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Numerical simulation of the segregation process of metal In early magma ocean

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Earth's core is considered to have been formed by separation of iron from the silicate magma ocean. This metal-silicate separation is important because it controls the initial states of the core and mantle, in particular concerning the distribution of heat and chemical species between them. In this process, the size of metal droplet is critical, which is estimated as an order of 1 cm by a simple balance of the surface tension and the shear stress (Rubie et al., 2003). Here we report quantitative estimate how the metal size evolves during the metal-silicate separation based on numerical simulation of two-phase flow under gravity. The gravitational energy that is gained, is transformed in heat by viscous heating and we want to quantify the resulting thermal structure.

In the numerical method that simulates the process, tracking of the metal-silicate boundary is crucial. In this study, we adopt the moving particle semi-implicit (MPS) method based on the Lagrangian particle method. This method avoids numerical diffusion in the surface tracking of metal-silicate phase boundary because of its Lagrangian nature. Incorporation of the surface tension between metal and silicate phase is another critical factor in this simulation. In the 2-D simulation, we adopted the model by Nomura et al., 2001 implemented in MPS. In 3-D, we employed a new model that we invented.

In the simulations, several interesting features have been clarified: irrespective of the initial size, size of the metal droplets evolve to a stable size of the order of 1 cm, which is mainly controlled by the surface tension and the viscosity of silicate melt. We discuss the size and shape of droplets, their falling speed, the interaction between droplets, and the resulting temperature distribution.