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Oxygen isotopic compositions of melilite in Fluffy Type A CAI from Efremovka meteorite

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Calcium-Aluminum-rich inclusion (CAI) is the oldest rock in the solar system and preserves a record of events in the early solar system. Reversely zoned crystals of melilite have been found in Fluffy Type A CAIs, and have been condensed directly as solids from a hot nebular gas in the early solar system (MacPherson and Grossman 1984). In this study, oxygen isotopic compositions and chemical compositions of melilite crystals in a Fluffy Type A CAI of Efremovka CV3 chondrute has been described. A polished thin section of the CAI was used. Petrographic studies and the chemical compositions have been measured by a field emission type secondary electron microscope equipped with an energy dispersive spectrpmeter (FE-SEM-EDS, JEOL JSM-7000F; Oxford INCA Energy). Crystal orientations of the CAI melilite have been determined by an electron back scattered diffraction system (EBSD, HKL Channel 5) equipped with the SEM in order to determine crystal boundaries of the melilite grains. Oxygen isotopic compositions have been measured by secondary mass spectrometry (SIMS, Cameca ims-1270).

The CAI is 10 x 3 mm in size with fluffy shape. The CAI has core-mantle structure. The core part contains of large amounts of spinel which are poikilitically enclosed by anorthite, melilite and Al-Ti-rich diopside. The mantle part mainly consists of melilite, Al-Ti-rich diopside. The abundance of spinel is smaller than in the core part. A Wark-Lovering Rim (WL-Rim) surrounds the mantle. Typical size of mantle melilite crystal is 15-25 micrometers. From the distribution of chemical compositions and oxygen isotopic compositions of melilite in the mantle are classified into two distinct regions.

The first region in the mantle, domein-1, shows that melilite crystals positioned shallower than ~200 micrometers in depth from the WL-Rim have grown as reverse zoning, Compositions of the crystal center and grain boundary are ~ak25 and ~ak5, respectively. The oxygen isotopic compositions of single crystals are distributed homogeneously within the analytical error. However, oxygen isotopic compositions are systematically changed among crystals. The melilite crystals positioned near WL-rim are more 16O-rich (DELTA-17O=-19 permil) while the melilite crystals near the CAI core are 16O-poor (DELTA-17O=-4 permil). The oxygen isotopic compositions change continuously from rim to core of the CAI.

The second region in the mantle, domein-2, melilite crystals positioned shallower than ~40 micrometers in depth from the WL-Rim have grown as reverse zoning. Compositions of the crystal are ~ak25 in the center and ~ak8 at the grain boundary. While the melilite crystals of domein-2 positioned deeper than the ~40 micrometers have grown initially as reverse zoning and then grown as normal zoning, i. e., oscillated. The compositions are ~ak30 in the center, ~ak45 in the intermediate, and ~ak55 at the grain boundary. Typical width of the normal zoning part is 2-5 micron. Oxygen isotopic composition of melilite crystals existed in the domein-2 are homogeneously distributed, DELTA-17O=-3, despite of complex growth patterns.

The oxygen isotopic heterogeneity observed in the domein-1 suggests that oxygen isotopic ratios of nebular gas surrounding the melilite growing did not changed during the growth of each melilite crystal, while gradually changed from 16O-poor to 16O-rich during the total duration of melilite formation of domein-1. In this nebular condition, the melilite was directly condensed form the nebular gas and accumulated together. The oxygen isotopic compositions observed in domein-2 suggest that the melilite seems to be directory condensed from 16O-poor nebular gas and accumulated together. Then the domein-1 and domein-2 were accreted together. After that, moderate heating of the CAI occurred. Grain boundaries of melilite of domein-2 were partially molten because of the high ak compositions. The normally zoned melilite was overgrown on relicts of melilite during cooling.

Keywords: CAI, melilite, oxygen isotope, solid solution, chondrite