HIGH-RESOLUTION ISOTOPIC STUDY OF FE,NI AND TI(C,N) SUBGRAINS IN THE LARGEST KNOWN PRESOLAR SIC X-GRAIN

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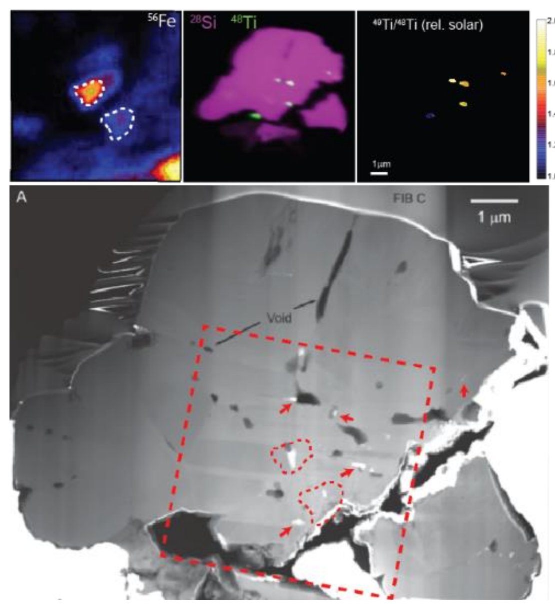
Introduction: Presolar grains from Type II supernovae (SNe) include low-density graphite and SiC X-grains [1]. X grains represent 1-2% of presolar SiC in chondrites. Their scarcity and small average size (< 1µm) have long been limiting factors for extensive studies. The discovery of a 25µm diameter X grain, called Bonanza, enabled the conduction of an extensive isotopic and mineralogic study [2]. TEM analysis of FIB sections of Bonanza revealed numerous, typically < 0.2 µm diameter, Ti(C,N) and FeNi subgrains. NanoSIMS Ti, Fe, and Ni measurements also suggested the presence of subgrains, but the spatial resolution of ~400 nm was not sufficient to resolve the individual inclusions identified by TEM. Similar subgrains were trapped during SN graphite condensation. In contrast, the Bonanza TEM data suggest subgrains may have formed by exsolution. The formation mechanism is important for interpreting isotopic data in terms of mixing in the parent SN gas. Here we report a high resolution *in situ* study of Ti, Fe, and Ni isotopes in subgrains identified in the prior TEM study and made possible thanks to the new Hyperion RF plasma O^- ion source installed on the Carnegie NanoSIMS 50L ion probe.

Method: A FIB lift-out of Bonanza of *ca*. 8×10µm (Fig. A in [2]) was removed from the TEM grid, welded with Pt onto a gold foil, and analyzed with the NanoSIMS in multicollection mode. The distribution of C, O, and N across the section were first mapped with a 100-nm Cs^+ beam. Ti isotopes were then imaged with the Hyperion ~150-nm O^- beam; ^{28}Si was measured along with ^{46,47,48,49,50}Ti and ^{51}V, with synthetic TiC used as a standard. Fe and Ni isotopes were measured in a 5×5 µm sub-region in which TEM had shown the presence of FeNi subgrains. Masses measured were ^{54,56,57}Fe and ^{58,60,61,62}Ni, and Fe,Ni metal grains in the Acfer 094 meteorite were used as standards. Prior to these measurements, the full grain was imaged in ^{28}Si, ^{52}Cr, and ^{54}Fe to aid in image alignment and check for possible Cr interferences to either ^{50}Ti or ^{54}Fe. Cr was found to be negligible in the subgrains. We corrected for possible ^{50}V contributions to ^{50}Ti assuming a solar composition of V in each subgrain and ^{58}Fe interferences to ^{58}Ni were corrected based on the solar ^{58}Fe/^{56}Fe value. Future work will use SN simulations to more accurately determine this correction [e.g., 2,3].

Results and discussion: We identified 7 Ti-rich subgrains and 3 Fe,Ni rich subgrains resolved from each other and mostly identifiable with subgrains identified by TEM. The O isotope map revealed no O associated with the Ti(C,N) subgrains, in contrast with TiC measured in SN graphites [4]. All Ti(C,N) subgrains have Ti isotopic compositions consistent with the bulk compositions of Bonanza [2]. In addition, all are enriched in ^{46,49,50}Ti and close-to-solar ^{47}Ti content. We note that δ^{50}Ti/^{48}Ti ratios of the subgrains are significantly higher than the reported compositions for TiC inside graphite grains [4], with ratios ranging between 110 and 310 ‰. Fe,Ni subgrains have δ^{57}Fe/^{56}Fe and δ^{54}Fe/^{56}Fe ratios comparable to the ones reported by [2] and display a high variability in Ni/Fe ratio (~67%). Independently of large uncertainties, those subgrains display larger enrichments in Ni isotopes than most previously reported in X grains [3].

Notably, neither Ti-rich nor Fe,Ni-rich subgrains display significant isotopic deviations from one another. This provides evidence to strengthen the microstructure-based arguments that the subgrains formed by exsolution, but co-condensation cannot yet be ruled out. The absence of oxygen anomalies in the subgrains and their location in a host SiC further attest in favor of a formation in a C/Si region in a core-collapse SN exposed to high shock velocities [5].



(bottom) STEM image of FIB section [2]. Fe,Ni 5×5 µm raster and subgrains are depicted by dashed lines. Arrows point toward Ti subgrains identified in this study

References:

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