Secular change of oxygen isotope composition in the solar protoplanetary disk recorded in a fluffy Type A CAI from Vigarano CV3 by Al-Mg chronological study

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Fluffy Type A Ca-Al-rich inclusions (CAIs) containing reversely zoned melilite crystals are suggested to be direct condensates from solar nebular gas (MacPherson and Grossman, 1984). We conducted an investigation of ^{26}Al–^{26}Mg systematics of a fluffy Type A CAI from Vigarano, named V2-01, with known oxygen isotopic distributions of reversely zoned melilite crystals (Katayama et al., 2012); we also conducted oxygen isotope measurements of coexisting minerals. The oxygen and Al-Mg isotope measurements were conducted using SIMS of Hokkaido University (Cameca ims-1280HR). Petrography suggests that the constituent minerals of V2-01 formed in the following order: first spinel and fassaite enclosed by melilite, then reversely zoned melilite crystals, and spinel and diopside in the Wark-Lovering rim. The spinel enclosed by melilite has ^{16}O-rich compositions ($\Delta^{17}O$ ~ −24‰) and an initial value of $(^{26}Al/^{27}Al)_0$ = (5.6 ±0.2) ×10^{-5}. The fassaite enclosed by melilite crystals shows variable oxygen isotopic compositions ($\Delta^{17}O$ ~ −12‰ and −17‰) and plots on an isochron with $(^{26}Al/^{27}Al)_0$ = (5.6 ±0.2) ×10^{-5}. The oxygen isotopic compositions of reversely zoned melilite showed continuous variations in $\Delta^{17}O$ along the inferred direction of crystal growth, suggesting that surrounding nebular gas, during the formation of the reversely zoned melilite, changed from ^{16}O-poor ($\Delta^{17}O$ values larger than −10‰) to ^{16}O-rich ($\Delta^{17}O$ ~ −25‰). The six reversely zoned melilite crystals show indistinguishable initial $^{26}Al/^{27}Al$ values with an average $(^{26}Al/^{27}Al)_0$ of (4.7 ±0.3) ×10^{-5}, which is clearly distinguishable from the value of enclosed spinel and fassaite, indicating a younger formation age than the enclosed spinel and fassaite. The spinel and diopside from the Wark-Lovering rim shows ^{16}O-rich compositions ($\Delta^{17}O$ ~ −23‰) with $(^{26}Al/^{27}Al)_0$ = (4.5 ±0.4) ×10^{-5}. The values of $(^{26}Al/^{27}Al)_0$ are consistent with the formation sequence inferred from petrography. The formation period for the V2-01 CAI is estimated to be 0.18 ±0.07 Myr from the difference in initial $^{26}Al/^{27}Al$ values. These data suggest that the oxygen isotopic composition of solar nebular gas surrounding the CAI changed from ^{16}O-rich to ^{16}O-poor and back to ^{16}O-rich at least recorded as one cycle during the first ~0.2 Myr of Solar System formation.

Keywords: Al-Mg chronology, Ca-Al-rich inclusion, SIMS, oxygen isotopes, solar protoplanetary disk

