AL-MG DATING OF CA-AL-RICH INCLUSIONS IN ACFER 094 CHONDRITE. N. Sugiura$^1$ and A.N. Krot$^2$, $^1$Department of Earth and Planetary Science, University of Tokyo, Japan. E-mail: Sugiura@eps.s.u-tokyo.ac.jp, $^2$University of Hawai‘i at Manoa, USA. E-mail: sasha@higp.hawaii.edu.

Introduction: Acfer 094 is one of the most primitive chondrites, which appears to have escaped thermal metamorphism above 300°C [1] and can potentially provide important clues to primary, undisturbed by parent body processes, abundances of short-lived radionuclides in its components. Krot et al. [2] have recently described mineralogy and petrography of the Al-rich chondrules and refractory inclusions in Acfer 094. Here we report Al-Mg systematics of Ca-Al-rich inclusions (CAIs) in Acfer 094 determined by secondary ion mass spectrometry.

Experimental: 14 CAIs in two polished sections of Acfer 094 were investigated, including 1 corundum-rich, 7 grossite-rich, 3 melilite-rich, 3 anorthite-rich [one of them is an amoeboid olivine aggregate (AOA)]. An O primary beam ~10 µm in diameter was used for sputtering. In some spots repeated measurements were made. Also, if Mg-rich and Al-poor minerals were present in the CAIs studied, their Mg isotopic compositions were measured to determine the y-intercept on the isochron diagram. Secondary ions of $^{24}$Mg, $^{25}$Mg, $^{26}$Mg were measured by an ion counting system based on an electron multiplier and $^{27}$Al was measured with a Faraday cup. The mass resolving power was set to ~4500, which is high enough to resolve doubly charged $^{48}$Ca from $^{24}$Mg. Since the relative sensitivity factor (Al/Mg') / (Al/Mg) for grossite is not well known, we assumed that it is similar to that for hibonite (~1.1).

Results: The results are illustrated in Figure 1. The vertical errors attached to data points are 1σ error based on the counting statistics. The errors of the Al/Mg ratios are almost entirely due to uncertainty (~8%) of the relative sensitivity factors. The canonical initial $^{26}$Al/$^{27}$Al ratio of 5×$10^{-5}$ is shown for reference. Out of 14 CAIs, 11 show nearly canonical initial ratios. The remaining 3 CAIs (#s2, corundum-rich CAI, #s1, grossite-rich; and #24, anorthite-rich; Fig. 2), have no resolvable excesses in $^{26}$Mg ($^{26}$Mg*). Anorthite in an igneous, AOA-like object #11a (Fig. 3) has the canonical $^{26}$Al/$^{27}$Al ratio.

Discussion: Refractory inclusions in Acfer 094 show bi-modal distribution of $^{26}$Mg*; ~75% of CAIs studied and an AOA-like object have the canonical $^{26}$Al/$^{27}$Al ratios, whereas ~20% of CAIs show no resolvable $^{26}$Mg*. Since the Acfer 094 has largely escaped aqueous alteration and thermal metamorphism, these observations may suggest that the intermediate initial $^{26}$Al/$^{27}$Al ratios detected in CAIs from thermally metamorphosed and/or hydrothermally-altered chondrites (e.g., Allende [3]) may have resulted from parent body alteration rather than late-stage (a few half-lives of $^{26}$Al after CAIs with canonical $^{26}$Al/$^{27}$Al ratio) reheating in the solar nebula.

The grossite-rich CAI #s14 (Fig. 1) has the initial $^{26}$Al/$^{27}$Al ratio of (6.3 ± 0.5) × $10^{-5}$ (1σ), which is higher than the canonical value (relatively large error is mostly due to the uncertainty in the relative sensitivity factor for grossite). If $^{26}$Al is interpreted chronologically, this CAI is significantly older than other CAIs in Acfer 094, suggesting that CAI formation may have lasted for several hundred thousand years, consistent with [4].

The previously reported initial $^{26}$Al/$^{27}$Al ratios for three AOAs from Y-81020 (CO3.0) are ~3×$10^{-5}$ [5]. It was suggested that AOAs could have formed significantly later than CAIs with the canonical $^{26}$Al/$^{27}$Al ratios [5]. The $^{26}$Al/$^{27}$Al ratio in the AOA-like object #11a from Acfer 094 is indistinguishable from the canonical, suggesting nearly contemporaneous formation with typical CAIs. Since Y-81020 is nearly as primitive as Acfer 094 [1], the small $^{26}$Al/$^{27}$Al ratios in the Y-81020 AOAs cannot be entirely attributed to a different degree of parent-body alteration. It seems more likely that grain sizes of anorthite are an important factor. The anorthite analysed in this study was ~20 µm across. Although sizes of Y-81020 anorthite [5] were not specified, judging from the size (2-5 µm) of the O primary beam, they were probably smaller than that of this study and hence more easily disturbed during parent body metamorphism. Future studies of coarse anorthite grains in AOAs from Y-81020 and other primitive chondrites can test this hypothesis.

Three CAIs from Acfer 094 showed no resolvable $^{26}$Mg*. Since parent-body processes are unlikely to reset the initial $^{26}$Al/$^{27}$Al ratios of these CAIs, these observations may indicate that lack of $^{26}$Mg* could be either due to a late-stage remelting (e.g., during chondrule formation) or due to heterogeneous distribution of $^{26}$Al in the protoplanetary disk, as has been previously inferred for isotopically anomalous platy hibonites and FUN CAIs. The very refractory nature of the corundum-rich CAI #s2 and the grossite-rich CAI #s1 and the presence of Wark-Lovering rim layers around them appears to favor lack of $^{26}$Al in their precursors. The anorthite-rich CAI #24 is less refractory,
has an igneous texture, and appears to lack Wark-Lovering rim layers. This CAI may have experienced late-stage remelting during chondrule formation. Oxygen isotopic studies of the $^{26}$Al-free CAIs is in progress and should be able to test both hypotheses.

**References:**

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**Fig. 1.** Al-Mg evolutionary diagram of refractory inclusions from Acfer 094. 11 out of 14 inclusions studied have $^{26}$Mg* corresponding to a canonical $^{26}$Al/$^{27}$Al ratio of 5×10−5. The remaining 3 CAIs (#s2, corundum-rich CAI, #s1, grossite-rich; and #24, anorthite-rich; Fig. 2), shown by open circles, have no resolvable $^{26}$Mg*.

**Fig. 2.** Backscattered electron images of the CAIs showing no evidence for $^{26}$Mg*. a – Corundum-rich CAI s2. b – Grossite-rich CAI s1; c – Anorthite-rich CAI #24. an = anorthite; cor = corundum; grs = grossite; hib = hibonite; mel = melilite; px = Al,Ti-diopside; sp = spinel. For details of their mineralogy and petrography, see [2].

**Fig. 3.** Backscattered electron image of an AOA-like, igneous object composed of anorthite (an), Al-Ti-diopside (px) and forsterite (ol). For details of its mineralogy and petrography, see [2].