinking density marker.

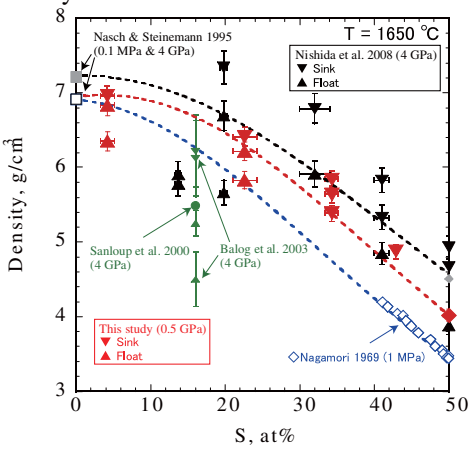

Fig. 2 Density of liquid Fe-S as a function of sulfur content.

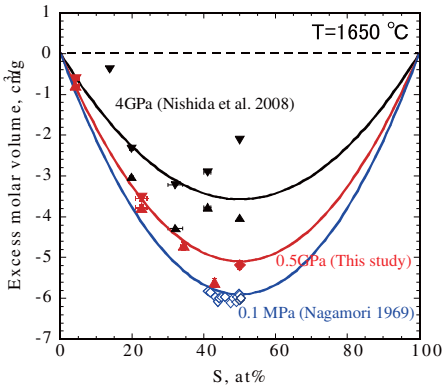

Fig. 3 The excess molar volume of liquid Fe-S as a function of Sulfur content.

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