Size and cooling rate of chondrules formed thorough collision between planetesimals containing volatile materials

*Sin-iti Sirono[1]

1. Department of Earth and Planetary Sciences, Nagoya University

Chondrite meteorite contains "chondrules", which are silicate spheres with sizes of 0.1-2 mm. Volume fraction of chondrules exceeds 80% in some chondrites. Its shape and high fraction indicate that chondrules were formed through common heating event in the solar nebula. Cooling rate of chondule has been estimated as 10-1000 K/h from laboratory experiments. The size and cooling rate are the most important quantities which characterize chondrules. Although many models have been proposed, the parameter range suitable for chondrule formation is limited in most models.

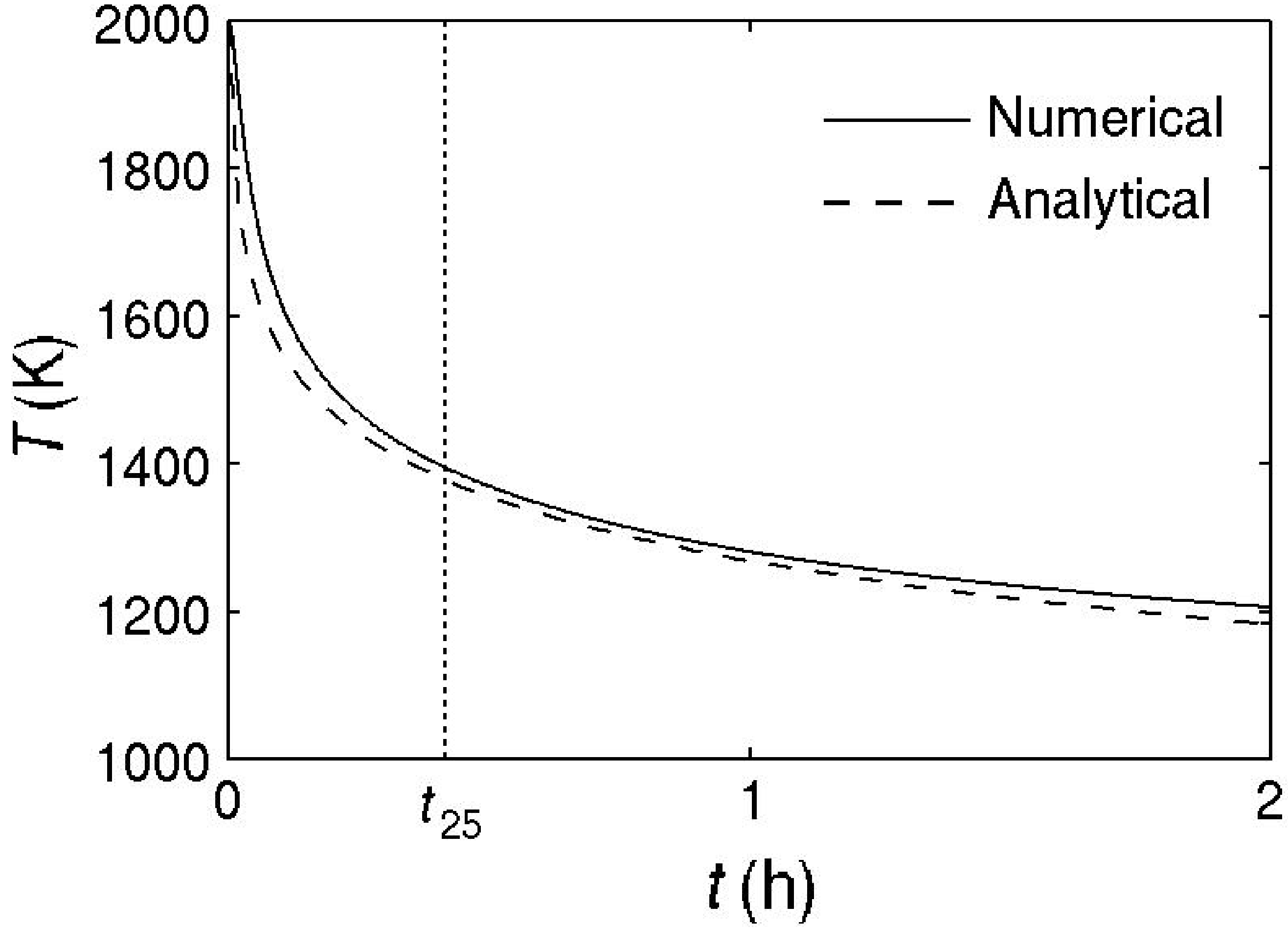
Collision of planetesimals has been studied as a chondrule forming mechanism. It requires high velocity collision > km/s which is difficult to attain in the solar nebula. However, the formation of Jupiter can excite the motion of planetesimals. Nagasawa et al. (2019) showed that the impact velocity between planetesimals can exceed 10 km/s due to the exitation. Moreover, the age of chondrules ranges between 1 and 3 Myr after CAI. This is consistent to the timing of Jupiter fomation and duration of excited motion of planetesimals.

In order to form chondrules of 0.1-2mm size, high gas dynamic pressure is necessary. The gas in the solar nebula is too rare to breakup silicate melt down to the size range. If a colliding plantesimal contains volatile materials, they evapolate quickly and expand because of the collisional heating. The velocity difference between silicate melt and gas can lead to breakup of silicate melt. The size of melt droplet is determined by Weber number, which is a ratio between gas dynamic pressure and surface tension. I conducted 1-D numerical simulation of expansion of gas-melt mixture. The simluation parameters are the thickness of the mixture L, mass fraction of volatile materials f, and initial temperature $T_{0.}$ I adopted physical parameters of H_2O, and ideal gas is assumed for simplicity.

Figure shows typical evolution of temperatrure. The temperature of the mixture decreases by the expansion of the gas. In this case, the cooling rate is ~1000 K/h. I conducted simluations with various parameter sets. The range of droplet size is 0.3-2mm. Cooling rate is 100-10000 K/h. These ranges are consistent to those of chondrules.

It is possible that the volatile material is not water but organics. If this is the case, the gas is reducing and Fe becomes Fe metal, not FeO. Then the variation of oxidation condition of Fe can explain by the variation of volatile materials. Moreover, if the inside of a planetesimal is melted due to heating by ^{26}Al, Fe migrates to the center of a planetesimal and avoid collision. Then the variation of Fe content (seen as H, L, LL chondrites) can be explained by the internal melting of a planetesimal.

Keywords: chondrule, volatile material, planetesimal, size, cooling rate


2000
1800
1600
1400
1200
1000
T (K)
0
t25
1
2
t (h)
Numerical
Analytical

