TITANIUM AND OXYGEN ISOTOPE COMPOSITIONS OF INDIVIDUAL CHONDRULES FROM ORDINARY CHONDRITES

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Introduction: Chondritic meteorites are known to carry nucleosynthetic isotope variations that are generated by the heterogeneous distribution of presolar material in the solar system [e.g. 1]. Titanium is a refractory element that displays correlated nucleosynthetic variations in ^{46}Ti and ^{50}Ti in bulk rock meteorites, which are of different nucleosynthetic origin [2]. Previous work also reveals correlations between ε^{50}Ti and ε^{54}Cr [2] in bulk meteorites with the exception of carbonaceous chondrites. In carbonaceous chondrites, the ε^{50}Ti values are strongly influenced by anomalous Ti from CAIs, while those of ε^{54}Cr are less affected because of the lower Cr content in CAIs [2,3]. While the relationship of ε^{50}Ti and ε^{54}Cr in carbonaceous chondrites does not allow for a linear correlation in a ε^{54}Cr- ε^{50}Ti diagram, a correlation is revealed between ε^{54}Cr and Δ^{17}O [4]. This correlation is puzzling, because Cr isotope variations are likely carried by presolar dust (e.g., spinels [5]). In contrast, O isotope variations in carbonaceous chondrites are interpreted as the result of mixing of ^{16}O-rich solids with ^{16}O-poor solar gas and are thus heavily influenced by the solar gas [6].

This study aims to evaluate the relationship between nucleosynthetic Ti isotope anomalies and O isotopes in single chondrules. To this end we analyzed single chondrules from ordinary chondrites, which show nucleosynthetic Ti isotope anomalies at a bulk rock scale. The O isotopes of chondrules are likely to reflect exchange of chondrule precursors with a ^{16}O-poor solar gas during chondrule formation [7], while Ti is influenced by the precursor dust. Therefore, Ti isotope data on single chondrules will allow us to assess the extent of isotopic diversity in the precursor dust of chondrules. In addition, we have also applied the Ti double spike technique [8] to a selection of our chondrules to obtain absolute Ti isotope composition and evaluate stable isotope fractionation that could have occurred during the chondrule formation.

Material and Methods: Individual chondrules or fragments thereof were separated from the ordinary chondrites Tieschitz (H/L3.6), Parnallee (LL3.6) and Saratov (L4). They were characterized and classified for type and texture by CT scanning. Fourteen chondrules were selected for Ti and O isotope analyses. The chondrules were powdered and an aliquot was used for triple-O isotope analysis. The samples were reacted by CO_2- laser fluorination and passed through a separation line and a GC column for purification and separation from interfering NF^+ [9], before being introduced into a Thermo Finnigan MAT253 mass spectrometer. Reference gas and mineral standards (NBS-28, UWG-2 and San Carlos olivine) were measured with the chondrule samples. An aliquot of each powdered chondrule was dissolved by Parr bomb acid digestion, and Ti was separated by a three-step column chemistry procedure [8,10]. The first column was adapted from [11] using TODGA resin. The samples were measured with a Neptune plus MC-ICPMS at the ETH Zürich. The Ti isotope ratios are internally normalized to ^{49}Ti/^{47}Ti=0.749766 [12]. Terrestrial samples (DTS-2b, BHVO2) as well as bulk samples of several ordinary chondrites (St. Severin, Richardton, Allegan) were used to assess data accuracy. Larger chondrules were also analyzed using a ^{47}Ti-^{49}Ti double spike method [8].

Results and Discussion: The isotopic compositions of chondrules from the same meteorite are variable for both O and Ti isotopes. They lie in the range of previously published data for ordinary chondrites e.g. [2,8,13]. Most δ^{18}O and δ^{17}O values fall close to a line of slope ~1, which is generally interpreted to represent mixing from ^{16}O-rich solid and ^{16}O-poor gas [13]. Tieschitz chondrules show deviations from this line, which may indicate aqueous alteration or contamination with matrix material. Most chondrules display small positive or negative ^{50}Ti isotope variations (ε^{50}Ti from -0.3 to -1.1) relative to bulk ordinary chondrite (ε^{50}Ti =-0.5 ± 0.2). This indicates that each individual chondrule has sampled a unique mix of precursor materials. At the same time, the data also fall close to the ε^{46}Ti-ε^{50}Ti correlation [2] defined by bulk rock meteorites. This suggests that they also formed from a dust mixture with a similar ratio of presolar ^{46}Ti and ^{50}Ti carrier phases as bulk meteorites. Three chondrules from Parnallee and Tieschitz display similar mass-dependent Ti isotope compositions to bulk ordinary chondrites and therefore show no evidence for Ti isotope fractionation during chondrule formation.

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