# $^{50}$Ti EVIDENCE FOR DIFFERENT REFRACTORY PRECURSORS IN CHONDRULES

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**Introduction:** Understanding potential genetic and temporal links between chondrules and Ca,Al-rich inclusions (CAIs) is a major goal in cosmochemistry. Whereas it is well established that most CAIs formed in a short time interval of possibly smaller than 20 ka [1], the chronology of chondrules is less understood with the possibility that some chondrules may have formed contemporaneously with CAIs while other formed over several few million years [2]. This raises the question to what extent CAIs were directly involved in the chondrule forming process as precursors. To this end, Al-rich chondrules, a widespread albeit rare constituents of non-carbonaceous and carbonaceous chondrites (e.g., [3-9]), are of special interest, as they have been suggested to have formed from precursors including CAIs. The detailed study of the Na-rich variety of these chondrules from ordinary, Rumuruti, and CO3 chondrites has shown that they typically consist of euhedral to subhedral mafic minerals embedded within a brownish nepheline-normative, glassy mesostasis and having group II, III, and ultra-refractory Rare Earth Element (REE)-patterns similar to those found in some CAIs [9,10]. This has lead to the conclusion that CAIs and/or AOAs were part of the Na-rich chondrule precursors [9], raising the question of whether these chondrules display the $^{50}$Ti excesses typically observed for CAIs. CV CAIs show an average $\varepsilon^{50}$Ti excess of ~9-10 with a variation ranging from ~2-16 $\varepsilon^{50}$Ti [11,12]. Similar observations were made in a recent study for CO, OC and RC CAIs [13]. Thus, if CAIs with an $\varepsilon^{50}$Ti excess were part of the chondrule precursors, then Na-rich chondrules should also show a $^{50}$Ti excess according to the amount of CAIs in the precursors. In this study we have therefore examined the Ti-isotope systematics of 18 Na-rich chondrules from five OC (15 chondrules) and one CO3 chondrite (three chondrules) to test this hypothesis. For comparison, we also obtained data for one OC Fe-Mg chondrule and one RC Fe-Mg chondrule.

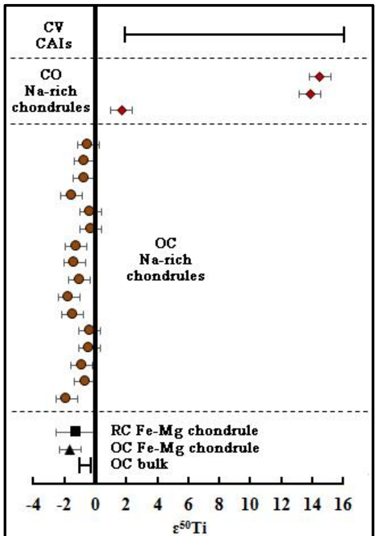


Fig. 1: $\varepsilon^{50}$Ti data for various types of chondrules. Errors are 2σ. Data for OC bulk from [11,15,16] and for CV CAIs from [11,12].

**Methods and Results:** The Na-rich chondrules were detected and classified with the Jeol 6610-LV SEM and then drilled out with a MicroMill. Samples were dissolved and Ti was separated via two-stage ion-exchange chromatography after [14]. The Ti isotope analyses were performed on a Thermo Scientific Neptune *Plus* multicollector inductively coupled plasma mass spectrometer in Münster. The Na-rich chondrules from the OCs have $\varepsilon^{50}$Ti values between -1.8 ± 0.7 and -0.3 ± 0.7 and do not show any $^{50}$Ti excess (Fig. 1). The OC and RC Fe-Mg chondrules have $\varepsilon^{50}$Ti = -1.6 ± 0.4 and -1.2 ± 1.3. Two Na-rich chondrules from the CO3 chondrite have high excesses with $\varepsilon^{50}$Ti = 13.9 ± 0.7 and 14.5 ± 0.7 respectively, while one Na-rich chondrule from the same meteorite exhibits a small excess of 1.7 ± 0.7.

**Discussion:** The Na-rich chondrules from the CO3 chondrite show that refractory CAI-like precursors with an $\varepsilon^{50}$Ti excess were incorporated into these chondrules, as predicted by [9]. However, the Na-rich chondrules from the OCs do not show any $^{50}$Ti excess and have similar values as bulk OCs and OC/RC Fe-Mg chondrules. Thus, although Na-rich chondrules from OCs show ultra-refractory, group II and group III REE patterns [9], they appear to not have incorporated any $^{50}$Ti-enriched material during chondrule formation. Therefore, the refractory material incorporated into the OC Na-rich chondrules must have been different from the precursor material of the CO3 Na-rich chondrules. Remarkably, CAIs from OCs also have an excess in $^{50}$Ti similar to that of CO3 and CV CAIs [13], whereas none of the OC Na-rich chondrules show an excess. Thus, since the refractory precursor for the Na-rich chondrules in OCs did not have an excess in $^{50}$Ti, two different refractory CAI-like materials are required to explain the contrasting Ti isotopic signatures observed in Na-rich chondrules from ordinary and CO3 chondrites.

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