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# Al-Mg systematics of a compound CAI-chondrule object from Allende

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We have previously reported the discovery of CAI-025, a compound Ca-Al-rich Inclusion (CAI) - chondrule object, from Allende. CAI-025 consists of interior portion that contains anorthite, spinel, olivine and Al-bearing low-Ca pyroxene with a chondrule-like igneous rim completely surrounding the interior portion. Petrographic, oxygen isotopic and REE studies of CAI-025 indicate that: (1) the interior portion is a molten mixture of a CAI and chondrule material with an inferred mixing proportion of 3 to 7 by weight; (2) spinel is a relict phase from the precursor CAI that formed by condensation under $^{16}$O-rich environment; (3) olivine and anorthite is crystallized from CAI-chondrule mixture melt under moderately $^{16}$O-rich environment. Interior portion has experienced different heating events, precursor CAI formation and CAI-chondrule mixing, under different environments. However, difference in the timing of the different heating events remains unclear. We report here Al-Mg systematics of the interior portion of CAI-025 to give chronological constraint on these processes.

Aluminum and magnesium isotopes were analyzed in situ by SIMS (Cameca ims-1270) at Hokkaido University. Spinel and olivine were analyzed by multiple faraday collectors. Details of the analysis are described in Itoh et al. (2008). Anorthite was analyzed by peak jumping mode. Standards are matrix-matched to the sample minerals. Excess $^{26}$Mg (delta$^{26}$Mg*), expressed as parts par thousand difference from the terrestrial $^{26}$Mg/$^{24}$Mg ratio in logarithmic scale after mass fractionation correction, was calculated by assuming the natural Mg isotope fractionation factor as 0.51400 (Davis et al., 2002). Typical reproducibility of delta$^{26}$Mg* was 0.12 and 8.9 for multi-collection and peak jumping measurements, respectively.

Seventeen spinel analyses all agree within analytical errors and show clear $^{26}$Mg excess (delta$^{26}$Mg * = 0.53 +/- 0.15). The measured $^{27}$Al/$^{24}$Mg is 2.53 +/- 0.19. Olivine has a constant excess $^{26}$Mg of 0.30 +/- 0.08 (n = 10). The $^{27}$Al/$^{24}$Mg ratios of all olivine analyses are smaller than 0.01. Anorthite has delta$^{26}$Mg* indistinguishable from 0 (1.6 +/- 2.8, n = 10) while its $^{27}$Al/$^{24}$Mg ratio varies from 5 5.8 to 227.

Spinel has large excess $^{26}$Mg compared with olivine. This clearly indicates that $^{26}$Al was alive at the time when spinel has crystallized. Anorthite, on the other hand, has no evidence of live $^{26}$Al at the time of its crystallization. This indicates that $^{26}$Al had totally decayed prior to the anorthite crystallization, and thus anorthite crystallization is temporally separated from the spinel crystallization. Olivine also has significant $^{26}$Mg excess. Very low $^{27}$Al/$^{24}$Mg of olivine indicates that the effect of the in situ decay of $^{26}$Al is negligibly small. Thus, the excess $^{26}$Mg of olivine is inherited from the CAI-chondrule mixture melt from which the olivine has crystallized. REE compositon of CAI-025 suggests that the mixing proportion of the CAI to chondrule material is 3: 7. Using the Al and Mg abundance of CAI-025 and assuming Al and Mg abundance of the precursor CAI from literature value (Mason and Taylor, 1982), delta$^{26}$Mg* of the CAI-chondrule mixture melt can be calculated. If the precursor CAI had canonical $^{26}$Al/$^{27}$Al ratio at the time of its formation and the CAI-chondrule mixing event took place after the total decay of $^{26}$Al, delta$^{26}$Mg* of the CAI-chondrule mixture melt will be 0.25. This is in good agreement with the measured delta $^{26}$Mg* of olivine. If the mixing event took place earlier, delta$^{26}$Mg* of the mixture melt will be lowered. This model calculation suggests that olivine crystallization occurred after $^{26}$Al had totally

decayed and is simultaneous with anorthite crystallization. The Al-Mg systematics of CAI-025 revealed the temporal difference between the spinel crystallization at precursor CAI stage and the CAI-chondrule mixing event.

Keywords: CAI, chondrule, CAI-chondrule compound object, Al-Mg chronology, solar nebular