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TEM investigation of forsterite dendrites

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ABSTRACT

Transmission electron microscopy (TEM) has been used to investigate dendritic forsterite systematically, in order to understand its morphology in three dimensions. TEM images of olivine dendrites are reported for the first time. Crystals have been obtained by dynamic crystallization in the CaO–MgO-Al_2O_3-SiO_2 (CMAS) system in a one-atmosphere vertical furnace. A fast cooling rate (1890 °C/h) has been used with degrees of undercooling varying from 156 to 356 °C. Different microstructures were observed depending on their location in the dendritic crystal. The external part of the crystal reveals true olivine dendrite propagation, as classically observed in other materials (succinonitrile, alloys). In the inner part of the crystal, this microstructure changes to the formation of single crystalline units with well-defined crystalline faces. The shapes observed are very reproducible. These units are limited by the usual forms of olivine [(010), {021}, {110}, {120}, {101}] and also by less common forms [(001), {130}, {140}] as additional faceting. All these elementary units present the same morphology, the hopper shape that corresponds to the skeletal form of olivine. These units are linked in a peculiar spatial organization giving rise to dendrite branches. It is shown that the [101] preferential direction of growth of dendrites is a mean direction and corresponds to the juxtaposition of these elementary units. In the innermost part of dendritic crystals, a dissolution-recrystallization process of elementary units occurs and a typical textural ripening microstructure is observed. This textural ripening starts early and is coincident with the real dendritic growth (external part of the crystal). Thus, the final appearance of dendritic forsterite crystals mainly results from textural ripening. This study emphasizes that dendritic solidification is a complex phenomenon, and the various microstructures suggest that multiple mechanisms are involved during the formation of so-called dendritic crystals.