Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS020-02 Room:103 Time:May 24 08:45-09:00

Evolution of the size of dust grains by evaporation and condensation

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1.Background

The coagulations of dust grains of sub micron size which have silicate cores covered by ice mantle form the dust aggregates with high porosities in the outer protoplanetary disk in the initial phase of the planet formation. Whether dust grains grow up by coagulations in initial phase affects the planet formation materially.

On the other hand, the previous experiments indicate that the chondrules in meteorites were formed by temporal heating and cooling. If temporal heating events which increase the temperature to 10^3 K occurred in the disks, temporal heating events which increase the temperature to 10^2 K such that the ice evaporates often occurred. Thus, we consider that dust grains experience the evaporation and the condensation through the temporal heating events

We consider that H_2O gas molecules condense on the surface of dust grains through the decreasing temperature in the temporal heating event. In this process, the dust grains are covered by the ice in this process to grow up for the ice mantle thickening. Then the larger size of dust grains has the lower saturation pressure of water vapor than smaller by the effect of the surface tension for sub-micron size of dust grains. Thus, the larger dust grains become larger by condensation. This process changes the size distribution of dust grains. The size development of the dust grains affects collision velocity and static adhesion, and changes the mechanical property of the dust aggregates.

2.Purpose

We calculate the time development of the probability distribution function for the size of dust grains through the temporal heating event by the numerical simulation.

3.Results

We calculate at 3AU from the central star in typical disk. We set the initial time at the time of beginning the condensation and that initial distribution function for the size of dust grains is proportional to power low -3.5 of size (Mathis et al. 1977). We calculate in the range of cooling rates from 10^6 Kh^{-1} to 10^2 Kh^{-1}. The results indicate that the growth phase bisects and time evolution of size is stopped. In the stopped time, the size distribution of the dust grains becomes the bipolar distribution of many small dust grains of silicate and a few large dust grains covered by the ice.

We divide the growth phase between the first phase and the second phase. In the first phase, the larger dust grains become larger from the largest dust grains by the condensation for the decrease of saturation pressures of water vapor of dust grains by the temperature. On the other hand, the decrease of the pressure of surrounding water vapor by the condensation catches up with the decrease of the saturation pressures to decide the minimum size covered by the ice. Next phase is the second phase. In this phase, the transferring H_2O molecules among smaller dust grains and larger dust grains works because the decrease of the surrounding pressure is larger than the decrease of the saturation pressures of dust grains. The transferring effect evolves small dust grains covered by the ice into smaller dust grains. In the case, dust grains once developed become initial size by the evaporation. Finally, few surrounding H_2O gas molecules by the condensation and the lower temperature stop the size development. The distribution of dust grains becomes the bipolar distribution of a few larger dust grains and many smaller dust grains. We discuss possible effects of the bipolar distribution to the planet formation.

Keywords: dust grain, evaporation, condensation