MAXIMAL SIZE OF CHONDRULES IN SHOCK-WAVE HEATING MODEL: FINAL SIZE THROUGH A STRIPPING OF LIQUID SURFACE

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Most meteorites falling on the Earth are chondritic meteorites. Chondrules are major component of the chondritic meteorites. From mineralogical features, it is thought that chondrules were formed through melting at least once and re-solidifying with rapid cooling. One prominent feature of chondrules is that they have a characteristic size distribution: diameters are in a range from 0.1 mm to 1 mm. Many formation models for chondrules have been proposed to date, but none has been widely accepted. The formation model for chondrules must be consistent with this size distribution.

The shock wave heating model is one of the most plausible models for chondrule formation, since many chondrule features are accountable. When a shock wave is generated in the solar nebula, the relative velocity between dust particles and the gas in the flow is generated, and that leads to the friction and heating on the dust particles. For a completely molten dust particle, hydrodynamics equations were solved with linear approximation, and deformation, internal flow, and pressure distribution in the molten particle were obtained (Sekiya et al. 2003; Uesugi et al. 2003). On the other hand, the possible maximal size of chondrules was estimated based on the balance between the ram pressure by the hypersonic gas flow and the surface tension of the totally molten dust particles (Susa and Nakamoto 2002).

In the shock wave heating model, the temperature in a dust particle was assumed to be uniform. However, when the time scale of heat conduction in a dust particle is longer than the time scale of melting, the dust particle would gradually melt from the surface to the center, and a partial melting state would be realized. So, a dust particle that has a central solid core surrounded by a liquid mantle may be formed.

In this study, we analytically solve hydrodynamics equations for the core-mantle structure particles with linear approximation, and obtain the deformation, the internal flow, the pressure distribution in the liquid mantle, and the force acting on the solid core. In addition, we estimate the time scale with which the solid core would leave from the liquid mantle due to the force. This phenomenon can be regarded as the stripping of the liquid mantle from the solid core.

We discussed this possibility by evaluating some time scales: the heating, the conduction, and the dynamical time scales. We found that when the dust radius is larger than about 1 - 2 mm, the stripping is expected to take place before the entire dust particle melts (reported in the Joint Meeting 2004).

In this work, we further compared the duration the force acting and the heating of the dust particle by hypersonic gas flow in the post-shock region. In consequence, large dust particles may be stripped over and over again in a shock wave and may finally become smaller than about 1-2 mm in chondrule-forming shock waves.

Moreover, we compared the fission of the completely molten dust particle (Susa and Nakamoto 2002) and the stripping from the partially molten dust particle as a mechanism that could determine the maximal size of chondrules. It turned out that the critical size for the fission is larger than the critical size for the stripping in chondrule-forming shock waves. Thus, the stripping of the liquid mantle occurs more likely than the fission of totally molten dust particles. Therefore, the maximal size of chondrules seems to be determined not by the fission, but by the stripping of the liquid mantle from the partially molten dust particles in the shock waves. This maximal size, about 1 - 2 mm, seems consistent with sizes of natural chondrules.