Silicate Spherulites Rapidly Crystallized from Hypercooled Melt Droplets

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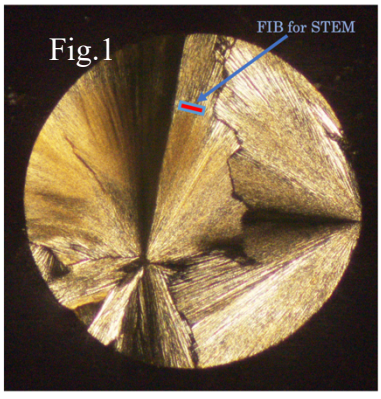
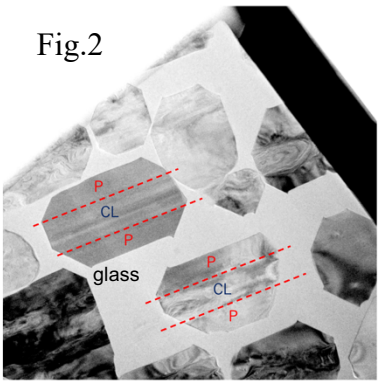
Growth mechanism of radial pyroxenes ($MgSiO_3$) that appear as spherulites in silicate meteorites are important both for space sciences to understand the origin of our solar system and for the formation of the peculiar crystal texture, the latter of which is the main aim of this study.

We have synthesized radial pyroxene texture by using gas jet levitation method at large supercooling >200K. Various microscopies were applied to these crystals to reveal the microstructure of spherulites. Especially STEM (atom resolved-scanning electron microscopy) was very powerful to discern slight difference of atomic arrangement of the crystal structure of needles which compose the radial pyroxene texture, Fig.1. Pyroxene shows variety of polytypes with the stable temperatures in the phase diagram for proto-pyroxene (at >1000℃ with liquidus temperature of 1600℃), ortho-pyroxene (600-1000℃) and clino-pyroxene (<600℃). The last one is the most stable. Two specimens for TEM, normal and parallel to the elongation of the needles were made by FIB. Fig.2 is from the former orientation.

The fist surprise was to find that the needles do not consist of single crystals but of two polymorphs, metastable proto-pyroxene, outside and stable cline-pyroxene, inside, with the sandwiched texture which consists of two types of thin long platelets, Fig.2. The second surprise was the presence of metastable proto-pyroxene, which is believed, if it were formed, to be phase-changed immediately to the stable clino-pyroxene and thus should not be present. Therefore, the physical property and the crystal structure were obtained only from the crystals that were synthesized by solid state reaction. Discussion will be made on these surprising points to present the growth model of this type of spherulites. It was later found that this type of sandwich structures is often find also in other silicate crystals and thus seems general.





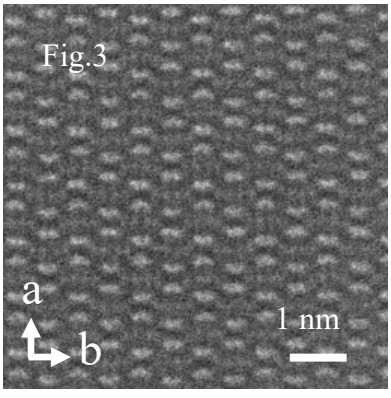


Fig.1: Radical pyroxene imaged by polarization microscopy, about 1mm ϕ, Fig.2: Normal section to the elongation of the needles, TEM image vertical in the square area in the Fig.1. Note the sandwich structure, stable clino-pyroxene (CL), inside and metastable proto-pyroxene (P), outside. Fig.3: Atomic resolved image by STEM, where brighter dots show silicon atoms and darker dots are magnesium atoms.