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In-situ observation of the condensation process near the melt interface by real-time phase-shift interferometer under microgravity

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To suppress the effect of convection and heterogeneous nucleation, microgravity environment has been utilized for the condensation of fine cosmic dusts from silicate vapor.

The refractive index of the evaporating gases around the silicate melt was successfully measured by employing the real-time phase-shift interferometer. The refractive index around the melt was much higher than that of the equilibrium vapor concentration. This large refractive index can be explained if nucleation of fine particles were formed near the melt interface.

The gases near the interface were sampled for TEM analysis to reveal the varieties of fine particles. The size, phases and the chemical compositions of these fine particles are different depending the gravity level and total pressure

Evaporation and condensation processes of IDP in the early solar nebula play an important role on the chemical and isotopic fractionation. The condensation of these materials in the early solar nebular has been discussed based on the observation of products of synthesis of fine particles by TEM or SEM. However one of the problems in this synthesis is the heterogeneous nucleation on the wall of the container due to the reduction of the interface tension between the wall and the crystals. To avoid heterogeneous nucleation, microgravity environment has for the first time been utilized for this study.

Forsterite, enstatite, diopsite, quartz glass and CAI (Ca-Al rich inclusion) glass (SiO_2=31%, Al_2O_3=27%, CaO=29%, MgO=11%) were used as the starting materials. These starting materials were melted by CO_2 laser (100W) to get a spherical shape before the experiments, and the glass was fixed with a Pt-Rd (Rd=10%, diameter is 0.1mm) wire in a vacuum chamber. Experiments were done (1) in normal atmosphere under gravity, (2) in normal atmosphere under microgravity and (3) in vacuum ($P=10^3$Pa) under microgravity.

In order to measure both temperature and concentration of the gas around a melt droplet with the diameter of ~3mm, both Mach-Zehnder interferometer and newly developed Michelson-type real-time phase-shift interferomer were applied to the evaporation process from the melt.

By the measuring of the time dependent refractive index of the gas near the melt, the temperature and concentration field around the silicate melt droplet were successfully be analyzed. As increasing the silicate melt temperature, the gas refractivity around the melt surface becomes higher. The gas refractivity observed during the heating was 10^3 times lager than that of the gas refractivity calculated based on the equilibrium vapor pressure (10^{-6} bar to 10^{-5} bar in this experiment). This high concentration was observed in about 20 seconds after the heating. This large refractive index can be explained if nucleation of fine particles were formed near the melt interface.

In order to characterize the high concentration zone near the melt, the gas near the melt-gas interface were sampled for TEM analysis.

The particles formed under gravity were spherical and amorphous by electron diffraction. The average size of these particles is about 30 nm and thus classified as fine particles. The fine particles formed in normal atmosphere under microgravity were in crystalline state. The shape varies depending on the size. The fine particles formed under microgravity were crystalline and their average size was about 50nm.

The difference can be interpreted in the following way: The fine particles moved upwards by thermal convection, but under microgravity the particles stayed in the area where these particles were formed. Thus the fine particles under microgravity experienced long annealing time, which will result in the transition from amorphous to crystals.

The difference can also be seen in the chemical composition of these particles in SiO_2-Al_2O_3 plot. The chemical compositions of the particles formed in vacuum under microgravity are more depleted in Al_2O_3 content than those formed in atmosphere under microgravity.