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Petrographic study and Mg isotope distribution in Type C CAI from Allende meteorite

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It is believed that Ca-Al-rich inclusions (CAIs) are the oldest materials in the solar system (4567 Ma). CAIs also contain a short-lived radionuclide of ^{26}Al from supernova and this shows evidence of crystallization in the first few million years in the early solar system. The ^{26}Al-^{26}Mg dating using a short-lived radionuclide of ^{26}Al is useful to determine the time scales by precisely measuring excess ^{26}Mg decayed by ^{26}Al. In previous in-situ Al-Mg isotopes studies, it was reported that an initial ^{26}Al/^{27}Al ratios of CAIs are distributed among 0 - 5 x 10^{-5}but it is unclear whether this shows the time difference of each crystallization event or not. These distributions are estimated from plagioclase. However, the initial ^{26}Al/^{27}Al ratios from spinel and Ti-Al rich diopside are limited. In this study, we report a high precision Al-Mg isotopic study by secondary ion mass spectrometry (SIMS) in EK 1-04-2 Type C CAI from Allende meteorite in order to give a chronological constraint for the crystallization sequence of each mineral in this CAI. Ito et al. (2000) reported that each mineral of EK 1-04-2 CAI crystallized at different times, which experienced multiple melting events.

In order to estimate the crystallization sequence in this CAI, petrographic observation, bulk chemical conpositions and X-ray mapping analyses were performed by FESEM-EDS. Experimental crystallization sequence of CAI liquid (Stolper, 1982) using this bulk chemical composition is the order of spinel, anorthite, olivine and Ti-Al rich diopside. In addition, the crystallization sequence from petrographic texture with X-ray mapping is the order of spinel, olivine and Ti-Al rich diopside. However, there are two kinds of crystallization sequence for anorthie, which is the order of spinel, anorthie and olivine, or the order of spinel, olivine and anorthite.

In-situ Al-Mg isotope measurements for spinel and anorthite in this CAI were performed by a Cameca ims-1270 of Hokkaido University. Excess of 26Mg were calculated using 0.51400 assuming as the mass fractionation factor of CAI crystallization events (Davis et al., 2005). Al-Mg isotopes in high Al/Mg ratio phases, anorthites, were measured by peak switching of magnetic field. Standard mineral is used as Miyakejima anorthite. The overall analytical accuracy of delta ^{26}Mg$_{excess}$is estimated as 5 - 10 per mil. Al-Mg isotopes in low Al/Mg ratio phases, spinels, were measured by fixing of magnetic field using NMR control and detected secondary ions at the same time using four detectors. Standard minerals are used as Russian spinel and Takashima augite. The overall analytical accuracy of delta ^{26}Mg$_{excess}$is estimated as 0.1 per mil.

Anorthites in a CAI show no significant excess ^{26}Mg, and initial ^{26}Al/^{27}Al ratio is calculated as 8 (5) x $10^{-7}$by the model isochron. Spinels in a CAI show a significant ^{26}Mg, and initial ^{26}Al/^{27}Al ratio is calculated as 4.41 (20) x $10^{-5}$by the model isochron.

The time difference of crystallization age between spinels and anorthies is inferred as 4.2 (7) Myr. However, this relative age is an upper limit because it comes from the model isochron assuming the initial ^{26}Mg/^{24}Mg ratio of each crystallization event as same as zero. The crystallization sequence from the Al-Mg model isochron is consistent with that of petrographic observation. This indicates that spinels are resulting from relict grains during partial melting event for the crystallization of anorthite. In the future work, it would be confirmed that the model isochron by

spinel and anorthite are verified by high precision Al-Mg isotope analysis of olivine and Ti-Al rich diopside in EK 1-04-2 CAI in order to evaluate the difference in initial $^{26}Al/^{27}Al$ ratio of each mineral.

Keywords: Ca-Al-rich inclusion, short-lived radionuclides, Allende meteorite, secondary ion mass spectrometry, Al-Mg isotope