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Oxygen isotopic distribution of Fluffy Type A CAI from Efremovka

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A formation process of planetesimals from dust grains is most uncertain part in the planetary formation theory. The dust grains in the micron-to-centimeter size range are preserved in chondrite. Especially, "fluffy" shaped Type A Ca-Al-rich inclusions (FTA CAIs) are aggregates of domains that contain micron-sized grains thought to be condensed from the nebular gas. In the CAI-forming region, distinct ^{16}O-rich and ^{16}O-poor gaseous reservoirs are considered to be co-existed (Yurimoto et al. 2008). In this paper, we study petrology and oxygen isotopic distribution of a FTA CAI from Efremovka CV3 chondrite in order to reveal the growth process and the environment of the grain size evolution.

FE-SEM-EDS-EBSD system (JEOL JSM-7000F; Oxford INCA Energy; HKL Channel 5) was used for petrologic study. Oxygen isotopic compositions have been measured by SIMS (Cameca ims-1270).

The CAI is 1 cm x 4 mm in size with "fluffy" shape and surrounded by the Wark-Lovering rim (WL rim). The CAI is divided into two domains that named as domain-1 and domain-2. The WL rim surrounds each domain.

In the domain-1, melilite crystals near the WL rim show reverse zoning and are observed as a layer of ˜40 micron in width. The reverse zoning is typically ak30 in the center and ak15 at the grain boundary. Melilite crystals inside of the layer show oscillatory zoning, initially started as reverse zoning and changed to normal zoning. The compositions are ak35 in the center, ak30 at intermediate, and ak40 at the grain boundary. The oxygen isotopic compositions of the melilite crystals in the domain-1 are distributed homogeneously, delta-^{18}O = 5-10 permil. In the domain-2, melilite crystals positioned shallower than ˜150 micron in depth from the WL rim show reverse zoning that are typically ak15 in the center and ak5 at the grain boundary. The oxygen isotopic compositions of these crystals are distributed along CCAM line ranging between delta-^{18}O = -40 and 0 permil and change from ^{16}O-rich to ^{16}O-poor with the distance from WL rim.

Reversely zoned melilite crystals in FTA CAIs are readily explained by the condensation from a solar nebular gas with falling pressure (MacPherson and Grossman 1984). The reversely zoned melilite crystals in the domain-1 and the domain-2 were also condensed from the nebular gas with decreasing pressure. The oscillatory zoned melilite crystals may be the result of overgrowth of normal zoning on the grain boundary of partially molten reversely zoned melilite crystals. The homogeneous oxygen isotopic composition in the domain-1 indicates melilite crystals were formed in a ^{16}O-poor nebular gas. On the other hand, the oxygen isotopic distributions observed in the domain-2 suggests that the gas was changed from ^{16}O-poor to ^{16}O-rich during the condensation of melilite.

Typical compositions of the reversely zoned melilite crystals in the domain-1 and the domain-2 are ak30-15 and ak15-5. They formed below the eutectic temperature of melilite and fassaite. According to Yoneda and Grossman (1995), these crystals condensed below 1570 K and lower pressure than 10^{-2} atm. If the temperature is constant, the pressure of the gas surrounding the reversely zoned melilite crystals in the domain-2 is about 1.5-2 times lower than that of domain-1. For example if the temperature is 1400 K, the pressure was changed from 3.2 x 10^{-4} atm to 2.2 x 10^{-4} atm for domain-1, and from 2.2 x 10^{-4} atm to 9.7 x 10^{-5} atm for domain-2. However these conditions seem to be occurred continuously, the oxygen isotopic compositions of the melilite grains in each domain indicate that they were formed in the different nebular environment and incorporated into the FTA CAI.

In this study, we revealed that the micron-sized dust grains that were condensed from gas experienced different nebular environment during the accumulation to millimeter-sized domains. These domains were accreted together to form the centimeter-sized FTA CAI.

Keywords: Fluffy Type A CAI, melilite, chemical zoning, dust coagulation, oxygen isotopes, solar nebula