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Silicon isotope compositions of chondritic components: Insights into early Solar System processes

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Nucleosynthetic isotope anomalies in chondrules provide crucial insights into early disk processes, including mass mixing and transport and the formation of the first planetary bodies. Controversy surrounds the origins of isotope anomalies in chondrules, which may reflect either their formation from isotopically distinct precursor dust[1] or local heterogeneities of anomalous phases[2]. To date, the bulk of mass-independent data for chondrules pertain to tracers that are both minor chemical constituents and sensitive to "nugget effects" from anomalous phases, making them less-than-ideal tracers of precursor dust compositions. To address this issue, we obtained the first high precisions mass-independent isotope data for silicon, the fundamental non-volatile mineral-forming element of rocky planets, for a selection of petrologically diverse chondrules from the carbonaceous CV chondrite Allende. The Si isotopic compositions of chondrules are distinguished according to their petrography (porphyritic vs. non-porphyritic). Non-porphyritic chondrules record ^{30}Si compositions comparable to those of non-carbonaceous achondrites, whereas porphyritic chondrules have compositions ranging from non-carbonaceous-like to values exceeding those of bulk CV chondrites. The ^{30}Si isotope signatures of non-porphyritic chondrules are indicative of their early formation in the inner disk prior to transport to the CV accretion region, which was presumably beyond Jupiter's orbit. We show that the compositional spectrum of CV chondrules cannot be explained by admixture of refractory anomalous inner disk phases, as the most anomalous chondrules with composition most akin to early Solar System condensates such as calcium-aluminium-rich inclusions (CAIs) and ameboid olivine aggregates (AOAs), are also the most refractory element depleted. In contrast, the data are consistent with the formation of porphyritic chondrules through the recycling of non-porphyritic chondrules from the inner disk following the accretion of pristine, volatile-rich CI-like dust from the outer Solar System. Collectively, the ^{30}Si systematics of individual chondrules indicate that the recycling of inner disk materials to the accretion region of carbonaceous chondrites was a crucial process governing the compositions of the various carbonaceous chondrites.

[1] Olsen et al., *Geochim. Cosmochim. Acta* (2016), **191**, 118–138.

[2] Gerber et al., *Astrophys. J.* (2017), **841**.