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TOF-SIMS Analysis of Presolar SiC X-Grains

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Since the first isolation of individual presolar grains from primitive meteorites in 1987 (Lewis et al., 1987) they were studied intensively to elucidate their origin from their elemental and isotopic composition as reviewed by Anders & Zinner (1993), Zinner (1998), and Hoppe & Zinner (2000). After diamonds, SiC grains are most abundant. While diamonds are only 2 nm in size, preventing analyses of individual grains, SiC grains have sizes of up to several micrometers that allow e.g. isotopic studies of individual grains. Many elements in presolar grains have isotopic compositions that are clearly distinct from average solar system values. They identify their stellar sources. Most SiC grains (main stream SiCs) formed in the wind of AGB stars. A sub-type of SiC, the so-called X grains, formed in the ejecta of supernova explosions.

Most isotopic analyses of presolar grains are done with double focussing (DF-) SIMS, TIMS, or gas mass spectrometry. Due to the limited (or lacking) spatial resolution of these techniques there is yet no information available on the homogeneity of element concentrations and isotopic compositions of these grains. To study this question we performed TOF-SIMS analyses of two X grains.

The advantage of TOF-SIMS is that it provides whole mass spectra of positive or negative secondary ions with a mass resolution up to 10,000 and ion distribution images with lateral resolutions down to 0.2 µm. We examined two X-grains that were extracted from the Tieschitz H3-chondrite with the method described by Gao et al. (1994). They were first identified by isotopic imaging with DF-SIMS through their characteristic large ^{28}Si enrichments. After the TOF-SIMS analyses the grains were photographed with SEM.

Results

Grain #177-1: The size of the grain is about 2 µm. Its euhedral crystal structure is still visible in the SEM image. The silicon isotopic ratios are δ^{29}Si = - (453 ±26) per mil and δ^{30}Si = - (647 ±24) per mil. Mg is dominated by ^{26}Mg. The calculated initial ^{26}Al/^{27}Al ratio is 0.495 ±0.010. No isotopic heterogeneity is observed in the grain.

Grain #480-3: This grain is smaller (about 1.5 µm) than grain #177-1 and has a smaller enrichment of ^{28}Si with δ^{29}Si = - (316 ±20) per mil and δ^{30}Si = - (505 ±19) per mil. The Si isotopic composition is constant across the grain within our error limits. However, ^{26}Mg and ^{27}Al are considerably heterogeneous. The inferred initial ^{26}Al/^{27}Al ratio varies from 0.170 ±0.005 to 0.074 ±0.004 from one side to the other. Similarly, the ^{26}Mg/^{24}Mg ratio varies from 2.35 ±0.05 to 1.6 ±0.1.

Discussion

With these measurements we again demonstrated the ability of TOF-SIMS to identify heterogeneous distributions of elemental or isotopic compositions inside µm-sized grains with very low sample consumption. The observed heterogeneous distributions - further studies are planned for clarification - at present may be explained in two different ways:

(1) Heterogeneity could result from the extraction procedure of the grains from the meteorite that involve heavy treatments with acids. They may affect the surface. eg. AlN as a soluble compound that forms a solid solution with SiC might be dissolved from the surface layer during grain extraction (Stephan et al., 1995). On the other hand, dissolved material from the bulk meteorite could have contaminated the presolar grains in that process. The subsequent DF-SIMS and TOF-SIMS measurements might have exposed material from different depths.

(2) The observed distributions could reflect heterogeneous condensation in the supernova ejecta.

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