EGU23-9162, updated on 25 Apr 2024
https://doi.org/10.5194/egusphere-egu23-9162
EGU General Assembly 2023

What is the cause of lattice rotation in clinopyroxene dendrites?

Thomas Griffiths[1], Gerlinde Habler[1], Olga Ageeva[1], Christoph Sutter[1], Ludovic Ferrière[2], and Rainer Abart[1]

[1]University of Vienna, Department of Lithospheric Research, Vienna, Austria (th.griffiths@univie.ac.at)

[2]Natural History Museum Vienna, Vienna, Austria

Dendritic crystallisation is a key geological pattern-forming mechanism, typical of, and recording information about, rapid crystallization events. In this contribution we report on clinopyroxene (Cpx) dendrites in a basaltic rock fulgurite, which formed due to electrical discharge impacting a basaltic rock. Unusually, these dendrites exhibit a curved morphology. The curved, tapering main dendrite branches are up to 50 µm long, range from 3 µm to 100 nm thickness, and are surrounded by several higher orders of branches, which are also curved. The morphological curvature corresponds to lattice rotation, so branches have consistent elongation directions in crystal coordinates. Total rotation exceeds 180° for some branches, with the highest curvature found being 7° per µm. Such "bent" Cpx dendrites have been observed in experiments (e.g. Hammer et al. 2010), but the mechanism of bending was not previously understood.

By combining microstructural observations with crystallographic orientation maps from electron backscatter diffraction analyses of multiple Cpx dendrites, their three-dimensional morphological and crystallographic configuration was reconstructed. Dendrites feature a planar latticework of branches parallel to the Cpx (010) plane. Branches in this plane are elongated either parallel to {001}* (i.e. normal to the (001) plane) or <10-1>, and exhibit strong and weak lattice curvature, respectively. Sprouting out of this plane are branches parallel to {021}* (originating from {001}* branches) and <12-1> (originating from <10-1> branches), both types being weakly curved. Regardless of the crystallographic direction parallel to elongation, all branches exhibit a crystallographic rotation axis parallel to [010] of Cpx. Furthermore, the rotation sense is consistent regardless of elongation direction in crystal or sample coordinates.

The crystallographic control on the sense of bending and on the rotation axis indicates that bending is not caused by sample-scale compositional, thermal, or mechanical gradients. Instead, asymmetric compositional and thermal fields around branch tips are responsible for bending, supported by the fact that compositional gradients exist in the glass surrounding dendritic crystals. The specific cause of bending is inferred to be asymmetric distribution of melt supersaturation at branch tips, resulting from unequal growth rates of different facets. Branch-tip morphology alone poorly explains the constant sense of rotation of all branches, as the sense of morphological asymmetry is unlikely to be consistent for all branch types. The [010] rotation axis implies that lattice rotation is accomplished by incorporation of a single sign of [001](100) edge dislocations, with a maximum inferred density of $2*10^{14}$ m^{-2}.

This work provides new insights into fundamental processes occurring during rapid crystallization of Cpx and other minerals. Furthermore, microstructural observations suggest that higher degree of undercooling correlates with greater lattice curvature. Bent dendrites may thus encode information about spatial variations in the cooling rate and/or undercooling of samples. Finally, the consistent [010] rotation axis is expected to be preserved during recrystallization, offering a potential way to identify curved dendritic growth stages even after recrystallization.

References:

Hammer et al. (2010), Geology 38:367-370. https://doi.org/10.1130/G30601.1

Griffiths et al. (2022), J Petrol, egac125. https://doi.org/10.1093/petrology/egac125

This contribution was funded by the Austrian Science Fund (FWF): P 33227-N