For Understanding of Fundamental Process of Chondrule Melt Crystallization

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Chondrules are millimeter-sized, once-molten, spherical-shaped crystalline grains primarily consisting of silicate materials. They are considered to have formed from chondrule precursor dust particles about 4.6×10^9 years ago in the solar nebula. It is believed that they were heated up to their melting point through flash heating events and cooled again to get solidified in a very short period of time. Chondrules occupy about 80 vol.% of chondritic meteorites in abundant cases, so they are one of the main components of natural rocks and minerals. Therefore, understanding of chondrule formation mechanisms is important to elucidate the evolution of silicate materials in early solar nebula.

To investigate the formation conditions of chondrules, various researchers have carried out many experimental studies. A sample of chemical composition similar to chondrule was heated and subsequently melted in, e.g., electronic furnace and then allowed to cool down and get solidified under controlled experimental conditions. The comparison between the experimental products and natural chondrules in terms of solidification textures and chemical zoning has provided us a lot of information. However, the fundamental mechanisms of formation of various solidification textures was are yet to be fully understood.

In this context, we have adopted some novel approaches to understand the fundamental process of chondrule melt crystallization; *in-situ* observation of the crystallization process and the numerical simulation based on theory of crystal growth. We first succeeded in reproducing rim-bar structure similar to barred-olivine texture of natural chondrules by using levitation methods [1]. *In-situ* observation of the crystallization process showed that the crystallization could be initiated at very large values of supercooling (~ a few hundred K or more), and never at lower supercoolings [2]. The crystallization speed is so fast that it took only about 1 sec or even less for the completion of the entire process of crystallization. The rapid crystallization results into the stochastic temperature increase due to the release of latent heat of crystallization, a phenomenon known as recalescence. Our numerical simulations showed that large temperature heterogeneity (~ a few hundred K) appears in a mm-sized melt during crystallization and it causes very complex crystallization patterns inside the melt. These new results are important to elucidate the formation mechanisms of chondrule solidification textures and their varieties.

Keywords: thermal processing; early solar nebula; chondrule; crystallization;

References

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