
Introduction: Analyses of comet 81P/Wild 2 samples returned from the Stardust mission have uncovered surprising similarities to meteoritic material, including the identification of inner solar system grains [1-3]. The TEM characterization of terminal particle (TP) 4 from Stardust track #147 revealed an assemblage consisting of symplectically intergrown pentlandite and nanocrystalline magnetite coexisting with high-Ca pyroxene [4]. Mineralogically similar cosmic symplectites (COS) containing pentlandite and magnetite in the primitive Acfer 094 meteorite are highly depleted in $^{16}$O ($^{18}$O, $^{34}$S $\sim$ 180 %) [5-7]. This isotopic signature is proposed to record alteration with primordial solar nebula water. Conversely, the normal O isotopic composition of the Stardust COS indicates alteration by a different aqueous reservoir, perhaps on the comet [8]. In this study, we analyzed the Wild 2 COS for S isotopes to further constrain its origin.

Experimental: Thin sections of TP4 (12 μm) were produced and their mineralogy was thoroughly characterized by TEM. Two of the sections were analyzed for O isotopes by isotopic imaging in the JSC NanoSIMS 50L. The sample in one of the slices was completely consumed. The remaining material in the adjacent slice was analyzed simultaneously for $^{16}$O, $^{33}$S, $^{34}$S, and $^{30}$Fe$^{16}$O in electron multipliers using a Cs⁺ primary ion beam. Quasi-simultaneous arrival (QSA) can have a significant effect on S isotopic ratios when using electron multipliers, resulting in undercounting of $^{33}$S [9]. Canyon Diablo troilite (CDT) was measured numerous times to deduce a correction factor for QSA and ensure measurement reproducibility. Isotopic ratios are reported relative to CDT.

Results and Discussion: The Wild 2 COS is enriched in the heavy S isotopes relative to CDT ($^{34}$S = 6.5 ± 1.6 ‰; $^{33}$S = 5.1 ± 0.7 ‰, 1e). The degree of $^{33}$S enrichment indicates mass-independent fractionation (MIF) with $\Delta^{33}$S = 3.9 ± 1.7 ‰. MIF of S has been observed in some chondrites ($\Delta^{33}$S up to 011‰) [10], but this effect has not been identified in sulfides from carbonaceous chondrites [11] or IDPs [12]. S isotopic analysis of Stardust impact craters also did not reveal MIF or anomalies, save for one potential $^{33}$S-rich presolar sulfide [13]. Measurement errors on these impact craters were much larger than those in this study, however. MIF of S has been proposed to result from heterogeneities in the solar nebula from nucleosynthetic components [14] or photochemical irradiation of solar nebula gas [10]. Presolar SiC grains are observed to have $^{33}$S enrichments [15, 16] contrary to the S isotopic composition of the cometary COS. The S isotopic composition more likely reflects irradiation of nebular gas.