HIGH PRECISION AL-MG INTERNAL ISOCHRON USING ZONED MELILITE IN CAI. N. T. Kita[1], T. Ushikubo[1], K. B. Knight[2, 3], R. A. Mendybaev[2, 3], A. M. Davis[2, 3, 4], F. M. Richter[2, 3]. Department of Geology and Geophysics, University of Wisconsin-Madison, Madison, WI 53706 (noriko@geology.wisc.edu), [2]Department of the Geophysical Sciences, The University of Chicago, Chicago, Il 60637, [3]Chicago Center for Cosmochemistry, [4]Enrico Fermi Institute, The University of Chicago, Chicago, Il 60637

Introduction: The ^{26}Al-^{26}Mg decay system ($\tau_{1/2}$= 7.3×10^5 y) is a useful chronometer providing ~0.1 My time resolution for the formation of CAIs and chondrules in the earliest history of our solar system. Recent high precision MC-ICPMS bulk analyses of CAIs yield well-defined isochrons with initial ^{26}Al/^{27}Al of (5.85±0.05)×10^{-5} [1], slightly higher than the canonical value of ~5×10^{-5} based on the peak value from the internal isochron of type B CAIs [2]. Furthermore, Laser MC-ICPMS and multicollector SIMS analyses of CAIs define internal isochrons with "supra-canonical" initial ^{26}Al/^{27}Al ratios of (6–7)×10^{-5}, suggesting multiple events occurred to CAIs over time scales as long as 0.3–0.4 My [e.g., 3]. However, these data obtained from low Al/Mg phases are often scattered on the Al-Mg diagram, indicating the inferred higher initial ^{26}Al/^{27}Al could be an artifact caused by the redistribution of radiogenic ^{26}Mg during parent body metamorphism after most of the ^{26}Al had decayed. Also, the choice of isotopic mass fractionation correction law affects excess radiogenic ^{26}Mg (δ^{26}Mg*) by small amounts that can significantly affect initial ^{26}Al/^{27}Al ratios for CAIs with heavy Mg isotope enrichments and low Al/Mg [4].

Recently, we analyzed Mg isotopes in zoned melilite in a type B1 inclusion from Leoville (USNM 3535-1, 6×8 mm with a 500µm thick melilite mantle) using an ion microprobe CAMECA IMS 1280 (Wisc-SIMS Lab). We found nearly homogeneous δ^{25}Mg between 4.5 and 5.5‰ except for Geh-rich rims [5]. In this CAI, a single ^{26}Al-^{26}Mg isochron was obtained from melilite in both the core and the mantle with a slope corresponding to an initial ^{26}Al/^{27}Al ratio of (5.68 ±0.34) ×10^{-5}, implying melting and crystallization of this CAI within 0.1 My of the primary formation of refractory precursors inferred from the bulk CAI isochron [1].

To extend the high precision ^{26}Al chronology of CAIs, we report here preliminary results of additional Mg isotopic analyses from the same CAI with improved precision. Because of the relatively homogeneous δ^{25}Mg in the zoned melilite, the choice of mass fractionation law [4] will not affect the slope of the isochron for this CAI, though it may affect the intercept. The goal of this study is to achieve higher precision and accuracy of the ion microprobe Al-Mg dating, enabling us to better distinguish between well-defined and scattered internal isochrons in CAIs.

Method: We used primary O$^-$ ion beam with a diameter of ~20 µm and an intensity of 20 nA. Multicollection detectors were used to simultaneously measure ^{24}Mg$^+$, ^{25}Mg$^+$, ^{26}Mg$^+$ and ^{27}Al$^+$. A single analysis consists of 60 s of presputtering, ~60 s for automated centering of the secondary optics, and 300 s of integration. We obtain ^{24}Mg signals of (0.5–2.4) ×10^8 cps for Åk$_{20}$–Åk$_{100}$. We used homogeneous melilite glass (~Åk$_{67}$) as a running standard. The fractionation-corrected δ^{26}Mg* values were calculated using an exponential law with slope of 0.514 from the evaporation experiment of [5]. Both internal errors and the reproducibility of fractionation-corrected δ^{26}Mg* values for the melilite glass standard were 0.1‰ (2SD). The reproducibility of the measured ^{27}Al/^{24}Mg ratios of the running standard was better than 2% (2SD).

Calibration of Standards: Synthetic zoned melilite crystals (Åk$_{20–70}$) were used to calibrate the matrix effect on both the ^{27}Al/^{24}Mg relative sensitivity, and on mass-fractionation-normalized δ^{26}Mg* values. We also made a small correction for negative bias on δ^{26}Mg* with decreasing Åk, as much as 0.1‰.

The relative sensitivity factor of the ion probe ^{27}Al/^{24}Mg ratios (RSF) was calculated by comparing the measured ^{27}Al/^{24}Mg with those converted from Al/Mg data obtained by SEM-EDS method, as shown in Fig. 1. We observed a systematic change of the RSF with Åk content as large as 7% from Åk$_{70}$ (0.93) to Åk$_{20}$ (1.00). Inaccurate calibration of RSF can be a potential artifact on the Al-Mg measurement, and can create a systematic bias on the corrected ^{27}Al/^{24}Mg ratios, changing the slope of the isochron.

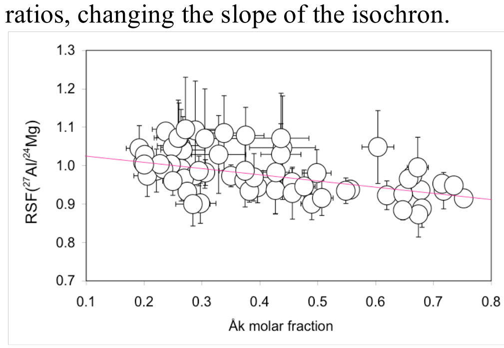

Fig. 1. Relative sensitivity factor of ^{27}Al/^{24}Mg ratios, as defined by (^{27}Al/^{24}Mg)$_{SIMS}$/(^{27}Al/^{24}Mg)$_{SEM-EDS}$.

Confirmation of the SEM-EDS analyses of the Al/Mg ratio of analyzed spots by WDS electron microprobe is needed.

Results: Fig 2a shows the isochron diagram for our previous analyses [5], which is revised by using the RSF shown in Fig. 1. The results of new analyses of melilite, 7 from the mantle ($^{27}Al/^{24}Mg \geq 2$) and 2 from the core ($^{27}Al/^{24}Mg \sim 1$), are shown in the isochron diagram in Fig. 2b. The isochron obtained from these new data are consistent with our previous data, though they show small deviations from the regression line, having the MSWD (Mean Square Weighted Deviation) larger than 1.

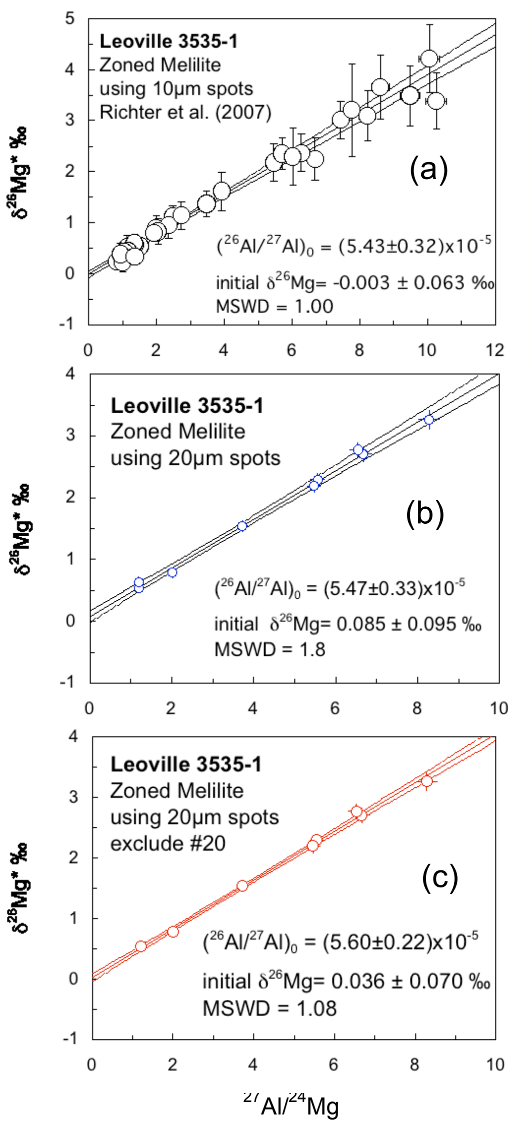

Fig. 2. The internal Al-Mg isochron diagram of zoned melilite from Leoville 3535-1 type B1 CAI. (a) Revised isochron from data obtained using 10 μm spots [4]. (b) New data obtained using 20 μm spots. (c) Isochron regression line without #20, which may have slightly overlapped nearby phases.

By omitting one of the core melilite analyses (#20, in Fig. 3), a less scattered isochron is obtained (MSWD~1) with an initial $^{27}Al/^{26}Al$ ratio of $(5.60\pm0.22)\times10^{-5}$ (Fig. 2c). The grain #20 is enclosed by plagioclase and contains abundant small grains of spinel, possibly affected by later isotopic exchange with other minerals. The initial $^{27}Al/^{26}Al$ ratio inferred from both isochrons (in Figs 2b and 2c) are significantly lower than the "supra-canonical value" ($\geq 6\times10^{5}$), and only slightly lower than or indistinguishable to that of the bulk CAI by [1].

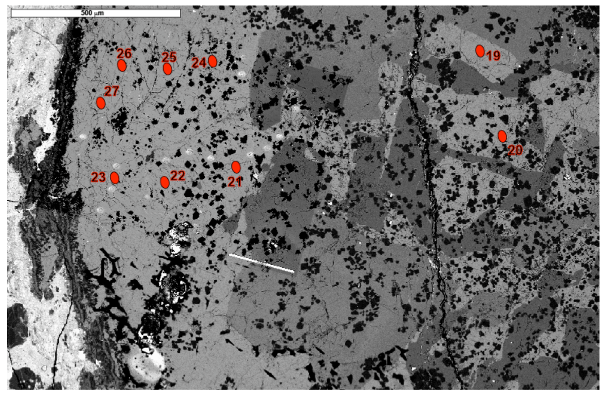

Fig. 3. The BSE image of Leoville 3535-1 CAI. Red oval spots are position of SIMS analyses. Scale bar; 500μm.

Discussion: Preliminary high precision analyses obtained here are mainly derived from mantle melilite with igneous zoning. The resulting isochron, therefore, corresponds to the final heating event experienced by this CAIs, within 0.1 My after the time that bulk isochron of the CAI [2] was established. More analyses from core melilite should be done to examine if the CAI recorded multiple events. Melilite is the common mineral phase in major types of CAIs (types A, B, and C), while anorthite, extensively used for the Al-Mg dating of CAIs in the past, is limited mainly to type B CAIs. Furthermore, anorthite has often lost radiogenic ^{26}Mg, resulted in disturbed isochrons [e.g., 6]. With the high precision melilite analyses we have achieved, we can evaluate a range of initial ($^{26}Al/^{27}Al$) ratios among different groups of CAIs and examine the evidence for multiple heating events in a single CAI, corresponding to events occurred in the protoplanetary disk on a time scale of 0.1 My.

References: [1] Thrane K. et al. (2006) ApJ. 646, L159-L162. [2] MacPherson et al. (1995) Meteoritics 30, 365-386. [3] Young E. D. et al. (2005) Science, 308, 223-227. [4] Davis A. M. et al. (2005) LPS XXXVI, Abstract #2334. [5] Richter F. M. et al. (2007) LPS XXXVIII, Abstract #2303. [6] Podosek F.A. (1991) GCA 55, 1083-1110.