FIRST DISCOVERY OF PRESOLAR MATERIAL OF POSSIBLE SUPERNOVA ORIGIN IN IMPACT RESIDUES FROM COMET 81P/WILD 2.

J. Leitner[1], P. Hoppe[1], and P. R. Heck[2], [1]Max Planck Institute for Chemistry, 55128 Mainz, Germany (jan.leitner@mpic.de), [2]University of Chicago, Chicago, IL 60637, USA.

Introduction: Comets are believed to have formed in the cold, outer fringes of the protosolar cloud. Thus, cometary material may represent the most primitive matter in the solar system. Dust particles from the coma of comet 81P/Wild 2 were collected by NASA's Stardust mission and returned to Earth in 2006 [1]. Besides low-density aerogel, aluminum foil provided a second valuable capture medium for cometary dust [1,2]. Impactor residues were found inside crater cavities or on crater rims. Preliminary examination revealed the dust to be an unequilibrated mixture of heterogeneous material of mainly solar system isotopy [2,3]. Three ^{17}O-rich presolar grains and one presolar SiC grain have been reported so far [3–6].

Samples and Experimental: In this ongoing study, 470 small impact craters (d=0.09–4.4 µm) were found in a SEM high-resolution survey on Stardust aluminum foils C2037N, C2044W, and C2052N. Impact residues in 169 small craters (d=0.24–1.76 µm) were subsequently investigated for O-isotopic compositions. For the isotope measurements a ~100 nm primary Cs^+ beam was rastered over 2×2 µm²- to 10×10 µm²-sized sample areas in the NanoSIMS 50 at the MPI for Chemistry in Mainz. $^{16}O^-$, $^{17}O^-$, $^{18}O^-$, $^{28}Si^-$, and $^{27}Al^{16}O^-$ ion images were acquired in multicollection mode. Presolar signatures are identified in situ by their O-isotopic composition, while detection of $^{28}Si^-$ facilitates the identification of the most common types of crater residues.

Results: For all 169 investigated craters (total residue area 68 µm^2), the $^{17}O/^{16}O$ ratios comply with solar system isotopy within 3σ, with $\delta^{17}O$ ranging from -108±82 ‰ to +202±135 ‰ (normalized to foil contaminations of solar system isotopy). 168 of the crater residues show no deviation from solar system composition for their $^{18}O/^{16}O$ ratios within 3σ, with $\delta^{18}O$ between -52±52 ‰ and +111±38 ‰.

One particular crater on foil C2037N, M40_004, has an $\delta^{18}O$ of 167±41 ‰ (1σ). The ^{18}O-anomaly is distributed nearly all over the crater area (Fig. 1) and meets a 4σ-criterion. While the three presolar silicate/oxide grains reported by [3,4] all belong to the O isotope group 1, most likely originating from low-mass AGB stars, the residue investigated in this study falls into group 4 and has probably formed in the ejecta of a type II supernova (Fig. 2) [7,8]. M40_004 is about 700 nm in size. A correlation between crater diameter and the diameter of the projectile is given in [9]:

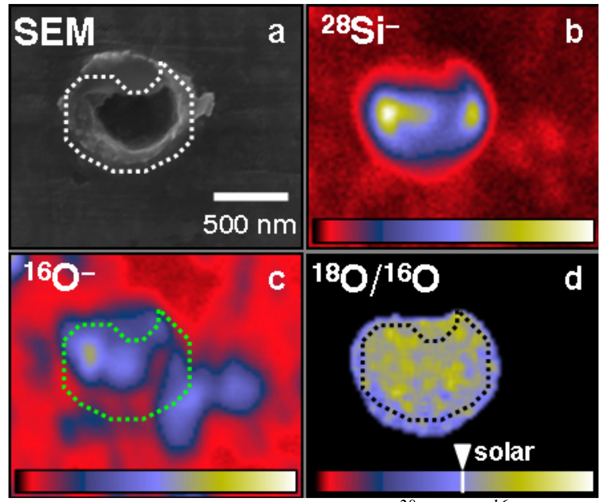

Fig.1. *SEM (a), Secondary Ion (b: $^{28}Si^-$, c: $^{16}O^-$), and $^{18}O/^{16}O$ ratio (d) images of crater M40_004. Dotted lines mark the outline of the ^{28}Si-distribution. Intensity in b, c, and d is color-coded from red (low) to white (maximum).*

$D_{crater}/D_{projectile}$ = 1.60±0.17 for $D_{projectile}$<2.4 µm. From this we infer a projectile diameter of ~440 nm.

Discussion: The current estimate on the abundance of presolar grains in matter from Wild 2 bears still large uncertainties. More than 90 percent of the investigated matter is located in impact craters larger than 20 µm. The crater residues consist of shock-produced melts and fragments of the impacting cometary particle. For a proper calculation of the presolar matter abundance in Wild 2 dust, information about the fraction of melted presolar grains within the residues is crucial. The results of this investigation suggest the fact that melting of presolar material during foil impact does indeed occur. However, due to the still limited statistics, a quantitative conclusion is not yet feasible, since only two grains have been detected in small (d<2 µm) impact craters: One was unmelted [4], while the distribution of the isotopic anomaly in crater M40_004 seems to indicate melting upon foil impact, provided the impactor was made not only of the presolar grain. This suggests that the results of investigations of large (d>2 µm) foil craters underestimate the content of presolar grains in the cometary dust. Even large isotopic anomalies of melted particles with diameters of 300 nm ("typical" size of a presolar silicate grain) are not detectable in craters produced by cometary particles with size of 1 µm or more. By focusing on small impact craters, such dilution effects can be minimized, and a more realistic estimate of the presolar grain abundance in Wild 2 matter can be made: E.g., for craters smaller than 800 nm corresponding to an impactor size of 500 nm, isotopic anomalies of a factor of 2 from a 300 nm-sized presolar grain contained in the impactor can be preserved at a level that permits their identification in the NanoSIMS even with total melting of the impacting cometary particle.

By using a binominal distribution, the probability of finding one presolar residue among 169 investigated craters is below 2 ‰, if the true abundance of presolar grains were only 11 ppm [10]. It is thus very likely that the true abundance is much higher. This is in line with inferences from recent test shots with powdered Acfer 094 material into Al-foils under Stardust-like conditions [11]. The best estimate for the abundance of presolar oxides/silicates in Wild 2 from our still limited data set can be calculated by dividing the original presolar grain's volume (d=300 nm assumed) by the total volume of small crater residue of solar system composition. This yields an abundance of ~1370 ppm. We point out that our current estimate for Wild 2 bears large uncertainties because it is based on the identification of only one presolar grain. Furthermore, even when studying only small impact crater residues we will miss comparatively small presolar grains or those with comparatively small isotope anomalies, i.e., our detection efficiency is less than 100 %.

It has to be taken into account that the abundance estimate for Wild 2 represents a bulk-normalized value, while abundances for primitive meteorites are matrix-normalized. Thus, for a direct comparison, corrections for the respective matrix content of each meteorite type have to be applied. With literature estimates of individual matrix contents for the meteorites with the highest presolar silicate abundances, ALHA 77307 [12], MET 00426 [13], QUE 99177 [13], and Acfer 094 [14], we obtain bulk abundances from 44–66 ppm. Antarctic micrometeorites (AMM) show a similar value, 57 ppm, for presolar silicates and oxides [15]. The 'primitive subgroup' of interplanetary dust particles (IDPs) has an abundance of 375 ppm [16], while IDPs from the "Grigg-Skjellerup collection" have an average presolar silicate/oxide abundance of 500 ppm, with up to 1.5 % for individual particles [17]. The inferred presolar silicate/oxide abundance of 1370 ppm for Wild 2 small crater residues lies at the upper end of the range of the abundances reported for other primitive solar system materials.

In conclusion, even if we consider the still large uncertainties of our abundance estimate, by investigating the residues of the small impact craters on Stardust Al foil, we can make a more realistic estimate of the abundance of presolar material in 81P/Wild 2. There is clear evidence coming from our work that it is significantly higher than previous calculations indicated. We hope to find more residues with presolar signatures in small craters which will permit to tighten the presolar grain abundance in Wild 2 further.

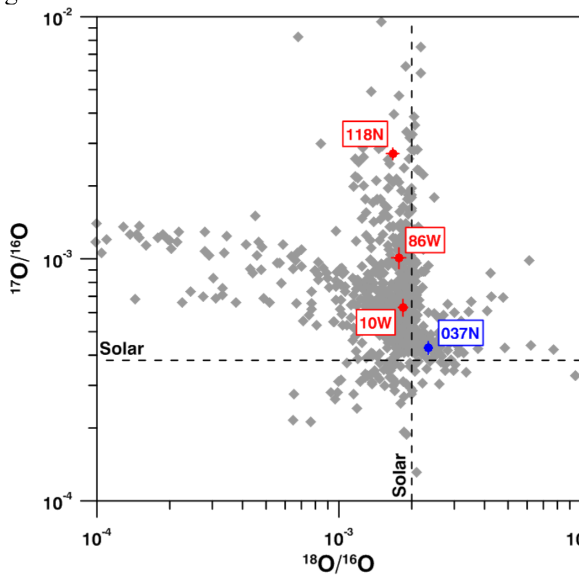

Fig.2. *Oxygen 3-isotope-plot of the presolar silicate/oxide grains found in comet 81P/Wild 2 matter. Red data points are from [3,4], blue from this study. Reference data (gray) are from [18].*

Acknowledgements: We thank Joachim Huth for his support on the SEM and Elmar Groener for technical assistance on the NanoSIMS.

References: [1] Brownlee D. et al. (2006) *Science, 314,* 1711–1716. [2] Hörz F. et al. (2006) *Science, 314,* 1716–1719. [3] McKeegan K. et al. (2006) *Science, 314,* 1720–1724. [4] Stadermann F. J. and Floss C. (2008) *LPS XXXIX,* Abstract #1889. [5] Messenger S. et al. (2009) *LPS XL,* Abstract #1790. [6] Brownlee D. et al. (2009) *LPS XL,* Abstract #2195. [7] Nittler L. R. et al. (2008) *ApJ, 682,* 1450-1478. [8] Vollmer C. et al. (2008) *ApJ*, *684,* 611–617. [9] Price M. C. et al., submitted. [10] Leitner J. et al. (2008) *LPS XL,* Abstract #1512. [11] Stadermann F. J. et al. (2009) *LPS XL*, Abstract #1188. [12] Nguyen A. et al. (2007) *ApJ, 656,* 1223–1240. [13] Floss C. and Stadermann F. J. (2009) *GCA, 73,* 2415–2440. [14] Vollmer C. (2008) PhD thesis, University of Frankfurt. [15] Yada T. et al. (2008) *MAPS, 43,* 1287–1298. [16] Floss C. et al. (2006) *GCA, 70,* 2371–2399. [17] Busemann H. et al. (2009) *EPSL, 288,* 44–57. [18] Presolar Grain Database (2009) http://presolar.wustl.edu/~pgd.