Experimental study of nucleation, coalescence and growth of nanoparticles

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Nucleation is a first step to form cosmic dust particles and is a beginning of their long evolutional history accompanying with stellar lives. Nucleation determines number, morphology, polymorph, size and size distribution of nanoparticles, which strongly affect to the infrared spectra and also formation of molecules on their surface. Accordingly, nucleation is fundamental process on the cosmic dust formation. When nanoparticles are formed directly from gas phase in ejecta gas of evolved stars and possibly in a plume after energetic shock in primitive solar nebula, at least first nanoparticles must condense homogeneously. Then, they should be condensed under supercooling with nonequilibrium state. In this situation, we cannot apply general thermodynamic equilibrium to find formation sequence of mineral particles. In fact, however, there is no quantitative experimental data concerning a homogeneous condensation from a gas phase. Here, we will show a first achievement of in-situ visualization of the environments during homogeneous nucleation and subsequent growth of nanoparticles in smoke experiment using Mach-Zehnder interferometer and attempt to determine the homogeneous condensation temperature and supersaturation of several kinds of materials in gas phase.

Figure 1 shows an example of our first smoke produced in newly constructed smoke chamber. The smoke was produced by heating of a tungsten wire with 0.3 mmϕ and 70 mm depth in a mixture gas of Ar (9×10^3 Pa) and O_2 (1×10^3 Pa). Tungsten has been evaporated as oxide at the source temperature ~1600 K, which measured by pyrometer. Evaporated oxide molecules are subsequently cooled following the convection current produced by hot source and WO_3 particles have been condensed and formed the smoke. Since there is no heterogeneous nucleation cite, solid grains were obtained homogeneously from the gas cloud. The evaporated tungsten oxide vapor is concentrated at the interface between interior WO_3 vapor rich atmosphere and outer mixture gas. Their condensation temperature can be determined from the interferogram. We observed the produced smoke particles using transmission electron microscope and recognized the formation of WO_3 single crystal nanoparticles with 20-200 nm in diameter.

We are trying to discuss using classical nucleation theory and calculated the growth velocity using Herz-Knudsen equation to this experimental result. As the result, we found that the theory no longer works in this nano-world and coalescence process, which is a process two different nanoparticles fused together and make larger nanoparticle, after nucleation is important to know the final product. In addition to the preliminary experiment using WO_3, experimental results concerning astronomically important materials, such as alumina, silica and iron, will be shown in the presentation.

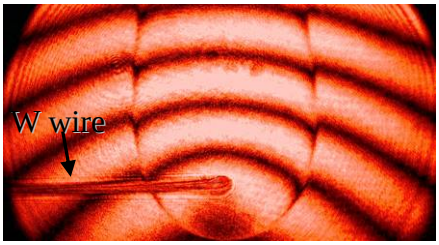

Figure 1: Typical interferometric image of smoke particles.