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浮遊液体から急速成長する放射状結晶の微細構造

Micro-texture of Spherical Radial Crystals in Levitated Liquid Droplets

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1. Introduction

Silicate minerals are the materials which compose large part of the Earth and other planets in the solar system. These minerals were originally formed before the birth of the planets from cosmic dusts that melted to form chondrules. Chondrules are mm sized small spheres and mainly made of Mg_2SiO_4(Olivine) and $MgSiO_3$(Pyroxene)[1, 2]. These are mainly present in meteorites and samples that returned from asteroids by satellites. Enstatite is one of the pyroxene polymorphs and often forms radial textures as in Fig.1. Enstatite is known to have five polymorphs depending on temperature. This was investigated during annealing of the glass samples and no direct crystallization experiment has been done. In case of cooling experiments, phase-transition has to be taken into account during growth, which makes us difficult to analyze the mechanism. This is the reason why we continue precise observation in atomic level.

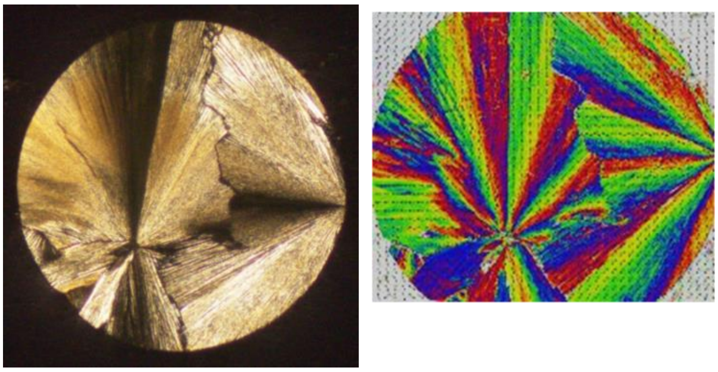

Figure 1 Radial pyroxenes, 0.8 mm in diameter. (a) by polarization microscopy, and (b) by optical main axis mapping showing the orientation of needle crystals.

Radial textures are rapidly grown from organic melts, solutions and glasses. Since these chondrules possess a lot of information on the origin of the early solar nebula 4.6 billion years ago, lots of studies have been done in space science. However, the origin of these needle crystals composing the radial texture has not been studied well, although discussion on the origin of metastable pyroxene had be started already in 1960’s. Therefore, the main aim of this investigation is to understand why each needle continue to grow as needles till the end of growth. Here we present the peculiarity of micro-textures of these needles for the analysis of growth mechanism of needles and then of radial textures.

2. Experimental

The radial enstatite chondrules were synthesized by gas jet levitation the enstatite melt droplet never crystalized at any supercooling and thus we sprayed enstatite particles as the seeds of crystallization to the melt surface at wide range of supercooling, $\Delta T \cong 300\text{-}1000K$ (melting point of enstatite is 1594-1549℃). The specimens were heated by 100W CO_2 laser.

3. Observation and Discussion

Specimens of the synthesized chondrules, 1-2 mm ϕ were thin sliced, 200 μm thick for optical observation. For TEM and STEM observations, EBSD was used to study the orientation and then cut by FIB normal to the elongation, the <001>, and parallel to the elongation. STEM was employed to get atomic resolution of enstatite for the study of origin of needles and planner defects as well as HRTEM. Polarization microscopy, micro-Raman spectroscopy, confocal-microscopies and maximum optical mapping method using phase-shift principle were employed as well.

Fig.2 is the TEM image of the section normal to the elongation, the <001>. It was expected that the needles consist of a single polymorph but was found to consist of two polytypes with different stable temperatures like the texture of sandwich. Outer part sandwiches the inner part as shown in Fig.2. The former is analyzed to be metastable protoenstatite pyroxene and the latter stable clinoenstatite with higher stability temperature. This means that outer part was formed first and then the inner part, which leads us difficulty to make a growth model. Fig.3 is a STEM micrograph which shows, for the first time, real atomic arrangement of the orthopyroxene. Observation results from two orientations are now being analyzed.

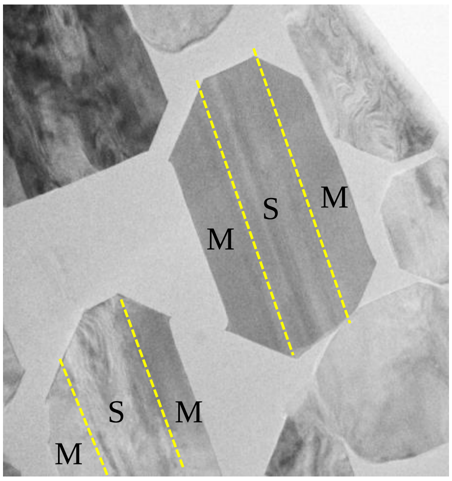

Figure 2 TEM image of the Fig.1 crystal. The needles were cut normal to the direction of radiation orientation. Note that each crystal is nearly apparel and sandwiched texture, namely the central part was sandwiched by another polymorph. M: metastable and S: stable crystals.

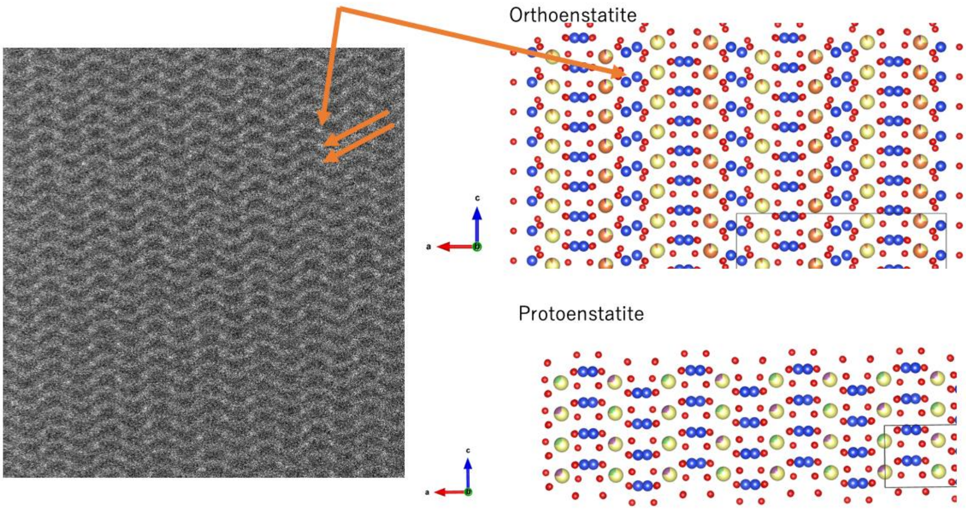

Figure 3 STEM images with the corresponding possible crystal structure of Orthoenstatite (stable polymorph at lower temperature). Clinoenstatite is next stable polymorph. Metastable is protoenstatite which is stable up to the melting point. Bright dots with different intensity in the micrograph represent each atom.

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