

OXYGEN ISOTOPIC COMPOSITIONS AND CHEMICAL ZONING OF MELILITE CRYSTALS IN FLUFFY TYPE A CAI FROM EFREMOVKA CV3 CHONDRITE. N. Kawasaki¹, N. Sakamoto² and H. Yurimoto^{1,2}, ¹Natural History Sciences, Hokkaido University, Sapporo 060-0810, JAPAN (kawasaki@ep.sci.hokudai.ac.jp), ²Isotope Imaging Laboratory, Creative Research Institution "Sousei", Hokkaido University, Sapporo, 001-0021, JAPAN.

Introduction: Coarse grained CAIs have heterogeneous distributions of oxygen isotopic compositions among their constituent minerals, and mixing of ^{16}O -poor and ^{16}O -poor nebular gases occurred frequently in the CAI-forming region [1, 2]. Reversely zoned melilite crystals found in fluffy Type A CAIs are readily explainable by condensation from a solar nebular gas during a period of falling pressure [3]. Therefore, the oxygen isotopic distribution of reversely zoned melilite crystals in fluffy Type A CAIs is critical to the discussion of oxygen isotopic compositions of nebular gas. Here we report the oxygen isotopic compositions and chemical zoning of melilite crystals in a fluffy Type A CAI of Efremovka CV3 chondrite.

Experimental: A polished thin section of the Efremovka CV3 chondrite was used. Petrographic studies and the chemical compositions have been measured by a field emission type secondary electron microscope equipped with an energy dispersive spectrometer (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 of melilite crystals have been measured by secondary ion mass spectrometry (SIMS, Cameca ims-1270). A Cs^+ primary beam (10 keV, 60-100 pA) of 3-10 μm diameter was used. $^{16}\text{O}^-$ was measured by faraday cup while both $^{17}\text{O}^-$ and $^{18}\text{O}^-$ were measured by electron multiplier. In order to correct instrumental mass fractionation, a synthetic åkermanite was used as a standard.

Results: The CAI is 10×3 mm in size with "fluffy" shape. The CAI is mainly composed of melilite (60%), fassaite (20%), spinel (15%), and contains diopside, anorthite, forsterite, hibonite and metal grains as accessory minerals. Nepheline exists as a secondary alteration mineral, but the amounts are very small. The mineral layer of gehlenitic melilite, spinel, diopside and forsterite, called Wark-Lovering rim (WL-rim) surrounds the CAI. The CAI separates the CAI into two domains by a WL-rim, which are named as domain-1 and domain-2 (Fig. 1a). The distributions of chemical compositions and oxygen isotopic compo-

sitions of melilite crystals in the two domains were different each other.

In the domain-1 (Fig. 1b), melilite crystals near the WL-rim show reverse zoning and are observed as a layer of ~40 μm in width. The reverse zoning of these crystals are typically $\Delta\text{O} = -25$ in the center and $\Delta\text{O} = -10$ at the grain boundary. The melilite crystals inside of the reverse zoning melilite layer show oscillatory zoning, initially started as reverse zoning and changed to normal zoning. The compositions are $\Delta\text{O} = -55$ in the center, $\Delta\text{O} = -30$ at intermediate, and $\Delta\text{O} = -60$ at the grain boundary. Typical width of the normal zoning part is 2-5 μm . Fig. 2 shows the oxygen isotopic compositions of the melilite crystals. Despite of the complex growth zoning pattern, oxygen isotopic compositions of melilite crystals of the domain-1 distributed homogeneously, $\delta^{18}\text{O} = 5 \text{ ‰}$.

In the domain-2 (Fig. 1c), melilite crystals positioned shallower than ~150 μm in depth from the WL-rim have grown as reverse zoning. The reverse zoning of these crystals are typically $\Delta\text{O} = -25$ in the center and $\Delta\text{O} = -10$ at the grain boundary. The oxygen isotopic compositions of melilite crystals of the domain-2 distributed along CCAM line ranging between $\delta^{18}\text{O} = -40$ and 0 ‰ (Fig. 2). The melilite crystals positioned near the WL-rim are ^{16}O -rich ($\delta^{18}\text{O} = -40 \text{ ‰}$) while the melilite crystals away from the WL-rim are ^{16}O -poor ($\delta^{18}\text{O} = 0 \text{ ‰}$). The oxygen isotopic compositions gradually change from ^{16}O -rich to ^{16}O -poor with the distance from WL-rim.

Discussion: The melilite crystals of the domain-1 have complex zoning patterns. The homogeneous oxygen isotopic composition indicate the melilite crystals formed in a ^{16}O -poor nebular gas. If we assume these melilite crystals formed in the nebular gas with decreasing temperature, the formation processes are described as below: First, the melilite formed as a direct condensation from gas with decreasing pressure because the zoning start from reverse zoning. The pressure decrease was stopped but the temperature decrease continued. The crystal growth changed from reverse zoning to normal zoning to make oscillatory pattern. Then the oscillatory zoned melilite grains were accurate to a CAI. After the accumulation, melilite crystals of reverse zoned melilite layer of domain-1 have grown as reverse zoning by direct con-

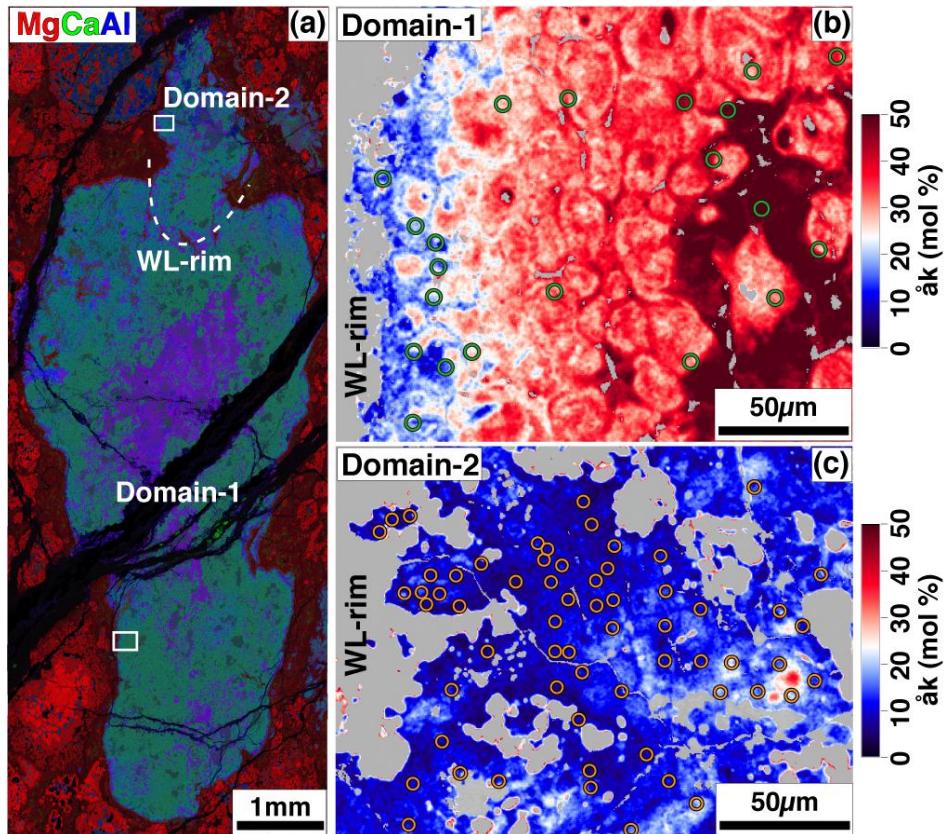


Figure 1. (a) X-ray map of the fluffy Type A CAI. X-ray map regarding åkermanite contents of melilite of squared regions of (a), (b) domain-1 and (c) domain-2. Circles in (b, c) indicate points of SIMS spots.

densation from the nebular gas and accumulated around the oscillatory zoned melilite core.

The melilite crystals of the domain-2 have grown as reverse zoning by the direct condensation from the nebular gas with decreasing pressure and accumulated together. The oxygen isotopic distributions observed in the domain-2 suggests that the oxygen isotopic ratios of nebular gas surrounding the melilite aggregates were gradually changed from ^{16}O -poor to ^{16}O -rich during the total duration of melilite condensation of the domain-2.

Both the domain-1 and domain-2 were surrounded by the WL-rim. Thus, the WL-rim was formed around the domain-1 and domain-2 after melilite formation, and the domain-1 and domain-2 were accreted together. The melilite crystals of the domain-1 and domain-2 were formed by different processes in oxygen isotopically different nebular gas conditions. The CAI was a aggregate of domains formed in different environments.

References: [1] Yurimoto H. et al. (1998) *Science*, 282, 1874. [2] Yurimoto H. et al. (2008) *Reviews in Mineralogy & Geochemistry*, 68, 141-186. [3] MacPherson G. J. and Grossman L. (1984) *GCA*, 48, 29.

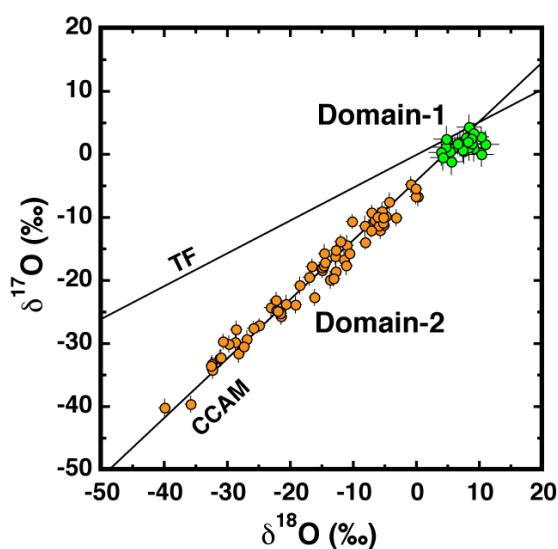


Figure 2. Oxygen isotopic compositions of melilite crystals of the domain-1 (green) and domain-2 (yellow). Oxygen isotopic compositions of melilite crystals of the domain-1 distributed homogeneously, $\delta^{18}\text{O} = 5\text{ ‰}$ and those of the domain-2 distributed along CCAM line ranging between $\delta^{18}\text{O} = -40$ and 0 ‰ .