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A Chondrule Formation Theory: Shock-Wave Heating Model

Taishi Nakamoto[1]; Hitoshi Miura[2]

[1] Tokyo Tech; [2] Department of Earth Sciences, Tohoku University

Chondrules are mm-sized spherical silicate objects in chondrite meteorites. They are abundant in primitive chondrites, so it is thought that chondrules were formed ubiquitously in the early solar nebula. Thus, to reveal the formation process of the chondrule should be one of the keys to understand the formation processes of the solar system.

Chondrules have spherical shape and there are some evidences that they experienced melting, it is considered thtat chondrules were heated and melted once, and thanks to the surface tension, they became spherical. On the other hand, it is hard to imagine a process that heats the silicate particles to melt, which requires an intensive heating. The heating mechanism for the chondrule formation remains an unsolved problem.

We have investigated the shock-wave heating chondrule formation model as the heating mechanism. Let us suppose that a shock wave is generated in the gaseous solar nebula. Then, dust particles in the nebula, which are precursors for chondrules, are heated by the shock wave due to the gas friction. When the fricitional heating is strong enough, the silicate dust particle can be heated and melted. This is the shock wave heating mechanism.

Generally speaking, we have to compare model results with observations/measurements in order to validate a theory. We have examined the model results with some observations and measurements, and found that some features of chondrules can be explained naturally by the theory. The features include that the melting of silicate dust particles, the temperature variation in the temperature rising phase, the temperature variation in the temperature decreasing phase, the maximum size of chondrules, the minimum size of chondrules, and the 3-D shape and the degree of deformation.

The current theme we are involved mainly is the formation mechanism of the compound chondrules. Compound chondrules are objects that consist of two or more independent chondrules. Probably, they are formed by collisions among chondrules while they are molten. The fraction of compound chondrule in all the chondrules is about 5%, which is rather high. In order to reproduce such a high fraction, chondrules should collide each other frequently in the chondrule forming region, in other words, the number density of chondrules (precursors) should be high. We have examined if such a high number density state can be realized in the framework of the shock wave heating model, and found that it is not so easy but the possibility is not so low.

In the shock wave heating chondrule formation model, of course, there are many issues that should be investigated in the future. There are a lot of features that have not been compared with model results. For example, chemical compositions of chondrules, isotopic compositions, and the frequency of voids in chondrules. We think that by investigating these features, we may be able to reveal the physical and chemical status of early solar nebula. Thus, we are planning to investigate those issues in the near future.