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Experimental approach to the core-mantle boundary region of Mercury

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MESSENGER mission revealed precise moment of inertia parameters of Mercury and its surface chemistry [1, 2]. These data allow to model the internal structure of Mercury, which has a large liquid core with ∼2000 km radius and a solid outer shell with ∼400 km thickness [3, 4]. As density of solid outer portion is apparently higher than that of the expected mantle silicate, the solid outer layer must include dense materials. Recent models [3, 4] showed that the Mercury's core contains sulfur and silicon as light elements due to high S fugacity and low oxygen fugacity of its interior. Those models presented a solid FeS layer at bottom of solid outer shell of Mercury as a dense layer, which separated from liquid outer core as a FeS-rich liquid due to liquid immiscibility of the Fe-S-Si ternary system. To investigate the FeS-rich layer at the top of Mercury's core, we performed the high-pressure experiments on the Fe-S-Si system using a KAWAI-type multi-anvil apparatus.

Pressure is fixed at 5 GPa corresponding to the CMB of Mercury and temperature is 1800 K, which is 200 K above the liquidus of Fe-S-Si system reported by Sanloup and Fei [5]. Fe-S-Si sample was kept for 30 min at this condition, and then it was quenched into room temperature. Oxygen fugacity of run charges was maintained around 3 log unit below IW buffer. Texture and chemistry of recovered samples were examined by electron microprobe.

We found two immiscible liquids in one run charge, which consist of Fe,Si-rich metallic liquid and FeS-rich sulfide liquid. Sulfur content of metallic liquid ranges 6 to 9 at%, which is higher by ∼5 at% than those reported by Morard and Katsura [6]. Differences in texture of recovered samples and run duration between this study and Morard and Katsura [6] suggest that the latter experiments were in disequilibrium state. Our data shows the liquid immiscible region has a narrower extent than the previous estimation and the Mercury immiscible Fe-S-Si core must contain at least 6-9 at% sulfur. The quenched FeS-rich liquid phase consists mainly of crystalline FeS (∼90 vol%) and Fe-Si alloy. In the case that FeS-rich liquid contacted with MgO sample container, $(Mg_{0.8}Fe_{0.2})S$ crystalline phase coexisted with FeS-rich liquid. Mg-sulfide phase could be made by Fe-Mg exchange reaction between MgO and FeS-rich liquid. In the Mercury core, when FeS-rich liquid ascends to add the bottom of the CMB due to its buoyancy, it makes a stable low density layer. Mg-sulfide phase is produced under low oxygen fugacity and high sulfur fugacity at CMB, and then it incorporates into mantle. This is consistent with the results of X-ray fluorescence spectrometry on the Mercury's surface, which indicates the presence of Mg and Ca sulfides [2].

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