3 dimensional structure of sulphide melt in peridotite

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Core formation of Earth has been inferred to occur at short interval of early Earth's history. At low temperature, segregation process of metal alloy from silicate mantle is controlled by grain boundary percolation of alloy melt. Dihedral angles between Fe alloy melt and silicate matrix have determined in variable system and shown over 90 deg. However, melt can interconnect over the critical melt fraction, even if the dihedral angle is large. Therefore, determination of the critical melt fraction can constrain the segregation process and partitioning of siderophile element between core and mantle. In the present study, we try to observe 3 dimensional structure to determine the critical melt fraction using high resolution X ray CT scanning.

The formation of an iron core and silicate mantle is a major event in the early history of the Earth. In a homogeneously accreting Earth, since silicates and metal alloys are at first intimately mixed, core formation requires a mechanism for separating and mobilizing the iron alloy. There are two major mode of segregation of iron alloy from the silicate mantle; grain boundary percolation and settling of iron droplets controlled by Stokes law.

As for the former case, there has been interest in the wetting properties of liquid iron or alloy melts in silicate matrix. Previous studies concerning about wetting behavior of alloy melts experimentally carried out a determination of dihedral angles under variable conditions. Most of the results show large dihedral angles over 90deg for Fe metal, suggesting a non-wetting property of iron-rich melts. For example, Shannon and Agee (1996) have found no significant pressure effect on sulfide-silicate dihedral angles to 20 GPa if pressure varies with temperature, i.e. along a geotherm. Although it seems reasonable from statistical angle measurements to conclude that the metal-rich melts cannot have segregated from a crystalline silicate mantle, a certain amount of liquid metal will connect along grain boundary when the dihedral angle is above the critical value of 60deg In this case, excess melts over the critical melt fraction (CMF) can segregate from the silicate matrix and residual melts trapped at grain boundaries and as inclusions in silicates. The stranded melts may influence absolute and relative abundance of siderophile element in the Earth's mantle. Therefore it is needed to determine the CMF to connect in 3 dimension.

It is hard to see how much Fe or sulfide melts could drain from a crystalline mantle by grain boundary percolation. Electrical conductivity measurements to determine melt connectivity in an olivine-iron alloy mix. In their experiments electrical conductivity was lost when percolation drainage had reduced the alloy volume to ~20%, indicating a lack of interconnectivity. However, the high resolution X-ray CT scanning would allow the visualization of interconnectivity of alloy melts in silicate matrix.

In order to assess the CMF in metal-silicate system and the feasibility of percolation as a core formation process, experiments over the mass fraction range (up to 0.3) in peridotite +sulfide system were performed. Using a starting material composed of a typical peridotite such as KLB-1, which phase relation is well known, including variable proportions of synthetic sulfide, will allow to examine the CMF with respect to a silicate mineralogy analogous to Earth's mantle. Sample material are packed into graphite capsule. Experiments were done at 1.5 GPa under variable temperature range across the solidus.Retrieved samples will be chemically analyzed with electron microprobe and measured apparent dihedral angles by backscattered electron image. A part of sample (0.5*0.5*0.5 mm) will analyze by a high resolution X-ray CT scanning at SPring-8. From the above analysis, the CMF will be determined.

Solidus temperatures at 1.5GPa in KLB-1+FeS system are about1200 degree C, which is lower than that in only KLB-1. Mineral assemblage is ol-opx-cpx-sp (with basaltic melt over 1250 degree C). In the 2 dimensional image, melt pool size of FeS increases with increasing the amount of FeS. FeS melt shows large dihedral angle over 100 degree C. In contrast, silicate melt shows small dihedral angle. For example, results from run at 1250 degree C provide 41 deg (ol), 50 deg (opx) and 55 deg (cpx), respectively. When the silicate melt exists in the system, FeS melt is surrounded by slicate melt and shows spherical shape. These results suggest that when silicate melt exists, FeS melt is hard to connect in silicate solid matrix.