^{26}Al-^{26}Mg systematics of chondrules: Progresses and issues from the last 5 years. K. Nagashima[1], N. T. Kita[2], and T.-H. Luu[3], [1]Hawai‘i Institute of Geophysics and Planetology, University of Hawai‘i at Mānoa, Honolulu, HI 96822, USA (kazu@higp.hawaii.edu), [2]Department of Geoscience, University of Wisconsin-Madison, Madison, Wisconsin 53706, USA, [3]School of Earth Sciences, University of Bristol, BS8 1RJ, UK.

Introduction: The short-lived radionuclide decay system ^{26}Al-^{26}Mg (half-life ~0.7 Myr) has been considered to be a high precision chronometer to date processes in the protoplanetary disk. Since the first report of excesses of ^{26}Mg due to *in situ* decay of ^{26}Al in a chondrule [1], ^{26}Al-^{26}Mg chronometer have been applied to chondrules from several chondrite groups. If their initial ^{26}Al/^{27}Al ratios ((^{26}Al/^{27}Al)$_0$) represent the timing of their formation, ^{26}Al ages of chondrules provide important cosmochemical constraints such as lifetime of the protoplanetary disk, chondrule-forming processes, and chondrite accretion processes. The ^{26}Al-^{26}Mg systematics of chondrules and implications to the evolution of protoplanetary disk have been summarized based on the data obtained before 2012 [2]. This abstract serves as a summary for the recent progresses and issues on ^{26}Al-^{26}Mg systematics of chondrules from the last 5 years.

^{26}Al abundances in chondrules inferred from internal isochrons: The (^{26}Al/^{27}Al)$_0$ in chondrules from three ordinary and carbonaceous chondrite groups (LL3.0, CO3.0, and Acfer 094 ungrouped C3) are ~6-7×10^{-6} [2]. Since then, reliable (^{26}Al/^{27}Al)$_0$ have been obtained for chondrules from CR2-3 [3-5], CH3 [6], and CV3.1 [7]. The (^{26}Al/^{27}Al)$_0$ from CR2-3 and CH3 chondrules are distinctly different from those in LL3.0 and CO3.0. While a few chondrules have (^{26}Al/^{27}Al)$_0$ of ~6×10^{-6}, most of them are systematically lower than 3×10^{-6}. The (^{26}Al/^{27}Al)$_0$ of chondrules in Kaba (CV3.1) have (4.8±1.1)×10^{-6}, similar to/slightly lower than those of LL3.0 and CO3.0. The (^{26}Al/^{27}Al)$_0$ of the chondrules from the chondrite groups decrease in the order of LL ~ CO ~ Acfer 094 ≥ CV ≥ CR ~ CH. In addition, each chondrite group may have multiple populations of chondrules [4].

^{26}Al abundances for chondrule precursors inferred from bulk chondrules: The model (^{26}Al/^{27}Al) ratios of chondrule “precursors” have been estimated from bulk chondrules ^{26}Al-^{26}Mg isotope analyses that range from ~5×10^{-5} to ~1×10^{-5} [8,9]. Luu et al. [9] suggested the minimum value (1.2×10^{-5}) corresponds to the time that formation of the precursors stopped or were separated from a nebular reservoir. The difference of (^{26}Al/^{27}Al)$_0$ between the bulk and *in situ* data may correspond to a time difference between the precursor formation and the last melting of chondrules.

Homogeneous/heterogeneous distribution of ^{26}Al in the disk: To convert (^{26}Al/^{27}Al)$_0$ values to relative ^{26}Al ages, we have to assume that ^{26}Al/^{27}Al was homogeneously distributed throughout the disk. This assumption has been challenged and is highly controversial. Recent studies on multiple chronometers (^{26}Al-^{26}Mg, ^{182}Hf-^{182}W, ^{206}Pb-^{207}Pb) of CAIs, chondrules and achondrites suggest consistent relative ages that support the homogeneous distribution of ^{26}Al throughout the disk and its chronological significance. For example, the Allende CV3 chondrule ages determined from ^{182}Hf-^{182}W systematics (2.2±0.8 Myr after CV CAIs [10]) and U-corrected Pb-Pb age (1.8±0.9 Myr after CV CAIs [11]) are in good agreement with 2.5 (-0.4/+0.7) Myr obtained from the (^{26}Al/^{27}Al)$_0$ of Kaba CV3 chondrules [7]. In contrast these are largely inconsistent with the old Pb-Pb ages of Allende chondrules [12], that might be due to the Pb-Pb ages compromised by the common Pb [13].

On the other hand, the Al-Mg and U-corrected Pb-Pb ages of volcanic angrites determined by Schiller et al. (2015) indicate ^{26}Al-^{26}Mg and ^{207}Pb-^{206}Pb ages compared to CV CAIs are inconsistent by ~1.5 Myr. The U-corrected Pb-Pb ages of individual chondrules range from 0 to ~3-4 Myr after CAIs, and their (^{26}Al/^{27}Al)$_0$ are much lower than those expected from their Pb-Pb ages, supporting the reduced abundance of ^{26}Al in the disk regions where chondrules originated [12,14].

Because of this controversy, it is not clear what the differences in (^{26}Al/^{27}Al)$_0$ among and within chondrite groups represent: spatial heterogeneity of ^{26}Al abundances in chondrule-forming region(s) and/or reflect multiple generations of chondrules formed at different times.

Implication for thermal history of parent asteroids: Despite the possibility of heterogeneous distribution of ^{26}Al in the disk, the (^{26}Al/^{27}Al)$_0$ recorded in chondrules potentially provide an upper limit on ^{26}Al abundances available as a heat source of their parent asteroids due to decay of ^{26}Al. The inferred (^{26}Al/^{27}Al)$_0$ of chondrules are similar to/slightly higher than those indicared from thermal modeling of their parent asteroids [15], suggesting rapid accretion of chondrules into their parent bodies after their formation. The (^{26}Al/^{27}Al)$_0$ in the Kaba chondrules is too low to melt a CV parent asteroid [7] and contradicts the existence of a molten core (e.g., [16]).

We will present more details at the workshop and in a chapter of the forthcoming book.

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