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Melting and crystal growth textures developed in rapid heating and cooling of olivine fine particles

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Olivine is one of the most common mineral in the solid Earth and chondritic meteorites. Olivine crystals show characteristic textures in chondrules depending on heating and cooling histories in chondrule formation processes at the early solar system. In this study, quick heating and cooling experiments of mixed olivine particles were carried out with a fine particles free falling apparatus (Isobe and Gondo, 2013). In the run products, characteristic melting and crystal growth textures controlled by phase relations, diffusion, and nucleation and growth behavior of olivine can be seen.

Starting material is mixed powder of natural olivine (Fo90), fayalite and an artificial olivine (Fo55). The typical diameter of the starting material particles is approximately 100 micron meters. Each particle is single crystal of olivine or mixture of two or three kinds of raw materials. Heating and cooling experiments are carried out in a high temperature furnace with mass flow controllers to regulate oxygen fugacity and total gas flow rate. Particles can be heated to 1400 degrees C within two seconds, are kept over 1400 degrees C approximately one second and quenched within a second. Maximum temperature has negative correlation to diameter of the particles, and cooling rate has positive correlation to the diameter depending on the falling velocity of the particles. Run products show spherical shape when the particles mostly melted, and are crystal fragments when the particles did not melt. The outside shape of the retrieved run products are observed with a scanning electron microscope. Inner textures of the particles are observed on polished section of the particles. Chemical compositions are also analyzed on the sections.

Fayalite grains are completely melted and Fo90 olivine grains are not melted by themselves concordantly with the phase relation of olivine. Internal textures of Fo55 olivine crystals show quick partial melting when the temperature reach solidus temperature. In the mixed olivine particles, relict crystals of Fo90 and Fo55 olivines dissolve to iron-rich melt derived from melting of fayalite. The dissolution of relict crystals produce steep chemical gradient at interface between crystals and melt.

Run products like barred olivine chondrules or melted cosmic spherules are produced from completely melted particles. In the particles including relict crystals, overgrowth textures from the relict crystals can be seen. Dendritic olivine crystals with regulated crystallographic orientation are developed in melted particles. Surface texture of melted particles may be affected by the dendritic olivine crystals. Oriented magnetite dendrites may also occur between olivine crystals when oxygen fugacity was in the magnetite stability field. Melting, nucleation and crystal growth processes in a few seconds can be discussed from the textures in the run products.

Keywords: Olivine, chondrule, nucleation, crystal growth, dendrites, quench texture