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原始太陽系星雲の高温過程で形成されたコンドリュールの再現実験

Reproduction experiments of chondrules formed at high-temperature processes in the protoplanetary disk

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1. Introduction

Chondrules are small solid particle with a diameter of about 1 mm occur in primitive chondritic meteorites (Figure 1) and are the major component of solid particles that were suspended in the protoplanetary disk. Chondrules are thought to have been produced by high-temperature heating of the precursor dust in the no gravity conditions of the protoplanetary disk, followed by various rates of cooling, but the specific formation mechanism has not been specified[1-3]. The main reason is that the structure and the elemental distribution of chondrules cannot be reproduced perfectly by ground-based experiments. In this study, we aim to reproduce chondrules in microgravity experiments in the ELF equipment.

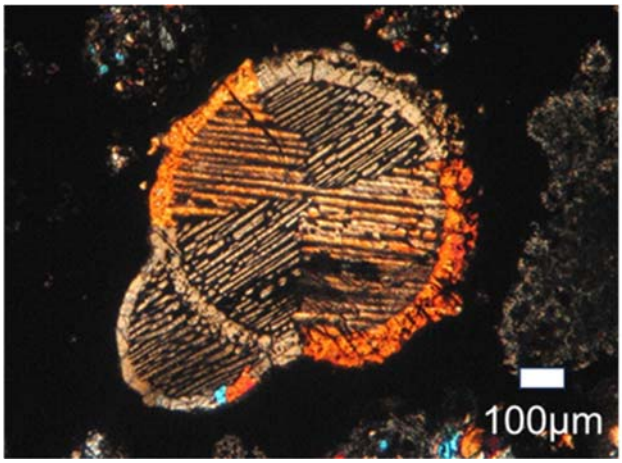

Figure 1. Barred olivine chondrule.

Chondrules are classified into several categories based on their textures, and the chondrule that we will

reproduce in this experiment is barred-olivine (BO) chondrule (Figure 1). We chose this type of chondrule because (i) it was formed by total melting of the precursor material, which clearly constrains the melting and cooling conditions in the experiment, and thus the high-temperature phenomena that occurred in the nebula, (ii) it has a characteristic texture (Figure 1: barred olivine and glass between them, with an olivine rim surrounding the whole structure). (iii) because it is easy to determine the success or failure of reproducible experiments.

2. Experiments at ELF

In this experiment, starting materials has chemical composition of BO chondrules in meteorites (Table 1). The starting material is heated to a temperature (about 1700°C) to melt total and then cooled to approximately 700°C by various cooling rates (0.5 K/s to 100 K/s in the crystallization temperature range). The detailed cooling profile will be determined basis on simulations based on phase field theory and the results of ground experiments. In developing the experimental conditions, we would like to perform experiments that reproduced perfectly the texture and compositional features as seen in natural BO chondrules. Table 2 is the updated success criteria for our experiment.

Table 1. Chemical compositions of starting material.

	Type I	
Na_2O	1.5	mol %
MgO	46	mol %
Al_2O_3	4.5	mol %
SiO_2	38	mol %
CaO	4.5	mol %
FeO	5	mol %
NiO	0.5	mol %

Table 2. Updated success criteria of our experiment.

Success	Criteria
Minimum Success	To obtain the temperature history of the sample from melting to solidification. To recover the solidified samples to the earth. To obtain information on the internal structure and composition of samples solidified at different rates of cooling.
Full Success	In addition to the above, one of the following must be possible The olivine bar structure found in natural chondrules is formed. Form part of the olivine rim structure. Investigate the effects of vibration on the rim bar structure.

Extra Success	In addition to the above, one of the following must be possible. Rim structures covering the entire chondrule can be formed. Rims of different thicknesses can be formed under different conditions. Elemental fractionation between olivine (bar and rim structures) and glass can be reproduced.

4. Summary

Chondrules are the major building blocks of the asteroids and the Earth, they are the most important solid particles in the formation of the inner solar system bodies [1]. Therefore, to uncover the chondrule formation mechanism and the heat source is one of the most important issues in solar-system science. If we can reproduce the BO chondrules perfectly in terms of texture and elemental distribution in our ELF experiments, the obtained conditions for chondrule formation (e.g., cooling rate and surface vibration) will provide strong constraints on the currently available many models of chondrule formation (Figure 2).

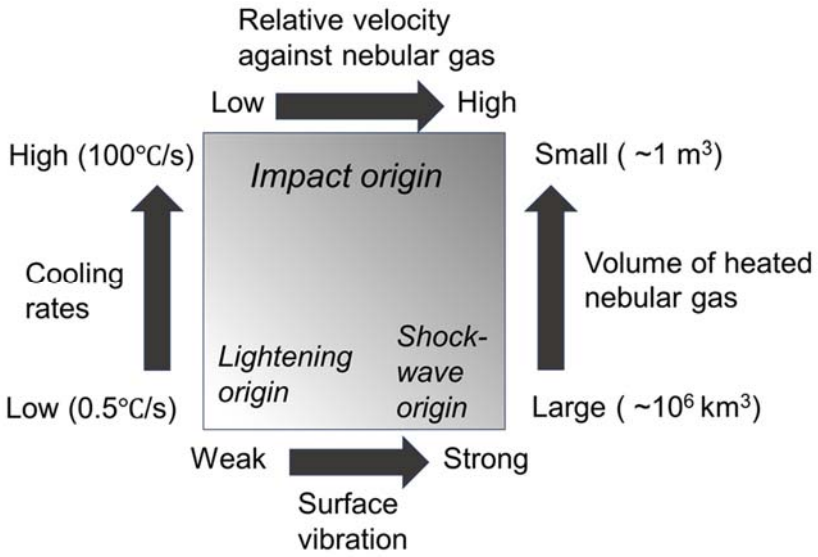

Figure 2. Relationship between chondrule formation conditions and corresponding formation models.

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