The effect of the oxygen pressure to the condensation and accumulation kinetics under microgravity

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Although equilibrium conditions of silicate materials had been investigated by several authors, the condensation kinetics to simulate the early solar nebula has not been investigated so far. It has been difficult to determine the supersaturation and the location where the particles condensed from the vapor, because of the existence of the thermal convection. To solve this problem, we have done the condensation experiment under microgravity by utilizing the parabolic flight of airplane to suppress the thermal convection.To know the effect of the ambient gas species to the condensation kinetics, we have used several gases, which have different oxygen content.

The starting materials we used for this study were Sun Carlos olivine, Enstatite, CAI glass and Gehrenite. These starting materials were melted before the experiment to obtain the spherical shape. These starting materials were fixed by the Pt wire, which diameter was 0.1mm, in the vacuum chamber. The base pressure of this vacuum chamber was about 10 Pa. The total pressure was adjusted to 10^5 Pa and 10^3 Pa by introducing pure Ar gas and 1000 ppm O2 mixing Ar gases into the chamber. The starting materials were evaporated by CO2 laser ablation. The temperature of the starting materials was measured by pyrometer. And the gas temperature distribution was measured by Pt-Pt10Rd thermocouple and Michelson type real-time phase-shift interferometer. The fine particles condensed from the vapor were collected on the grids for electron microscope at two locations, which were (A) 14 mm and (B) 18 mm from the vapor source, respectively. The collected fine particles condensed from the vapor were investigated by TEM and AFM analysis.

TEM observation shows that all particles condensed from enstatite vapor under microgravity were amorphous. We can see the size difference between the particles formed in pure Ar gas and in O2 mixing Ar gases. The size of the particles formed in pure Ar gas at 10^3 Pa was 75 nm (the standard deviation =36), while the size of the particles formed in O2 and Ar gases at 10^3 Pa was about 26 nm (standard deviation = 8 nm). The particles formed in pure Ar at 10^3 Pa were also amorphous, and their size was 61 nm (standard deviation =13 nm).These particles formed the network aggregates by attaching each other. The ratio, x/r (x is the diameter of the adhesion face and r is the diameter of the particle) vary remarkably depending on the oxygen concentration. That ratios of the network aggregate formed in Ar gas at 10^3 Pa and at 10^5 Pa were 0.35 and 0.44 respectively, that ratio of network aggregate formed in O2 mixing Ar gas were 0.73.

The difference of the particle size indicates that high supersaturation was achieved in the O2 induced experiment. However, the oxygen partial pressure in the experiment with O2 mixing Ar gas is not high enough to change the equilibrium condition, since the O2 concentration was only 1000ppm. So the interfacial free energy may increase so that high supersaturated condition can be allowed. And further, high interfacial free energy will accelerate the necking process of the particles to reduce the surface area. So we may conclude here that the oxygen plays an important role to changing the condensation and accumulation kinetics with increasing the interfacial free energy of the silicate materials.