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Interferometric Observation of nanoparticles condensation in smoke

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Growth processes of nanoparticles are different from that of bulk crystals. In addition, when nanoparticles are formed directly from gas phase in homogeneously, they should be condensed under supercooling with nonequilibrium state. This situation is common in the formation of cosmic dust particles. Significant effects due to nanoparticle interactions must be understood to model the growth and evolution of cosmic dust particles, which are actually nanometer order. Here, we will see the nucleation and growth environments of nanoparticles in a smoke using Mach-Zehnder interferometer.

One of the best methods of producing nanoparticles is the smoke experiment, which is termed the gas evaporation method. The gas evaporation method was developed in Japan (1963) after stimulation by investigation of Kubo, which has been known as the Kubo effect, in the field of solid-state physics [1]. Using the gas evaporation method, smoke particles are directly produced from the gas phase. When an evaporant is initiated in an inert gas, rising smoke from the evaporation source can be observed. The evaporated vapor subsequently cools and condenses homogeneously in the gas atmosphere, i.e., solid particles are obtained directly from the gas cloud. Then, the growth process of nanoparticles is different from that of bulk materials, because physical properties of nanoparticles are anomalous.

Recent development of nanotechnology shows unexpected significant phenomena of nanoparticles. For example, the melting point of silver decreases from 1233 to 667 K as particle size decreases from macroscopic scale to 15 nm in diameter [2]. In addition, the diffusion coefficient changes to 8.3×10^{-19} from 2.4×10^{-28} ($m^2 s^{-1}$) in the bulk material at 300 K (Cu atoms in Au nanoparticles) [3]. These phenomena induce an unexpected growth process of nanoparticles. It has been proposed based on transmission electron microscope observation of final products, i.e., ex-situ, that coalescence growth is regarded as a characteristic and an important process of nanoparticles. Coalescence among the nanoparticles is composed of two stages: a liquid-like coalescence stage and a surface melting coalescence stage [4]. At the initial stage of nucleation, when two nanoparticles are contact, they fuse together and thus make a larger particle. When two different kinds of materials are mixed, an alloy particle is produced immediately. These two stages depend mainly on grain size and temperature. The morphology and grain size can be controlled by the mass density and the temperature of the smoke, which depend on the atmospheric gas and gas pressure. However, the formation environments such as temperature, concentration and degree of supersaturation in smoke have been invisible so far. We will perform in-situ observation of the formation environments nanoparticles using Mach-Zehnder interferometer.

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