

Lamellar Fe zoning in low-Ca pyroxene in ordinary chondrites

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Diffusion is an important fundamental process for atomic transportation in rocks. It is well known that dislocation (one-dimensional defect) acts a high-speed diffusion pathway of atoms, namely pipe diffusion. Due to larger spatial connectivity within a crystal than dislocation network, two-dimensional defects such as stacking faults and twinning are also expected to be effective diffusion pathway. Our current study is focusing on natural occurrences of cation diffusion along planar defects in silicate minerals.

Following previous studies on lamellar Fe zoning found in chondritic low-Ca pyroxene [1, 2], we have investigated two unequilibrated ordinary chondrites, Felt (L3.5) and NWA7676 (LL3.5) by electron microcopies. SEM-EDS analyses clarified that a few of low-Ca pyroxene grains in chondrules of both samples showed bright lamellar contrast less than $\sim 10 \mu\text{m}$ in width by back-scattered electron imaging. The lamellar zoning is significantly dominant compared to normal core-rim zoning, and it corresponds to Fe concentration in X-ray chemical mapping. The bright portions were further processed into ultrathin films by focused ion beam equipment and examined by TEM-EDS. The pyroxene grains showed numerous stacking faults on the (100) plane. Its orientation is consistent with that of lamellar Fe zoning observed by SEM-EDS. However, such lamellar Fe concentration has not been clearly seen under TEM-EDS analysis. It is probably due to very small Mg-Fe heterogeneity in a sub-micrometer scale. In Felt, low-Ca pyroxene grain also showed high density of elongated dislocations parallel to the (100) plane. The portion showed distinct lamellar Fe zoning even in sub-micrometer scale.

Stacking disorder on (100) in low-Ca pyroxene in chondrules is thought to have formed during inversion from protoenstatite to clinoenstatite mainly due to cooling from above 1000 °C [3]. The straight dislocation microstructure in Felt would have formed by impact deformation based on its shock stage (S4). The lamellar Fe zoning is likely to have been produced by diffusion along stacking fault planes and dislocation arrays, and subsequent volume diffusion along lateral direction to the (100) plane. The present results preliminary imply that planar defects as well as dislocation array is a potential high-speed atomic diffusion pathway in low-Ca pyroxene during heating events in chondrites.

References:

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