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Disturbed ^{26}Al-^{26}Mg system among CAIs and chondrules in mildly metamorphosed chondrites

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The ^{26}Al-^{26}Mg chronometer is useful to determine the relative formation time between Ca, Al-rich Inclusions (CAIs) and chondrules in unequilibrated chondrites. Previous studies have shown that CAIs formed within a few 0.1 million years (Myr) and chondrules formed 1-3 Myr after CAIs, which are also referred to as the time scale of the proto-planetary disk. As the initial ^{26}Al/^{27}Al ratio in the solar system is very small (5×10^{-5}), plagioclase with high ^{27}Al/^{24}Mg ratios (>100) is often used in order to detect small ^{26}Mg excess. However, there are numbers of CAIs and chondrules without any detectable ^{26}Mg excess, indicating young formation ages of more than 4 Myr.

In this study, we present our recent ^{26}Al-^{26}Mg data on CAIs and chondrules in mildly metamorphosed chondrites (Ningqiang carbonaceous chondrite and Y82038 H3.2 chondrite). A Type C CAI in Ningqiang (W2#3) showed detectable ^{26}Mg excess (~1‰) in Ca-pyroxene with a high referred ^{26}Al/^{27}Al initial ratio (~5×10^{-5}) as other CAIs. However, there is no detectable ^{26}Mg excess (<2‰) in plagioclase, corresponding to the age of >5Myr. A plagioclase-olivine inclusion (W2#4) consists of a dendritic and a poikilitic texture. The plagioclase in the poikilitic area showed correlated ^{26}Mg excesses, giving the ^{26}Al age of ~2.5Myr. The dendritic area showed higher ^{27}Al/^{24}Mg ratios without any detectable ^{26}Mg excess, which plot off the above isochron. These data indicate that the isotopic disturbance occur >3.7Myr. The glass in type IA chondrule in Y82038 (F2) showed a limited ^{26}Mg excesses (~1‰) that do not correlate with the ^{27}Al/^{24}Mg ratios and give an upper limit of 3.6Myr. The ^{27}Al/^{24}Mg ratios in the glass range 90-140, which is extremely higher than those in typical type IA in LL3.0-3.1 (<10).

These results indicate that the young ^{26}Al ages of CAIs and chondrules are probably caused by mild metamorphism on their parent bodies 4-5 Myr after the CAI formation. There is a tendency of Mg removal from plagioclase or glass during the metamorphism, that caused apparent young ages on the ^{26}Al-^{26}Mg isochorn diagram.

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Contemporaneous formation of chondrules and CAIs inferred from the ^{26}Al-^{26}Mg clock

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We report high-precision Mg isotope measurements of CAIs and chondrules from the Allende (CV3) and Dar al Gani 313 (LL3) meteorites determined by MC-ICP-MS. Analysed material comprised ca. 0.2-0.5 mg whole-rock fragments of chondrules or CAIs sampled with boron carbide micro-drills (300 μm) from polished slabs of the meteorites. Following table-top digestion in HF-HNO_3, Mg was purified by cation exchange chromatography. ^{26}Mg excesses are reported as δ^{26}Mg*, which is the per mil deviation of internally normalised (exponential law) ^{26}Mg/^{24}Mg values from the average internally normalised ^{26}Mg/^{24}Mg of two bracketing standards (DSM3), with each sample being analysed at least three times. The reproducibility of the δ^{26}Mg* value estimated from the BCR-2 basaltic standard is 0.023‰ (2 sd; n = 10). Al/Mg was determined by MC-ICP-MS to < ±2%.

$(^{26}Al/^{27}Al)_0$ values inferred from the CAI dataset range from $3.5\pm1.0\times10^{-5}$ to $6.3\pm1.8\times10^{-5}$, indicating that these objects formed over a period of 0.6 Ma, or that some CAIs have been reworked or re-equilibrated with the host. An internal Al-Mg isochron (n = 5) for one CAI yielded $(^{26}Al/^{27}Al)_0 = 5.3\pm0.5\times10^{-5}$, identical to the canonical $(^{26}Al/^{27}Al)_0$ value of 5.0×10^{-5}. Chondrules were selected for micro-drilling on the basis of their Al/Mg ratios, using a laser ablation system interfaced to an MC-ICP-MS to quickly screen a large number of chondrules. Seven ferromagnesian chondrules (^{27}Al/^{24}Mg = 0.117-0.274) and two aluminium-rich chondrules (^{27}Al/^{24}Mg > 0.75) were selected from Allende, while five ferromagnesian chondrules from Dar al Gani 313 with ^{27}Al/^{24}Mg = 0.035 to 0.145 were measured. Excess ^{26}Mg was detected in 4 ferromagnesian and two aluminium-rich chondrules from Allende, while no measurable excess was detected in chondrules from Dar al Gani 313. The $(^{26}Al/^{27}Al)_0$ values inferred from the Allende chondrules range from $1.7\pm0.6\times10^{-5}$ to $4.8\pm0.6\times10^{-5}$, suggesting that these objects formed over a period of ca. 1 Ma, and that some chondrules are as old as the oldest CAIs.