

Numerical anatomy for crystallization of chondrule melt

Hitoshi Miura[1]; Etsuro Yokoyama[2]; Katsuo Tsukamoto[3]; Ken Nagashima[4]

[1] Department of Earth Sciences, Tohoku University; [2] GUCC; [3] Graduate School of Science, Tohoku University; [4] Grad. School of Eng., Osaka Univ.

Most of chondritic meteorites falling onto the Earth contain mm-sized crystalline silicate spheres (chondrules), which are believed to have been formed from molten silicate droplets 4.6 billion years ago in our early solar system. Some of them have interesting double textures with outer crystalline rim and parallel bars inside. The rim has a thin shell-like morphology surrounding a chondrule. The bars are planar crystals parallel each other observed inside the rim. The remarkable features are that the rim connects with bars and the crystallographic orientation of the rim is the same as adjoining bars. Since such texture has not been reproduced in the laboratory experiments except a few examples, the formation mechanism is unclear.

We consider that the interface instability at the interface between the previously formed rim and the inside melt results into the formation of bars based on the linear stability analysis of Mullins & Sekerka (1964, J. Appl. Phys. 35, 444). In order to examine the rim formation and the consequent bar formation, we numerically simulate the crystallization of a supercooled silicate droplet by using the phase-field model. In our model, we solve the equations of the phase field and the temperature, but do not the equation of concentration because the droplet we consider here is composed of only one component. Initially, we assume that the nucleation (or seeding to initiate the crystallization) occurs at the surface of the supercooled droplet. The crystallization proceeds along the surface and/or to inside of the supercooled droplet depending on the initial temperature distribution of the droplet and the cooling process at the droplet surface. We carry out the numerical simulations for various conditions for the seeding temperature and the cooling rate and investigate the conditions in which the rim and bars form successively simultaneously. In some cases, we observed that the interface between the rim and the inside melt is unstable during the solidification and the instability grows nonlinearly and parallel planar crystals are formed. This morphology is very similar to that observed in some natural samples of chondrules.