SULFUR ISOTOPE ANALYSIS OF 24 SULFUR-RICH DUST IMPACT CRATERS FROM COMET WILD 2

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Introduction & Motivation: We present four S isotope NanoSIMS data of 24 S-rich dust impact craters on aluminum foil C2037N from NASA’s Stardust Mission [1]. Our objective was to detect large presolar S isotopic anomalies that eluded equilibration in the solar nebula, parent body, and upon impact capture. Although impact processes can strongly modify the dust composition [e.g., 2; 3], some material with presolar isotopic signatures survived: Five presolar grains (silicates/oxides, SiC), detected in Wild-2 dust in previous studies [4-8] as well as highly 15N-enriched material of presumably presolar origin [4,5]. The recent discovery of presolar S isotope anomalies in presolar SiC grains from the primitive, un-equilibrated chondrites Murchison and Indarch [9-11] as well as the finding of CaS inclusions in presolar SiC grains of Type AB [12] and the similarity of Wild-2 dust with primitive, un-equilibrated chondrites [e.g., 13] make Wild-2 dust a promising sample to search for presolar S isotopic anomalies [14]. Preliminary results of 14 craters were presented earlier [15].

Samples & Methods: Twenty-four Comet Wild-2 dust impact craters with S-rich impact residues were selected for NanoSIMS S isotopic analysis. The selection criterion were prominent S peaks in EDS spectra of craters found during a high-resolution survey of Stardust aluminum target foil C2037N with the Max Planck Institute for Chemistry’s LEO 1530 field-emission scanning electron microscope (Fig. 1). We used the Cameca NanoSIMS 50 ion probe at the Max Planck Institute for Chemistry for S isotopic analyses. Samples and standards were scanned with a primary Cs+ ion beam (~100 nm, ~1 pA) and secondary ions of 32S+, 33S+, 34S+, 36S+ and 28Si+ or 16O+ were detected in multicollection. To quantify reproducibility we analyzed a thin section of Mundrabilla troilite, and laboratory-produced pyrrhotite impact craters that were prepared for the Stardust preliminary examination [16]. Reproducibilities on the troilite thin section are 2‰, 3‰, and 11‰ (1SD) for δ32S, δ34S, and δ36S, respectively. The uncertainties are higher with the laboratory-produced pyrrhotite craters due to topographic effects that result in mass fractionation (10‰, 16‰, and 33‰ 1SD for δ33S, δ34S, and δ36S, respectively). This prevented us from detecting S isotopic variations produced in the solar system, which are typically much smaller than our uncertainties [17-18]. However, presolar S isotopic anomalies can be much larger than our uncertainties [e.g., 9] and are detectable.

Results & Discussion: NanoSIMS S isotope data of the 24 S-rich impact craters on foil C2037N are shown in Fig. 2. Most S-rich dust impact residues in craters (23 out of 24) on Stardust foil C2037N have normal S isotopic ratios within our analytical 2σ uncertainties. This implies that these sulfides and S-rich silicates most likely formed in the Solar System. The two craters (M4 and M18) with the largest δS values have very large errors and therefore cannot be considered isotopically anomalous on a >2σ level. Nevertheless, it is interesting that only the S isotopic compositions of craters M4 and M18 are on mixing lines between the solar compositions and the interstellar medium (Fig. 2).

We detected a small S isotopic anomaly (δ33S = −57±17‰, δ34S = −41±17‰, δ36S = −86±88‰) in crater 12 (Fig. 2) that we can interpret as a mixture between a presolar supernova sulfide and a sulfide of Solar System origin. Silicon carbide supernova grains show large enrichments in 32S [10], the signature of the Si/S zone [19]. The signature of crater 12 could be explained by mixing two components, one with solar S and one with del-33/34/36 = −810‰/−810‰/−1000‰ the signature of the Si/S zone of a 25 M☉ core-collapse supernova model (s25a34d[19]), in a ratio of 20:1. However, the small magnitude of the anomaly of the residue in crater 12 does not exclude chemical fractionation or a statistical outlier as explanations.
Fig. 2. Relative S isotopic compositions, given as permil deviations from the terrestrial VCDT standard, of dust impact residues on foil C2037N. Error bars are 1σ and include all uncertainties discussed in the text. Observed δS values of carbon star IRC+10126, δS(i=33, 34, 36) = (49‰, 39‰, 1410‰) [20], model-predicted δS values of solar metallicity asymptotic giant branch (AGB) stars (1.5 M⊙ (▽), 2 M⊙ (◇), and 3 M⊙ (△)) [22], and average δS values of different mass zones [23] of a 25 M⊙ SNIı model (s25a34d; [19]). Arrows point to δS values beyond the scale of the diagram.

The highest analytical uncertainty is due to isotope fractionations due to sample topography and impact fractionation. Therefore, future SIMS analyses of microcrater residues on flattened foils will significantly improve analytical uncertainties.


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