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Crystal growth textures developed in rapid 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 with controlled gas flow (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 depending on maximum temperatures and cooling rates.

Starting material is mixed powder of natural olivine (Fo90), fayalite and an artificial olivine (Fo57). 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. Oxygen fugacity is controlled to average of FMQ and IW buffer curves in log unit. In the each run, maximum temperature of particles is just above 1500 degree C or 1400 degree C. Gas flow rates are 2.6, 1.3 or 0.65 l/min@RT. Particles can be heated to the maximum temperature within two seconds, are kept 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 Fo57 olivine crystals show quick partial melting when the temperature reach solidus temperature. Then, compositional ranges of quench crystals developed in fractional crystallization show negative correlation to cooling rates. Growth rate of quench growth olivine may be much higher than homogenization in heterogeneous silicate melt.

In the mixed olivine particles, relict crystals of Fo90 and Fo57 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. Melting kinetics of Fo90 olivine produces quite characteristic projections from the surface of spherules.

Textures of quench growth olivine on relict crystals resemble to hourglass shape. Compositions of the quench crystals range between Fo50 and Fo20. Solidus temperatures of olivine in this compositional range may keep supercooling in quenching processes.

Keywords: Olivine, melting textures, nucleation, crystal growth, dendrites, quench textures