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Homogeneous nucleation and coalescence growth of dust analogs in supersaturated vapor

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To investigate the homogeneous nucleation and growth process of nanoparticles in vapor phase, interferometric observation was attempted for the fist time to the gas evaporation method, which has been a commonly accepted physical production method of nanoparticles. Using the gas evaporation method, fine particles with the size of several nm to ~1 micron are directly produced from the gas phase and recognized nanoparticles have a crystalline habit similar with the bulk crystal even in such tiny particles. When an evaporant is initiated in an inert gas, the evaporated vapor subsequently cools and condenses in the gas atmosphere, i.e., solid grains are obtained via homogeneous nucleation from the vapor phase. Therefore it can be assumed that nucleation occurs far from the equilibrium state, but it is not obvious how far condensation takes place. However, there is no report concerning nucleation and limited study in view of crystal growth for smoke experiment, although significant numbers of smoke experiments have been performed so far. Although there has been reports concerning homogeneous and heterogeneous nucleation from solution phases [1], there has been few reports concerning homogeneous nucleation from a vapor phase in recent years. Homogeneous nucleation rates of droplets were measured as a function of temperature and supersaturation using ethanol and nonane [2, 3]. The nucleation rates were different in several orders of magnitude from the classical nucleation theory.

In preliminary experiment, Tungsten oxide was evaporated by electrical heating of a tungsten wire in a mixture gas of Ar and O_2. WO_3 nanoparticles were formed via homogeneous nucleation and growth during a gas cools following a thermal convection produced by the evaporation source. The degree of supersaturation for nucleation was extremely high, $6.6*10^6$, which was determined from the interferogram. Surface free energy of WO_3 at 1100 K was calculated based on the classical nucleation theory and was $1.38*10^3$ erg cm^{-2}, which is within the reported values. Homogeneously condensed WO3 nuclei initially maintain their temperature for ~5 ms and then cool down with a rate of ~$5*10^4$ K/s. A part of the difference between actual formation rate of produced nanoparticles, which were determined based on a transmission electron microscope, and calculated values based on the semi-phenomenological nucleation theory [4] were well explained if we adopt the idea of coalescence growth.

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