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Oxygen isotope zoning in reversely zoned melilite in Fluffy Type A CAI from Vigarano meteorite

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The oxygen isotopic variations of each mineral in the Ca-Al-rich inclusions (CAI) are due to mass-independent fractionation and plot along a CCAM line with slope of ~1 (Clayton et al., 1973). These variations indicate that CAI minerals were not derived entirely from a chemically homogeneous, well-mixed reservoir, but from mixing of ^{16}O-rich and ^{16}O-poor reservoir (e.g., Clayton., 1993). In previous in-situ oxygen isotope analyses, the oxygen isotope distribution of each CAI mineral go along a CCAM line results from the oxygen isotope exchange among ^{16}O-poor gas reservoirs and ^{16}O-rich CAI melt occurred by multiple partial melting process in the CAI forming region (Yurimoto et al., 1998). In addition, the oxygen isotopic compositions of each mineral in fine-grained CAI condensed from gas are enriched in ^{16}O (e.g., Krot et al., 2002). However, the relationship among two reservoirs in the CAI forming region is not clear.

Fluffy Type A CAI (FTA) condensed as solids from the hot solar nebular gas, based on their irregular shaped and the existence of reversely-zoned melilite crystals (MacPherson and Grossman, 1984). Therefore the intra-grain distribution of oxygen isotopes in FTA is critical to discussion of the oxygen isotopic composition of nebular gas, because these inclusions are believed to be direct condensates from the nebula (Yurimoto et al., 2008). In this study, we report the in-situ oxygen isotope distribution corresponding to the reversely-zoned melilite crystal in order to estimate the relationship between ^{16}O-rich and ^{16}O-poor gas reservoirs in the CAI forming region.

X-ray mapping with ~ 1 micron spatial resolution using FE-SEM-EDS determined compositional zoning of melilite crystals. Grain boundary was determined by orientation mapping using FE-SEM-EBSD. A line profile of oxygen isotope distribution of melilite crystal was obtained across the reversely zoning using Cameca ims-1270 SIMS with 3-5 micron spot.

Most melilite crystals in V2-01 FTA show the reversely zoned melilite using the estimation of grain boundary of melililte crystal with the effect of deformation and compaction in the parent body. The intra-grain distribution of oxygen isotopes in melilite crystals indicates that some melilite crystals show the oxygen isotope zoning with ~ 30permil whereas shows no oxygen isotopic zoning. Two melilite single crystals (Grain 8 and 21) were estimated oxygen isotopic zoning with line profile correlated with reverse zoning. In the reverse zoning of Grain 8, ak content gradually change with the range of ~ 90 micron from core (~ak_{14}) to rim (~ak_5). The oxygen isotopic ratio changes with the range of ~ 40 micron from ^{16}O-poor (delta$^{18}O_{SMOW}$=-20permil, ~ ak_8) to ^{16}O-rich (delta$^{18}O_{SMOW}$=-30permil, ~ ak_5). In the reverse zoning of Grain21, ak content gradually change with the range of ~ 65 micron from core (~ ak_{23}) to rim (~ak_2). The oxygen isotopic ratio changes with the range of ~ 15 micron from ^{16}O-poor (delta$^{18}O_{SMOW}$=-15permil, ~ak_4) to ^{16}O-rich (delta$^{18}O_{SMOW}$ =-40permil, ~ak_2). This means that the line profile shows, correlated with a gradual decrease in akermanite content, a change of oxygen isotopic ratios from ^{16}O-poor to ^{16}O-rich in the range of 15~40 micron.

These results indicates that oxygen isotopic compositions of the gas reservoirs changed from ^{16}O-poor to ^{16}O-rich during crystallization of single melilite crystals. As results, there are gas reservoirs with oxygen isotope fluctuation changes from ^{16}O-poor to ^{16}O-rich in the CAI forming region.