Simultaneous determination of surface free energy and sticking probability based on formation experiment of cosmic dust and nucleation theories

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The degree of supersaturation for homogeneous nucleation in the vapor phase was directly determined from the condensation temperature and the concentration, as measured using a double-wavelength Mach–Zehnder-type interferometer during homogeneous nucleation. We succeeded to construct a method, which can be determined the surface free energy and the sticking coefficient of nanometer scale dust analogues, simultaneously, based on the classical nucleation theory (CNT) and semi-phenomenological (SP) model using the size of the resulting particles and the condensation temperature. Our experiments suggested that previously unknown values of the surface free energy and sticking coefficient of a material can be determined through the application of a combination of an experiment and nucleation theories.

We performed some experiments using manganese (Mn), tungsten oxide, sodium chloride for preliminary materials and currently are doing an experiment for iron. Condensation occurred at 500-900 K below the equilibrium temperature and the degree of supersaturation was as high as 10^4 - 10^8. In case of Mn, for instance, the surface free energy was very close to that of bulk (~1.5 J/m^2) and sticking probability was ~0.4. The nucleation theories predict that the critical nucleus contains only three and six atoms for CNT and SP, respectively, which are fewer than the number of atoms in a unit cell of Mn. Therefore, we concluded that molten Mn particles are initially formed and that these are subsequently converted into α- or β-Mn through a secondary nucleation event. The number, mean size, and size distribution of the particles are controlled by the nucleation of Mn, whereas the morphology, crystal habit, and polymorphism of the particles must be determined by a secondary nucleation process within the molten Mn clusters. In the presentation, we will show recent experimental result of iron and the difference with the experimental results under microgravity for ~20 seconds using air craft.