Experimental study on penetration of molten iron alloy into the lower mantle phase

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It has not been well understood whether the metallic core and silicate mantle has interacted chemically and physically after core formation. The core–mantle boundary (CMB) region is expected to be a region where direct physicochemical interactions between core and mantle may occur. Perturbations in the Earth’s rotation rate at decadal time period require the existence of dissipative coupling at the CMB. Theoretical modeling indicates that a core mantle boundary (CMB) coupling-torque of 10^{17} Nm requires a presence of a thin conductive layer having a conductance of 10^{8} S/m or greater (Holme, 1998; Buffett et al., 2002). Several models have been proposed to explain anomalously high electrical conductance in some regions above the CMB: (1) capillary rise of iron-rich melt into mantle (Poirier and LeMouel, 1992), (2) Suction mechanism for iron entrainment into the mantle (Kanda and Stevenson, 2006), (3) a presence of post-perovskite with high electrical conductivity in the D” layer (Ohta et al., 2008), (4) penetration of molten iron into mantle by morphological instability (Otsuka and Karato, 2012). High electrical conductivity of post-perovskite in the D” layer is a plausible explanation of the regional variations in electrical conductivity observed by geomagnetic jerks due to sudden changes in Earth’s magnetic field (Ohta et al., 2008). However, this interpretation on high conductance layer is not required for core-mantle chemical interaction and cannot explain abundance of highly siderophile elements in the bulk silicate Earth through the core-mantle interaction.

In this study, high pressure experiments on penetration of molten iron alloy liquid into the lower mantle phases was performed in a stability field of major lower mantle phase (bridgmanite and ferropericlase) using a large volume press to understand penetration process induced by the morphological instability at the CMB. The liquid metal had penetrated into the (Mg,Fe)O aggregate along the grain boundary and formed a layer containing many metal-rich blobs. In contrast, at interface between molten iron alloy and postspinel (or bridgmanite), penetration of molten iron alloy was not observed.
Penetration of iron alloy liquid into the (Mg,Fe)O aggregate is caused by the capillary rise or Mullins-Sekerka instability. Both the capillary rise and the morphological instability did not occur at the wall of pure polycrystalline MgO, indicating that the FeO in (Mg,Fe)O plays an essential part in this phenomena. If the ultralow velocity zone (ULVZ) with low shear velocity is composed of Fe-rich periclase, penetration distance of molten iron alloy into the core-mantle boundary region by capillary rise occurs in a limited range within 20 m. However, iron-rich melt could not penetrate into silicate-rich mantle. These observations suggest that the penetration of Fr-rich melt into the base of mantle is unlikey to account for geophysical anomalies observed at the core-mantle boundary region.

Keywords: core-mantle boundary, bridgmanite, ferropericlase, molten Fe alloy, penetration

