Reproduction of chondrules using ambient-controlled levitation system

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Chondrules are round (or irregular) shaped particles with sizes ranging of 0.1 –10 mm. They are mainly composed of silicates, iron metals and iron sulfides, and thought to be formed by the rapid cooling of fully or partially molten droplets before they accreted. They show unique and diverse internal micro-textures (e.g., porphyritic olivine, barred olivine, radial pyroxene, etc.) which reflect not only a composition of the stating material, but also 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-fO2) 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.
A summary of the newly developed equipment is as follows. A vertical tube furnace with a silicon carbide heater (double coiled spiral type) and an alumina core tube (OD 50mm, ID 42 mm, referred to as “outer-tube” hereafter) was used as a heating device. An alumina inner core tube (OD 32mm, ID 26 mm, referred to as “inner-tube” hereafter) was inserted into the outer tube, and an amorphous-carbon gas-nozzle (blowout hole diameter of 1 mm) was set on 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, and gas flow rates were controlled by digital mass flow controllers. 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 were observed by a long focal CCD camera thorough mirrors and infrared filters. To avoid lowering of the image contrast due to incandescence above 1500 K, area around the sample were irradiated by a system of high-power LED (20W) and large-aperture lens.
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 (F-rich) chondrule were used. They were melted at (i) 1773 K and (ii) 1673 K for durations of ~5 min and cooled with a rate of 10^4 K/hr under a reducing condition (log fO2 = IW-1) in the above system. Surfaces and internal textures of the recovered samples were analyzed using SEM-EDX. In the recovered samples of (i), residues of original olivine (Fa~10) were surrounded by overgrown Fe-poor olivine (Fa6) with zigzag surfaces. In the molten area, both platy (10 μm thickness) and porphyritic (3-20 μm) olivines were observed. Both of them showed distinct chemical zoning and are embedded in Al_2O_3-SiO_2-rich glass. The samples of (ii) were thought to be experienced by fully molten states. They shows also both platy (100 μm thickness) and porphyritic (10-30 μm) olivine embedded in an Al_2O_3-SiO_2-rich glass. Although previous studies suggest that porphyritic chondrules were formed from partially molten states while nonporphyritic chondrules from fully molten states, the present results indicates that porphyritic texture is still possible to be formed from fully molten states. 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.

Keywords: chondrule, gas levitation , quench texture