TOF-SIMS, NANOSIMS, AND TEM ANALYSIS OF INTERPLANETARY DUST PARTICLE SECTIONS.

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Introduction: Before in 2006 the Stardust mission will bring material from comet Wild 2 under controlled conditions to Earth [1], anhydrous IDPs represent probably the only source for cometary matter that is available for analysis in terrestrial laboratories. Like meteorites, IDPs have their own individual history that links them to their respective parent bodies and that can be revealed with modern analytical techniques. In most previous studies, only one analytical technique has been applied to individual particles and averaged properties from different sub-sets of the IDP collection were compared. Major technical developments during recent years provide the opportunity to study individual particles with a great variety of analytical techniques.

In continuation of a comprehensive consortium study of IDPs from stratospheric dust collector U2071 [2], three particles were selected for TOF-SIMS, NanoSIMS, and TEM analysis. This suite of analytical techniques allows to obtain information on the elemental, isotopic, and mineralogical composition of IDPs on a sub-micrometer scale. Since 1994, when the consortium study was initiated, technical improvements in both SIMS variants [3,4], especially in achievable lateral resolution and sensitivity have significantly enhanced the abilities to study these tiny, extremely fine-grained, complex particles.

Samples and Analytical Techniques: The IDPs selected for this study were U2071J2, U2071C9, and U2071H1h. All particles were previously characterized at NASA Johnson Space Center by SEM including bulk chemical analysis with EDS for major elements (including C) and secondary electron imaging (Fig. 1).

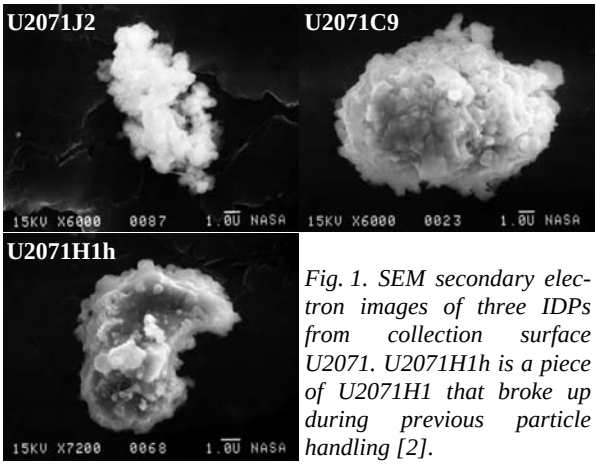

Fig. 1. SEM secondary electron images of three IDPs from collection surface U2071. U2071H1h is a piece of U2071H1 that broke up during previous particle handling [2].

After hexane rinsing to remove silicone oil residues from particle collection and storage, the IDPs were embedded in epoxy and ~80 nm thick microtome sections were produced. Sectioning was stopped after slicing approximately one half of the respective IDPs. The residual epoxy stubs were used for TOF-SIMS analysis, whereas the different sections were selected for TEM and NanoSIMS investigation. Unfortunately, no material from U2071H1h was found in the microtome sections.

Results and Discussion: Element ratios obtained by TOF-SIMS for sample sections are shown in Fig. 2. Individual secondary ion images are given in Figs. 3, 5, and 6. TOF-SIMS three color composite images, where red, green, and blue are assigned to the normalized intensities of Mg, Al, and Fe, are displayed in Figs. 4, 5, and 6. In Fig. 4 also a TEM overview image of U2071J2 is given. NanoSIMS results for O isotopes in U2071J2 and U2071C9 are discussed in [5].

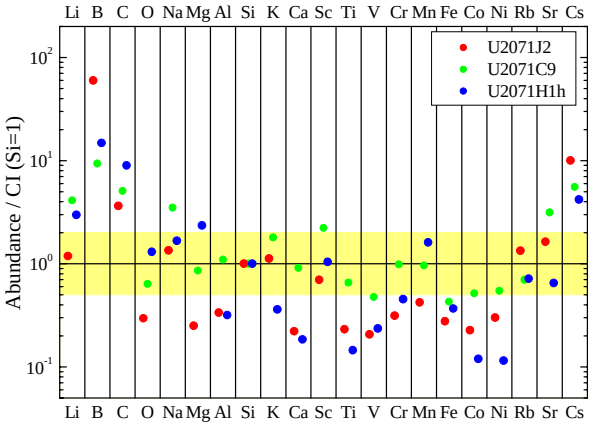

Fig. 2. Element ratios relative to Si and normalized to CI.

U2071J2. TOF-SIMS and TEM results (Figs. 3 and 4) yield typical sizes much lower than 1 µm for different phases within this heterogeneous IDP. Several of these grains can be identified as olivine, pyroxene, and Fe,Ni-sulfides. Al-rich areas are probably GEMS (glass with embedded metal and sulfides). Since there is no indication for the presence of hydrous minerals, U2071J2 can be classified as an anhydrous IDP, a class that is often connected to comets. However, NanoSIMS results show no indication of isotopic anomalies in oxygen or the presence of presolar matter [5]. Most element ratios relative to Si are below 1, an indication for the presence of residual silicone oil.

U2071C9 also shows heterogeneities on a sub-micrometer scale (Fig. 5). Olivine, pyroxene, and some Al-rich phases (probably feldspar, one also enriched in S) were identified by TOF-SIMS and TEM. NanoSIMS analyses again show no isotopic anomalies [5].

U2071H1h mainly consists of a single Mg-rich phase (Fig. 6). Onion shell like distributions of OH, F, and S (Fig. 6) are strong hints for contamination [6].

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References: [1] Brownlee D. E. et al. (2003) *JGR, 108*, E8111. [2] Stephan T. et al. (2001) *LPS 32*, #1267. [3] Stephan T. (2001) *Planet. Space Sci., 49*, 859–906. [4] Hoppe P. (2002) *New Astron. Rev., 46*, 589–595. [5] Hoppe P. et al. (2005) *LPS 36*, #1301. [6] Stephan T. et al. (1994) *LPS 25*, 1341–1342.

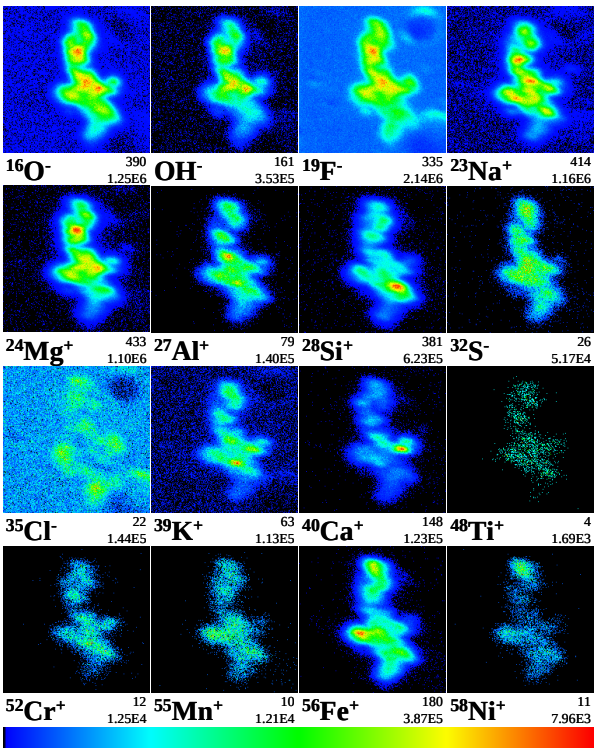

Fig. 3. TOF-SIMS secondary ion images of U2071J2. Field of view is 13×13 μm². All images use the same linear color scale normalized to the most intense pixel. Below each image numbers for maximum and integrated intensities are given.

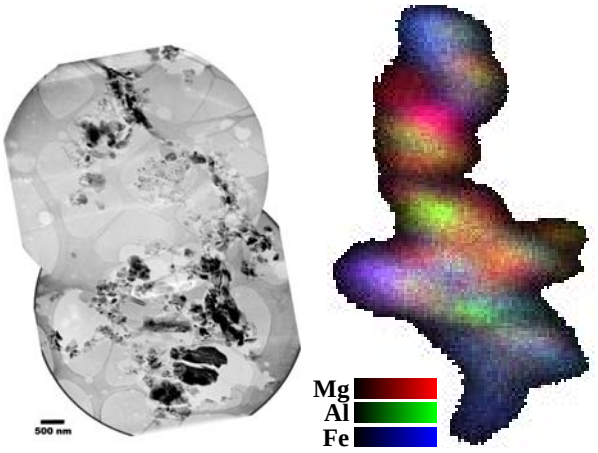

Fig. 4. TEM overview image (bright field, left) and TOF-SIMS composite image (right) of U2071J2.

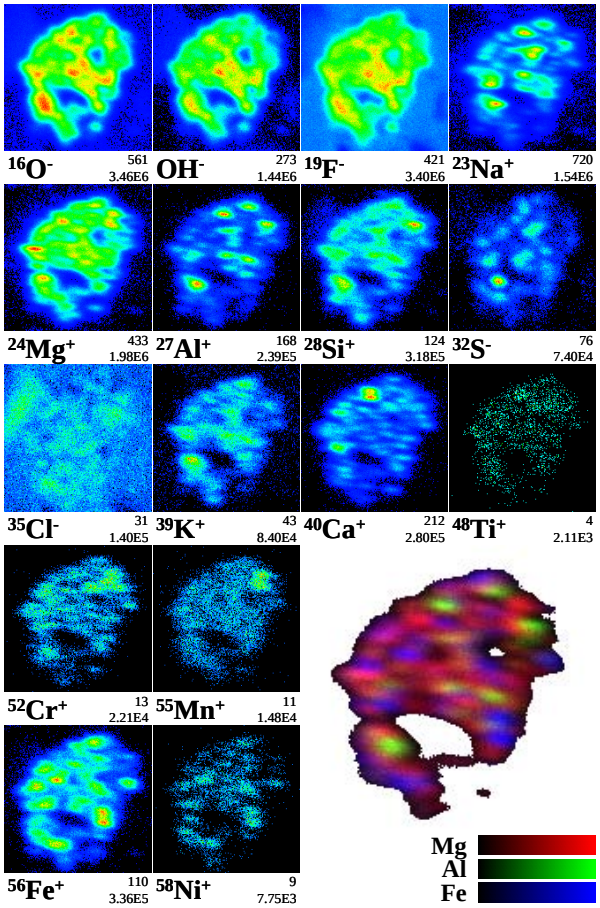

Fig. 5. TOF-SIMS images of U2071C9 (14×14 μm²).

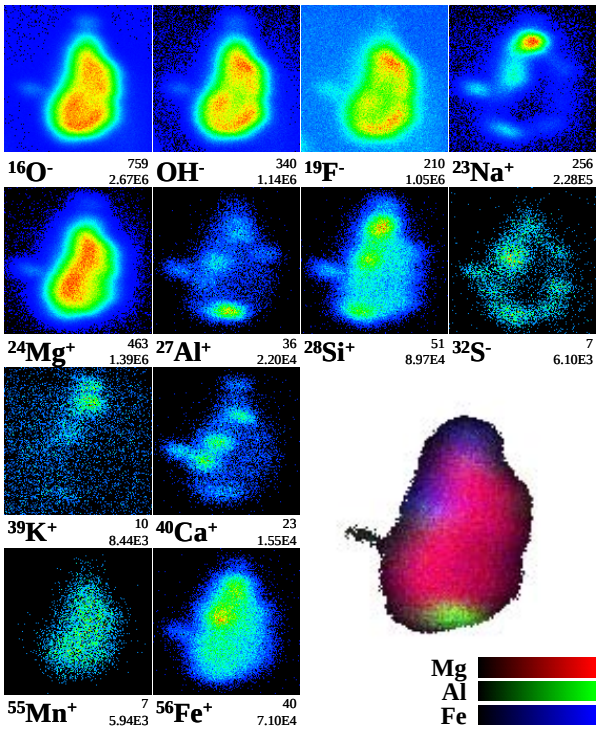

Fig. 6. TOF-SIMS images of U2071H1h (7.5×7.5 μm²).