Nucleation experiment of alumina and silica from vapor phase using the sounding rocket S-520-30

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Nucleation event determines the condensation sequence, number density, size, morphology and crystalline structure of cosmic dust particle, called dust, in a gas outflow of dying stars or a gas plume after shock wave heating in the primitive solar nebula. Using nucleation theories, such characters of dust have been expected. However, it has been well known that results obtained by classical nucleation theory and by experiments have a large difference each other. We believe that one of the reasons is the difference of physical parameters of nanometer sized particles from its bulk. Although nucleation is a process progressed in nanometer scale, physical parameters of bulk materials have been used. To determine the physical parameters of nanoparticles, we constructed an in-situ observation system of temperature and concentration during homogeneous nucleation in vapor phase using interferometry in the laboratory.

Nanoparticles are formed as dust analogues from a supersaturated vapor after evaporation of the starting material by electrical heating in a gas atmosphere. Using the specially designed double-wavelength Mach–Zehnder-type laser interferometer, nucleation temperature and partial pressure can be obtained simultaneously. Then, surface free energy and sticking probability can be determined using timescale for cooling based on nucleation theories (Kimura et al. 2012). In case of laboratory experiment, convection of gas atmosphere caused by thermal heating generates heterogeneity of nucleation environment, such as temperature and concentration profiles around evaporation source. In microgravity, evaporated vapor diffuses uniformly and the temperature profile becomes concentric around the evaporation source. As the result, nucleation will occur at the same condition. In addition, microgravity condition allow us to duplicate the ratio of timescale for cooling and collision frequency of vapor around supernovae and asymptotic giant branch stars. Therefore, we performed microgravity experiments using the sounding rocket S-520-30 launched on September 11th, 2015.

Two same experimental systems, which construct with the interferometer, nucleation chamber and camera recording modules were designed to fit the size and weight limitation and installed into the nosecone of the rocket. The evaporation source and gas atmosphere are silica and argon (4 $\times 10^4$ Pa) for silica dust, and alumina and a gas mixture of oxygen (2 $\times 10^3$ Pa) and argon (3.8 $\times 10^4$ Pa) for alumina dust. The experiments were run sequentially and automatically started after launch of the rocket. The evaporation sources of silica and aluminum were electrically heated in the gas atmosphere under microgravity. Evaporated vapor was diffused, cooled and nucleated in the gas atmosphere. The temperature and concentration at the nucleation site can be determined from the movement of the interference fringes. Here, we will show the results of the experiments including supersaturation ratio, and the physical properties of those nanoparticles.

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