WHAT WOULD A COMETARY INTERPLANETARY DUST PARTICLE LOOK LIKE AFTER HYPERVELOCITY IMPACT IN SILICA AEROGEL? B. T. De Gregorio[1] and R. M. Stroud[1], [1]Materials Science and Technology Division, Naval Research Laboratory (Code 6366, 4555 Overlook Ave. SW, Washington, DC 20375). E-mail: bradley.degregorio@nrl.navy.mil

Introduction: Chondritic porous interplanetary dust particles (CP-IDPs) are believed to originate from comets [1]. Studies of cometary coma grains collected by the NASA Stardust Mission to comet 81P/Wild 2 have uncovered representative examples of nearly every component of CP-IDPs [2], including the ubiquitous carbonaceous matter that coats and connects mineral grains in CP-IDPs [3,4]. However, the existence of authentic cometary GEMS (glass with embedded metal and sulfide) grains in the Stardust collection is controversial because of similar glassy material caused during impact melting and mixing of chondritic material with silica aerogel [5].

Coma particles from Wild 2 were collected at hypervelocity in silica aerogel. If present in the coma dust, CP-IDPs would be expected to disaggregate on impact with the aerogel collectors, producing bulb-shaped impact tracks [6]. However, if protected by one or more large mineral grains, it may be possible for a CP-IDP to survive capture. The extent to which the original structure, mineralogy, and carbonaceous components of the particle remains intact, or how much the aerogel interacts with the porous nature of the IDP is unknown.

Samples and Methods: We were allocated a keystone containing cometary Track 196 except for the main terminal particle (C2098,6,196,0,0). At least six small offshoot tracks were identified. The 15 μm terminal particle TP1 (C2098,6,196,1,0; Figure 1) was removed from the aerogel using freshly-pulled glass needles in a micromanipulator mounted to an EXpressLO ex situ FIB lift-out station. The terminal particle was placed in a molten sulfur droplet maintained at 110 °C on a temperature-controlled glass plate just above the sulfur melting temperature. Once crystallized around the particle, the sulfur droplet was adhered to an epoxy stub with cyanoacrylate adhesive and ultramicrotomed to various thicknesses, depending on the

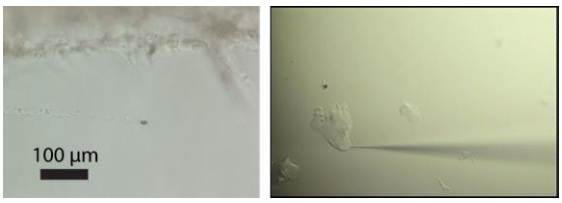

Figure 1. Optical photomicrographs of Stardust particle C2098,6,196,1,0 at the terminus of an offshoot track (left) and after removing the surrounding silica aerogel (right).

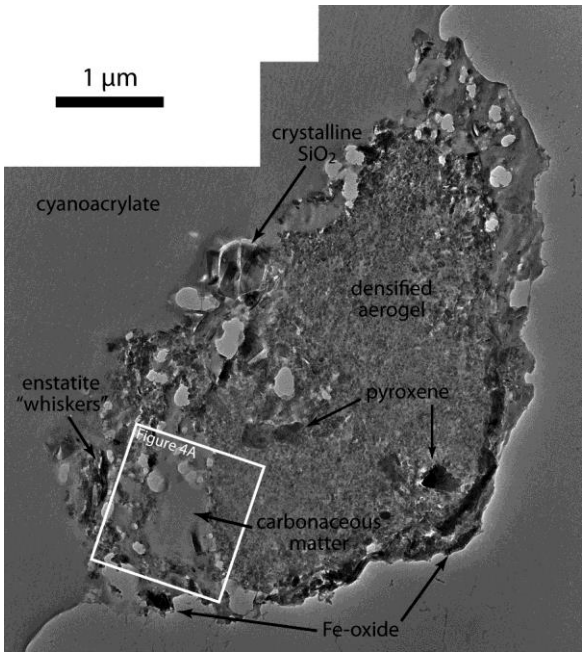

Figure 2. TEM mosaic of an ultramicrotome slice of terminal particle TP1 from Stardust track 196.

intended analysis. In addition, ultramicrotome sections were placed on a variety of substrates, including C support film grids for TEM, SiO support film grids for XANES, and SiN windows for NanoSIMS.

Initial characterization of ultramicrotome slices, including morphology, mineralogy, and composition was performed in a JEOL 2200FS TEM equipped with a 65 mm^2 Oxford X-Max SDD-EDS detector.

Preliminary characterization of the carbon bonding and functional chemistry of any carbonaceous matter in TP1 was performed by high-resolution EELS in a Nion UltraSTEM 200. Additional characterization of the carbon functional chemistry will be completed by February 2016 at the Advanced Light Source, Berkeley, CA, using the scanning-transmission X-ray microscope (STXM) at beamline 5.3.2.2.

Results: The main component of all ultramicrotome sections is densified aerogel. Within the aerogel are several sub-μm crystalline grains and at least one large domain of carbonaceous matter (Figure 2). At present, no amorphous silicate material or melted aerogel have been observed. The most common mineral grains are enstatite and high-Ca pyroxene, including several elongated "whiskers", some of which show

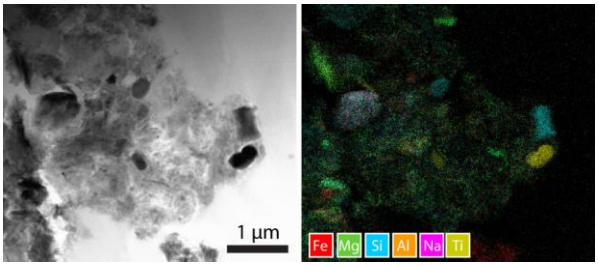

Figure 3. EDS map of major elements in TP1. Within this field of view are several pyroxene needles, an albite grain, TiO_2, SiO_2, and Fe-oxides.

characteristic 9 Å lattice fringes. Other mineral phases include albite and potassium feldspar, TiO_2, crystalline SiO_2, and clusters of Fe-oxide nanoparticles (Figure 3). The combination of Fe-oxide and carbonaceous matter was previously observed in Track 187 by laser Raman [7], but TEM characterization on those samples has not yet been performed to confirm the mineral form of the Fe-oxide or its relationship to the carbonaceous matter.

Preliminary EELS analysis of the carbonaceous matter within the particle show increased abundance of C=O bonding, consistent with ketone functional groups (Figure 4). The spectra are distinct from those of cyanoacrylate used in the sample preparation, which has more abundant C=C bonding. Unfortunately, these spectra are not representative of the true organic functionality of the sample because of the underlying carbon support film. This will be elucidated by XANES analysis, for which the sample was placed on a non-interfering SiO_x support film.

Discussion: Terminal particle TP1 is unusual in that it does not appear to contain a single large mineralic particle that would provide the necessary momentum to create a capture track in the aerogel collector. An alternate interpretation is that TP1 was originally a porous mineral aggregate held together by carbonaceous matter. As an aggregate, the porous particle had enough momentum to create a capture track. While travelling through the silica aerogel, a significant amount of aerogel was compressed and incorporated into the porous structure. Since the original porous structure of the particle is no longer present, this interaction with the aerogel served to both disaggregate the original particle structure, but also to keep much of the crystalline material in proximity within the densified aerogel.

The porous structure described above is consistent with that of CP-IDPs. In addition, both the presence of pyroxene "whiskers" and abundant carbonaceous matter are common characteristics of CP-IDPs [1,3]. However, some common CP-IDP components were not found in TP1, most notably sulfides and GEMS. Fe-oxide nanoparticle clusters, SiO_2, and TiO_2 grains are not found in CP-IDPs, although isolated magnetite grains and magnetite rims are common. It is possible that incorporation of densified aerogel into TP1 during its movement also incorporated mineral contaminants already present within the aerogel. It should be noted that most of the Fe-oxide, SiO_2, and TiO_2 sub-grains are located near to outer edge of the particle, while pyroxene and feldspar sub-grains are found throughout the particle.

Future Work: Nitrogen isotopic chemistry of carbonaceous matter present in the terminal particle will be measured using a Cameca NanoSIMS 50L at the Department of Terrestrial Magnetism, Carnegie Institution of Washington. These measurements will elucidate whether the carbonaceous matter in TP1 is similar to the isotopically-anomalous carbonaceous matter commonly found in CP-IDPs.

References: [1] Bradley J. P. (2003) In: Davies A. M. (Ed.) *Treatise on Geochemistry*, vol. 1, Elsevier, pp. 689-711. [2] Ishii H. A. et al. (2008) *Science*, 319, 447-450. [3] Flynn G. J. et al. (2013) *Earth Planets Space*, 65, 1159-1166. [4] Matrajt G. et al. (2012) *M&PS*, 47, 525-549. [5] Stodolna J. et al. (2012) *GCA*, 87, 35-50. [6] Trigo-Rodriguez J. M. (2008) *M&PS*, 43, 75-86. [7] Price M. C. et al. (2015) *LPSCXLVI*, 2000.

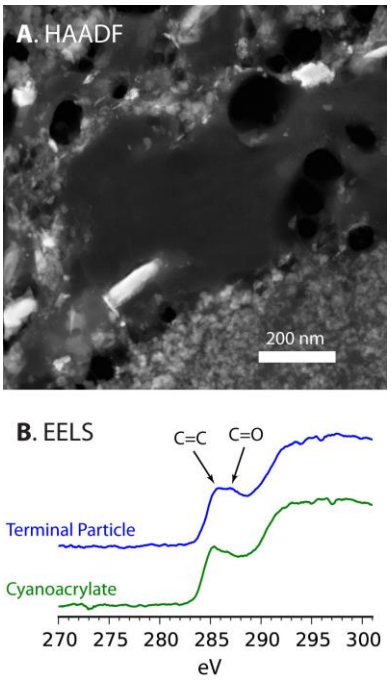

Figure 4. (A) High-angle annular dark field (HAADF) image of carbonaceous matter in TP1. (B) Representative EELS spectra of the carbonaceous matter in the particle, compared with that of cyanoacrylate.