

EXPERIMENTAL COMPARISON OF DENSITIES BETWEEN LIQUID AND SOLID PHASES IN THE FE-FES SYSTEM AT HIGH PRESSURE: IMPLICATIONS FOR THE EVOLUTION OF PLANETARY CORES. Y. Shibazaki¹ and Y. Fei¹, ¹Geophysical Laboratory, Carnegie Institution of Washington, 5251 Broad Branch Road, NW, Washington, DC 20015, USA. (yshibazaki@ciw.edu)

Introduction: Planetary core is considered to consist of iron and light elements. Sulfur is one of the most plausible light elements in the core. At the early stage of the differentiated planetary bodies, a metallic component separated from a silicate component and formed the metallic core at the center of bodies. The early cores must be molten due to the several kinds of heat sources (e.g. impact, release of potential energy, and radioactive decay of short-lived isotopes such as ²⁶Al and ⁶⁰Fe). Cooling the early molten cores would lead to partial solidification of the core. For the sulfur-bearing iron core, the partially solidified core would consist of Fe-S liquid coexisting with either solid Fe or FeS depending on the S concentration. The stratification of the core is largely controlled by the density contrast between the solid and liquid phases.

Based on the previous high-pressure and high-temperature density data of Fe-S liquid, solid Fe, and solid FeS [1-5], the Fe-S liquid at the Fe-rich side is predictably less dense than the coexisting solid Fe along the liquidus temperatures, whereas the Fe-S liquid at the FeS-rich side is denser than the coexisting solid FeS except only much near FeS. However, the previous densities of each phase have been measured individually by the different methods and those have large uncertainties, particularly for the liquid phase. In order to directly compare the densities between the liquid and solid phases in the Fe-FeS system, we have performed sink/float experiments and precisely determined the relative density relationship at high pressure and temperature.

Experimental procedure: High-pressure and high-temperature melting experiments in the Fe-FeS system were carried out using the multi-anvil apparatus at the Geophysical Laboratory. Experimental conditions were 4 GPa and 1273 – 1423 K. An Fe or FeS pellet was placed at the center surrounded by an Fe-FeS powder mixture (20 wt% S or 30 wt% S, respectively) in a MgO capsule. From the sink-float behavior of the centered pellet at high temperature, we determine whether the solid phase (Fe or FeS) is denser or less dense than the coexisting liquid phase.

Experimental results: The experiment at 4 GPa and 1423 K, using the Fe pellet and Fe-20 wt% S mixture (Fe-rich side) as the starting materials, showed that the solid Fe sank in the liquid with a composition of Fe-23.0 wt% S (Figure 1). On the other hand, the solid FeS floated in the liquid with Fe-26.0 wt% S using the

FeS pellet and Fe-30 wt% S mixture (FeS-rich side) as the starting materials at 4 GPa and 1273 K (Figure 2).

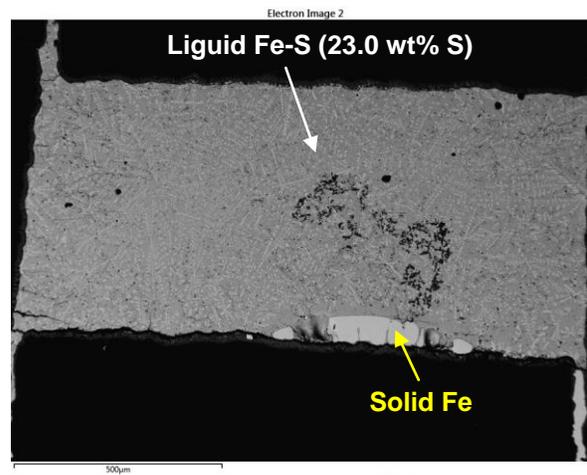


Fig. 1. Backscattered electron image of sample quenched from 4 GPa and 1423 K. Starting composition is solid Fe pellet and Fe-20 wt% S powder mixture.

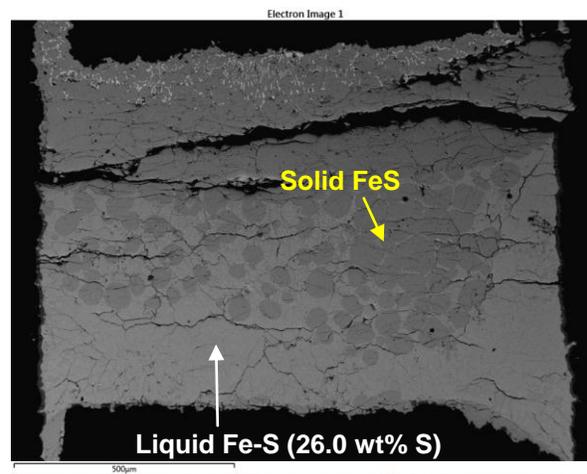


Fig. 2. Backscattered electron image of sample quenched from 4 GPa and 1273 K. Starting composition is solid FeS pellet and Fe-30 wt% S powder mixture.

Discussions: In order to understand the crystallization sequence and structure of a sulfur-rich core, we calculated an adiabatic gradient in the core with the compositions of Fe-26 wt% S, 30 wt% S, and 36.5 wt% S (FeS-rich side in the Fe-FeS system) by the following formulas:

$$dT/dP = \alpha(P)T/\rho(P)C_p \quad (1)$$

$$\alpha_0 K_0 = \alpha(P)K(P) \quad (2)$$

where T , P , α , ρ , C_p , and K denote temperature, pressure, thermal expansion, density, heat capacity, and bulk modulus, respectively. Comparing the adiabatic gradient in the core with the pressure dependence of liquidus of each composition at pressure between 4 and 10 GPa, the adiabats were shallower than the liquidus slopes of S-rich compositions. Then, the crystallization of the core is likely to proceed from its center, like Earth (bottom-up crystallization).

These results imply that crystallized FeS at the center is less dense than residual liquid phase and floats in the core. Therefore, the floating solid FeS forms the shell at the outermost core and then the S-rich core would consist of an “outer solid” core and an “inner liquid” core, in contrast to the Earth’s core.

References: [1] Nishida et al. (2008), *Phys. Chem. Minerals*, 35, 417-423. [2] Nishida et al. (2011), *Ame. Mineralogist*, 96, 864-868. [3] Balog et al. (2003), *JGR*, 108, 2124. [4] Sakamaki et al. (2009), *PEPI*, 174, 192-201. [5] Urakawa et al. (2004), *PEPI*, 143-144, 469-479.