

Reaction and separation of metal and silicate in the early Earth, and light elements in the core

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Recent metal silicate partitioning data of siderophile elements suggest that the metal silicate equilibrium occurred at the pressures corresponding to the lower mantle[1]. In order to discuss the the metal-silicate interaction and separation mechanism in the early Earth, we clarified the metal-silicate reaction and dihedral angle of iron and lower mantle at high pressure by using multi-anvil apparatus. We heated metallic iron sample in the MgSiO₃ capsule at 27 GPa and 2500°C, and observed formation of magnesiowustite as a reaction product of molten iron and Mg-perovskite. The reaction can be written as the follows; $(1+2x)Fe + xMgSiO_3 = xMgO + 2xFeO$ (in magnesiowustite and molten iron) + FeSi_x (in molten iron) for $0 < x < 1$. The amount of Si and O in molten iron and FeO content in magnesiowustite are dependent on the oxygen fugacity. In the oxygen fugacity of $\log f_{O_2} = -1.54 \sim -1.81$, we observed the Si content in molten iron in the range of 0.44~1.39 wt.%. Knittle and Jeanloz[2] reported a reaction of iron and MgSiO₃ perovskite at 40 GPa and 2500K to form magnesiowustite and FeSi_x, although they determined only by the X-ray diffraction. Our result is consistent with their work.

We measured dihedral angles between Mg-perovskite, magnesiowustite and molten iron at 24 GPa and 2270~2770K. The starting material was the mixture of the oxide and metal components. The oxide component is enstatite (Mg_{0.9}Fe_{0.1})SiO₃ or magnesiowustite (Mg_{0.9}Fe_{0.1})O, and the metal component is a mixture of reagent powders of Fe-Ni-FeS or Fe-Ni-FeO. The dihedral angle is 86~89° for the sulfur bearing metal-perovskite system. The dihedral angle is 76° for oxygen bearing system at the same condition, and it decreases with increasing oxygen content in metallic iron. The present results suggest that dihedral angles both of Mg-perovskite/iron and magnesiowustite/iron containing O and S, are larger than 60°, consistent with the results by Shannon and Agee [3]. The permeable flow may not be so important for separation of molten iron at the top of the lower mantle, but the rapid segregation of iron by the Rayleigh-Taylor instability.

Silicon up to 1.4 wt % can be dissolved in molten iron at the top of the lower mantle. Thus, the core can contain Si as a light element due to the metal-perovskite reaction at the bottom of the deep magma ocean.

References

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Kinetics of the graphite-diamond transformation in aqueous fluid determined by in-situ X-ray diffractions

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In-situ time-resolved X-ray diffraction experiments were performed for the graphite-diamond transformation with a MgO dissolved aqueous fluid as the diamond forming catalyst under conditions of 6.6-8.9 GPa and 1400-1835°C. The transformed volume fractions of diamond as a function of time under various pressure-temperature conditions were obtained. By analyzing the kinetic data using the Avrami equation and the Christian's model, and by SEM observations of the run products, it was determined that altering the pressure-temperature conditions drastically changes the spontaneous nucleation and growth process of diamond formation.

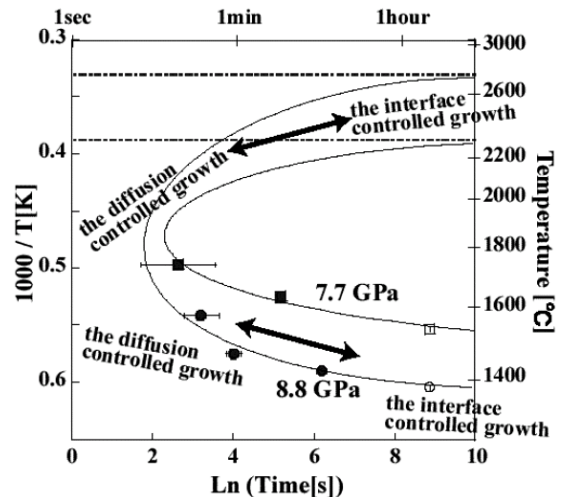


Figure 1: Time-Temperature-Transformation (TTT) diagram of graphite-diamond transformation and general tendency of the diamond growth process. Times required to complete 10% of the diamond transformation are plotted against temperature. Solid lines are the speculative TTT curves at each pressure, which should be asymptotic to the graphite-diamond equilibrium temperature (dot-dashed lines). At low temperatures the diamond growth process is interface-controlled and as the temperature approaches the “nose” of the TTT curve diffusion-controlled growth becomes dominant. When the temperature towards the graphite-diamond equilibrium temperature, interface-controlled growth is again dominant.

Reference

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