THE PRESOLAR HERITAGE OF ^{50}Ti AND ^{26}Al HETEROGENEITIES IN THE SOLAR SYSTEM'S FIRST SOLIDS AND THE PROTOPLANETARY DISK

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Introduction: Our Solar System formed 4,567.3±0.16 billion years ago [1] by the gravitational collapse of a dense molecular cloud core [2]. By this process, molecular cloud dust with a multitude of distinct nucleosynthetic origins from previous generations of stars were physically mixed and chemically reprocessed to form the solar protoplanetary disk (PPD) and ultimately, within the first few million years, the planetary system surrounding our young Sun [3]. Ca-Al-rich Inclusions (CAIs) in primitive meteorites are the Solar System's oldest dated solids and used as initial time-anchors for formation of our Sun and its PPD. They are refractory solids believed to have condensed from a hot gas close to the proto-Sun and thus can tell us about the very earliest chemical re-processing of molecular cloud dust in the PPD [4,5,6]. As such, studying the mass-independent nucleosynthetic isotope signatures of these refractory objects can provide clues to the earliest reprocessing of the molecular cloud dust that formed our planetary system. Here, we report new titanium isotope data for ^{26}Al-rich ('normal'-type) and ^{26}Al-poor (FUN-type; Fractionation and Unknown Nuclear effects) Ca-Al-rich inclusions (CAIs) from CV and CR chondrites. We compare this data with literature data for the same isotope systems in other CAIs, as well as hibonites from CM chondrites, presolar grains and bulk meteorites.

Methods: Sampling of bulk CAIs, chromatographic purification of Ti and high-precision isotope analysis were preformed according to procedures described in [7]. In brief, sampling was performed using a New Wave Research MicroMill and Ti purified through a series of ion chromatographic purification steps using cation and anion exchange resins. Ti isotope analysis was performed by sample–standard–bracketing using a Neptune Plus MC-ICP-MS.

Results and Discussion: We measured the Ti isotope composition of 13 CAIs from CV and CR chondrites, for some of which the Mg isotope composition and ^{26}Al/^{27}Al ratio has previously been determined [6,8]. These include both ^{26}Al-rich (at a ^{26}Al/^{27}Al ratio of about 5 x 10^{-5}) 'normal'-type CAIs and ^{26}Al-poor FUN-type CAIs (STP-1 and KT-1). Fine-grained ^{26}Al-rich CAIs record variable excesses in mass-independent μ^{50}Ti* and μ^{46}Ti* (deviation from the terrestrial ^{50}Ti/^{47}Ti or ^{46}Ti/^{47}Ti ratio in ppm), whereas re-molten ^{26}Al-rich CAIs record invariable excesses in μ^{50}Ti* and μ^{46}Ti*, with μ^{50}Ti* around 950. This suggests fine-grained ^{26}Al-rich CAIs condensed from a ^{26}Al-rich gas onto presolar nuggets characterized by large variations in μ^{50}Ti* and their subsequent aggregation and remelting to form larger re-molten CAIs. The two FUN-type CAIs exhibit almost identical μ^{50}Ti* and μ^{46}Ti* deficits with μ^{50}Ti* around -4500. Consistent with previous observations, when compared to literature data 'normal'-type and FUN-type CAIs record a mutual exclusivity between high ^{26}Al/^{27}Al and large μ^{50}Ti* anomalies. We find that this mutual exclusivity previously reported in refractory objects, Ca-Al-rich Inclusions (CAIs) and hibonites in CM chondrites [9] is also present in presolar grains. The magnitude of anomalies in μ^{50}Ti* of these meteoritic components scales inversely with their size. Thus, nucleosynthetic μ^{50}Ti* variability in disk solids can be accounted for if they were directly inherited from the molecular cloud by averaging and chemical reprocessing dust, consistent with the conclusions from another recent study [10]. We show that, through this averaging process, both micro-scopic and disc-scale μ^{50}Ti* variations are intrinsically linked to ^{26}Al/^{27}Al variability such that inner disk materials recording μ^{50}Ti* deficits also inherited reduced ^{26}Al/^{27}Al directly from their precursors. In this view, the proto-solar molecular cloud dust that ultimately formed our planetary system consisted of a mixture of old galactically inherited ^{26}Al-poor dust with large μ^{50}Ti* variations produced by numerous generations of stars seeded by freshly synthesized new ^{26}Al-rich dust. ^{26}Al-rich CAIs inherited the isotope composition of this new dust component (characterized by an average ^{26}Al/^{27}Al of about 5 x 10^{-5} and μ^{50}Ti* of 950) and therefore do not represent the average ^{26}Al/^{27}Al (or μ^{50}Ti) of the bulk Solar System, i.e. consistent with conclusions from previous studies [11,12,13,14]. Hence, ^{26}Al-rich CAIs cannot consistently be used as time-anchors for ^{26}Al-^{26}Mg age-dating early solar system materials.

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