Dust coagulation in the solar nebula

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This is a review presentation on dust coagulation in the solar nebula. Although dust coagulation is prerequisite for planetesimal formation and the first stage of the formation of planets, there are many problems to be resolved.

The main points clarified so far are:

1) Sticking velocities between a pair of dust grains

The critical sticking velocities are derived analytically by Choksi et al. (1993). Poppe et al. (2000) experimentally found that the velocities are one order of magnitude higher than the predicted value.

2) Sticking velocities for dust aggregates composed of 10-100 dust grains

Dominik and Tielens (1997) conducted numerical simulations of collisions between dust aggregates and the outcomes are well classified according to the interaction energies between a pair of composing grains. This classification was experimentally verified by Blum and Wurm (2000).

3) Effects of sintering on collisional outcome between aggregates

It was found that the efficiency of energy dissipation during a collision decreased significantly by sintering between dust grains (Sirono 1999). This effect suggests the temperature dependence of coagulation between dust aggregates.

4) Stickiness of organic materials

An interstellar dust grain contains substantial amount (~20%) of organic materials. Kouchi et al. (2002) experimentally reported remarkable stickiness of the organic materials. It was suggested that the dependence of coagulation of dust grains on composing materials.

Based on these items, I propose following topics being important to the dust coagulation:

1) Mechanical properties of grain composing materials and grain surface properties

A dust grain is mainly composed of minerals, ices, and organics. Mechanical properties of each component are relevant for coagulation. Especially a model for viscoelastic response of organics is desirable. Description on grain surfaces is also essential since the interaction between sub-micron sized grains is dominated by surface attraction.

2) Mechanical interactions between a pair of dust grains

In most cases, mechanical interactions between a pair of dust grains have been described by JKR theory which is based on the Hertz's solution for the interaction between two elastic spheres. Modified interactions by the organics layer and by sintering have to be properly modeled.

3) Macroscopic mechanical properties of a dust aggregate

A collisional outcome between dust aggregates composed of large numbers of grains would be described by macroscopic properties of an aggregate. The macroscopic mechanical properties of an aggregate depend on the interactions between composing dust grains and their arrangement in an aggregate. Elasticity and strength of an aggregate were derived analytically by Sirono and Greenberg (2000) with an assumption of a specific arrangement of grains. Dependence of the mechanical properties on the more general arrangement of grains is not clear yet. It is also important to measure experimentally the mechanical properties of an aggregate.