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浮遊法による放射状輝石コンドリュールの組織再現実験
Experimental reproduction of textures of radial pyroxene chondrules by a gas-jet levitation

野村 逸郎[1*] ; 中村 智樹[1] ; 木村 勇気[2] ; 塚本 勝男[3] ; 三浦 均[4] ; 上椙 真之[5] ; 上杉 健太朗[6] ; 星野 真人[6]
NOMURA, Itsuro[1*] ; NAKAMURA, Tomoki[1] ; KIMURA, Yuki[2] ; TSUKAMOTO, Katsuo[3] ; MIURA, Hitoshi[4] ; UESUGI, Masayuki[5] ; UESUGI, Kentaro[6] ; HOSHINO, Masato[6]

[1] 東北大学大学院理学研究科, [2] 北海道大学低温科学研究所, [3] 大阪大学大学院工学研究科, [4] 名古屋市立大学大学院システム自然科学研究科, [5] 宇宙航空研究開発機構, [6] 高輝度光科学研究センター
[1]Graduate School of Science, Tohoku University, [2]Institute of Low Temperature Science, Hokkaido University, [3]Graduate School of Engineering, Osaka University, [4]Graduate School of Natural Sciences, Nagoya City University, [5]Japan Aerospace Exploration Agency, [6]Japan Synchrotron Radiation Research Institute

Chondrules, igneous silicate spherules, formed by transient heating and rapid cooling, are ubiquitously contained in primitive chondrites. But, the formation conditions of chondrules in the protoplanetary disks are still unclear. In order to constrain the formation conditions of chondrules, a number of reproduction experiments in a electric furnace have been performed (e.g., Tsuchiyama et al., 1980). In these experiments, a melt droplet sample was hung on a platinum wire and thus the melt did contact with a platinum loop wire, possibly leading to heterogeneous nuclation near equiribrium temperatures. While, Tsukamoto et al. (2000) started a non-contact method, namely acoustic levitation method and microgravity levitation for the first time for chondrule synthesis, followd by Nagashima et al. (2006) who employed a gas jet levitation method. In both cases, space envieronment was simulated because crystallization of a melting silicate sphere occurs in a levitated condition.

In this study, we performed experiments to reproduce the textures of radial pyroxene chondrules using the gas jet levitation furnace used in Nagashima et al. (2006). Samples are 1-2mm spheres and chemical compositions of the samples are similar as of the natural radial pyroxene chondrules excluding iron. The sample was completely melted at about 1600-1800 ℃ with a 100W CO_2 laser and cooling rate after heating was about 10^4-10^6K / hr. We used an argon gas in order to levitate samples. After the experiment, the samples were analyzed by optical microscope and scanning electron microscope. Three dimensional images of the internal texture were also obtained after crystallization using X-ray computed tomography at at SPring-8 (BL20B2).

The textures similar to natural radial pyroxene chondrules were reproduced at the cooling rates of about 10^4K/hr. At faster cooling rates (10^5-10^6K/hr), samples became transparent glass without any crystals. These glass chondrules rarely exist in nature. The cooling rates (~10^4K/hr) that successfully reproduced chondrules are slower than the calculated cooling rate (10^6K/hr) of the melt whose temperature decreases by radiation alone in vacuum. When the nucleation center of the radial texture was observed by high magnification optical microscopy, there in most cases exists a tiny particle that is different from the radial pyroxene. This implies the importance of the heterogeneous nucleation from the tiny particles, which might be formed prior to the formation of the radial texture or impurities simply coming from dusts or the chemical reagent. These experimental data would lead to a discussion on the chondrule formation in the protoplanetary disk in the presence of gases that slowed down the cooling.

Keywords: chondrule, radial pyroxene chondrule, gas jet levitation