THE SEARCH FOR TRACE ELEMENTS IN PRESOLAR SILICATE GRAINS.

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Introduction: Isotopically anomalous dust grains that formed in the outflows of evolved stars and in the ejecta of stellar explosions are a minor, but important component of primitive Solar System materials. Such grains, which can be found today in primitive meteorites, interplanetary dust particles, and cometary dust, mostly escaped alteration and homogenization processes in the interstellar medium as well as during the formation of the protosolar nebula and protoplanetary disk [1]. The properties of these grains hold valuable information on stellar nucleosynthesis and evolution, grain formation in circumstellar environments, and the types of stars contributing material to the nascent Solar System. Silicates are the most abundant type of presolar dust available for single grain analyses [2], followed by refractory oxides, SiC, graphite, and Si_3N_4. Presolar SiC and graphite have been found to carry various amounts of trace elements, depending on the parent star's and circumstellar envelope's chemical composition, physical properties (e.g., pressure, mass-loss rate) and condensation behavior of the respective mineral phases [e.g., 3–9]. For O-rich grains, however, data for elements heavier than Fe and Ni are virtually non-existent; only a single study found Sr in one complex presolar grain [10]. Here, we report the first data for heavy trace elements in a presolar silicate grain.

Samples & Experimental: We conducted a search for trace elements in a particularly large presolar Ca-bearing silicate grain, NWA7540_3A_3 (890 nm × 420 nm) with the NanoSIMS 50 at the Max-Planck-Institute for Chemistry. The grain was identified during previous O-isotope mapping in the ordinary chondrite Northwest Africa (NWA) 7540 (LL3.15). Measurements were performed with the Hyperion RF plasma source, by rastering a focused O^- ion beam (~15 pA, ~300 nm) over a 5×5 μm^2-sized area around the presolar grain, with an integration time of ~44 min per measurement. Three different mass sequences were applied: (1) $^{24}Mg^+$, $^{28}Si^+$, $^{88}Sr^+$, $^{93}Nb^+$, $^{138}Ba^+$; (2) $^{24}Mg^+$, $^{28}Si^+$, $^{85}Rb^+$, $^{98}Mo^+$, $^{140}Ce^+$; (3) $^{24}Mg^+$, $^{28}Si^+$, $^{86}Sr^+$, $^{90}Zr^+$, $^{139}La^+$. Peak positions and relative sensitivity factors were calibrated and confirmed using an NBS 611 glass standard.

Results & Discussion: The elements Sr, Zr, and Ce could be positively identified within the grain, with the following abundances given relative to Si: Sr/Si = $1.7 \pm 0.9 \times 10^{-4}$, Zr/Si = $1.2 \pm 0.3 \times 10^{-4}$, and Ce/Si = $1.2 \pm 0.5 \times 10^{-4}$. The Sr/Si ratio is in a similar range as the one reported for the O-rich complex grain by [10]. The respective Solar System abundance ratios are Sr/Si = 2.5×10^{-5}, Zr/Si = 1.15×10^{-5}, and Ce/Si = 1.23×10^{-6} [11], significantly lower than what is observed in the presolar silicate. From model data for low-mass asymptotic giant branch (AGB) stars [12], we find that ratios of several 10^{-4} can occur during thermal pulses while the C/O ratios are below one, which would favor the condensation of O-rich dust. However, the Zr/Si and Ce/Si ratios of NWA7540_3A_3 exceed the respective model predictions, indicating additional effects governing the incorporation of these trace elements. During previous Ca-Ti isotopic measurements [10], a heterogeneous ^{48}Ti-distribution was observed for this presolar silicate, and the ^{90}Zr- and ^{140}Ce-distributions observed here show some correlation with the area having the highest ^{48}Ti-intensity. For a gas of solar composition, it is predicted that Sr and Ce would condense into titanate at similar temperatures (1464 K and 1478 K, respectively) [11], while Zr would form ZrO_2 at T~1741 K. Since Zr shares some chemical similarities with Ti (both are located in group 4 of the periodic table), ZrO_2 might have been incorporated into Ti-oxides, which could have served as condensation nuclei for the silicate grain [e.g., 14]. Comparison of the trace element data from this study with SiC grain results is not straightforward. Formation of O-rich and C-rich circumstellar dust occurs in chemically different environments, and also at different stellar evolutionary stages, and both factors likely have an influence on the availability and condensation behavior of a given trace element. Our results show that presolar silicates have to be considered, besides carbonaceous stardust, as carriers of heavy trace elements.

Acknowledgements: We thank Elmar Gröner and Philipp Schuhmann for technical assistance with the NanoSIMS, and Knut Metzler (Institute for Planetology, Münster) for making the NWA 7540 sample available.

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