Reproduction experiments of chondrule textures using an ambient-controlled levitation system embedded in tube furnace

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Chondrules are round shaped particles (mainly composed of silicates) with sizes of ~1 mm. They are thought to be formed in the early solar system by the rapid cooling of molten droplets before they accreted. They show unique and diverse internal micro-textures, which reflect nebular conditions, such as gas species and their partial pressures, heating and cooling rate. The conditions of chondrule formation, however, remain poorly constrained. This is mainly because the reproduction of the chondrule formation processes in a laboratory is experimentally difficult, especially in terms of a container-less arrangement and a reducing (low-fO_2) ambient. In the present study, we developed gas-levitation system embedded in ambient-controlled tube furnace in order to reproduce micro-textures of chondrules, and to constrain their formation conditions.

Fig 1 shows a summary of the developed equipment. A vertical tube furnace with a SiC heater and an alumina core tube (outer-tube) was used as a heating device. An alumina inner core tube (inner-tube) was inserted into the outer tube, and a gas-nozzle was set at the top of the inner-tube. H_2+CO_2+Ar mixed gas were separately introduced into the both inner and outer core tubes from a gas port at the bottom of the tubes. The inner tube with the gas-nozzle can move up and down by a motor-controlled pantograph, and thereby the seamless switching from a sample exchange positon to maximum temperature position is possible. Levitated samples can be observed in situ by a long focal CCD camera.

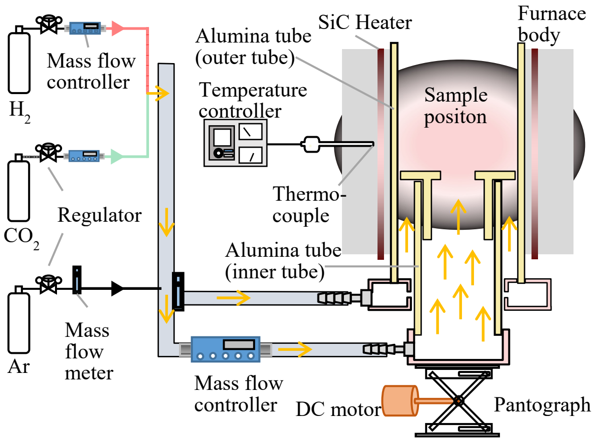

Fig.1. Schematic diagram of the present system.

Using the above system, we demonstrated the containerless cooling experiments for molten silicate droplets. As stating materials, (i) natural peridotite (analogue to a Fe-poor chondrule) and (ii) oxide mixture corresponding to a type IIA (Fe-rich) chondrule were used. They were melted at 1773 K for durations of ~5 min and cooled with a rate of 10^4 K/hr under a reducing condition ($\log fO_2$ = IW-1) in the above system. In the recovered samples of (i) (Fig.2), residues of original olivine (Fa~10) were surrounded by overgrown Fe-poor olivine (Fa6) with zig-zag surfaces (Fig.2c). In the molten area, both platy (3-12 μm thickness) and porphyritic (3-20 μm) olivines were observed (Fig.2d, e). Both of them showed distinct chemical zoning and are embedded in Al_2O_3-SiO_2-rich glass. The recovered samples of (ii) were thought to be experienced by fully molten states (Fig.3). They shows also both platy (10-50 μm thickness) and porphyritic (10-20 μm) olivine embedded in an SiO_2-FeO-rich glass. Previous studies suggest that porphyritic chondrules were formed from partially molten states while nonporphyritic chondrules from fully molten states. In the present study, even from fully molten states, porphyritic olivines were crystallized, although they are small (compared to actual porphyritic olivines) and show chemical zoning. At least, for the formation of porphyritic olivine, a partially molten state is not only sufficient condition. The demonstrations of the present study show that reducing-gas levitation experiments is a powerful technique to simulate the molten-quenched texture of early solar materials.

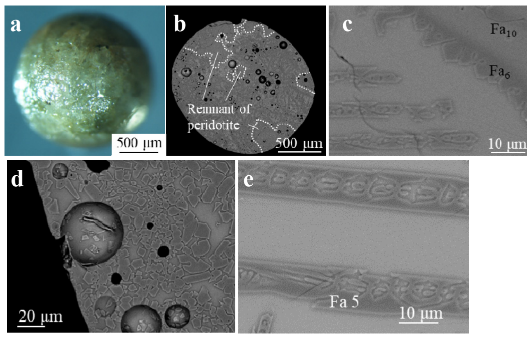

Fig.2. (a) Optical micrograph and (b-e) BSE images of quenched droplets of peridotite. (a) Surface. (b) Overall section. (c) Mg-rich olivine overgrown on remnant olivine. (d) Porphyritic olivine and (e) tabular/ skeletal olivine grown in the molten area.

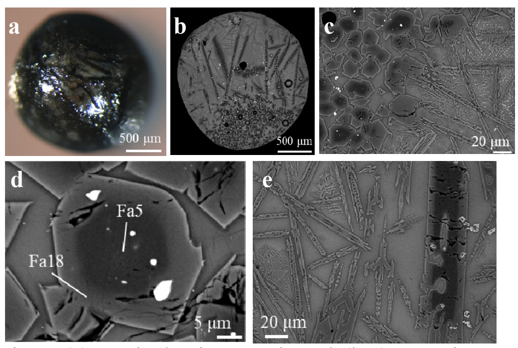

Fig.3. (a) Optical micrograph and (b-e) BSE images of quenched droplets of type IIA composition material. (a) Surface. (b) Overall section. (c-e) Tabular and porphyritic olivine are crystallized at each specified area.