Growth of nanometer-sized solid particles and their clusters

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In order to begin the formation process of objects such as planets, asteroids and comets in the solar nebula, many kinds of approaches such as astronomical observation, analysis of meteorites and subsequent theoretical calculations have been carried out. One type of useful investigation is experimental studies concerning nucleation, growth and evolution of dust, because dust is a basic ingredient of primitive objects. Results of experimental studies of dust to determine their characteristics such as optical properties, formation conditions and crystal habits, can then be compared with the actual material. Recently, fresh cometary dust was recovered from Wild 2 by the Stardust Mission. Since then, experiments on dust analogs will be more essential to reproduce observed characteristics.

Since the diameter of the dust is on the order of 0.1 μm or smaller, significant effects due to nano-particle interactions must be understood to model the growth and evolution of dust. For example, the melting point of gold (1336 K) decreases to 950 K as the particle size decreases to 2-3 nm [1]. In addition, the diffusion coefficient of copper atoms in gold nanoparticles changes to 8.3×10^{-19} from 2.4×10^{-28} ($m^2 \cdot s^{-1}$) in the bulk at 300 K [2]. As a result, the time scale to form nano-particle alloys becomes drastically faster than for the bulk, i.e., from a couple of years to several seconds. Sometimes, even the stable structure is changed for nano-particles [3].

Although astronomical conditions cannot be exactly duplicated in the laboratory, smoke experiments are favorable production methods for dust analogies. Using such methods, several nm to μm sized particles can be produced. The behavior of powders composed of nano-particles is also different from that of granular material. When smoke particles several tens of nanometers in diameter are produced using the smoke generator at GSFC [4], a current of smoke traveling at about 1 m/s produces a deposition layer, which is very fluffy, in the apparatus. The density of the layer is about 0.01 g/cm^3. After the sample is collected, placed in the bottle and shaken, the density increases to about 0.1 g/cm^3, immediately. The agglomeration of the smoke particles looks like a planetary regolith. This experimental demonstration would correspond to the initial stage of growth of small solar system bodies. In this study, growth of nano-particles, their assembly and sintering processes will be introduced and compared with the high porosity observed in small solar system bodies.

References

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