COMET DUST ANALOG CAPTURE EXPERIMENTS IN SILICON NITRIDE MEMBRANE "SPIDERWEBS". C. E. Jilly-Rehak[1], A. J. Westphal[1], V. Della Corte[2], A. Rotundi[2], and S. A. Sandford[3]. [1]University of California Berkeley, Space Sciences Laboratory, 7 Gauss Way, Berkeley, CA 94720. jillyrehak@ssl.berkeley.edu. [2]Istituto di Astrofisica e Planetologia Spaziali, Via del Fosso del Cavaliere, 100, 00133 Roma, & Università di Napoli "Parthenope", IC4, CDN, Napoli, Italy. [3]NASA Ames Research Center.

Introduction: For the Stardust mission, aerogel was used as a collection medium for capturing particles during a relatively high-speed (6.1 km/s) pass through the coma of comet Wild 2 [1]. While spectacularly successful at capturing hypervelocity particles, the aerogel has been a challenging capture medium for later extraction and analysis of the cometary material, due to organic contamination [2], melting and slag formation [3], and requiring complicated extraction and sample preparation techniques [4].

The motivation for this study is to develop a capture medium that is well-suited to low-speed coma dust capture. Measurements from the GIADA instrument of comet 67P/G-C indicate that the dust velocity in a comet nucleus ranges from ~2-10 m/s [5] reaching highest values of ~30 m/s at perihelion [6]. For this purpose, we have developed a new dust-capturing device made out of layered silicon nitride grids, a.k.a. "spiderwebs".

Methods: We fabricated the silicon nitride membranes at the UC Berkeley Marvell Nanofabrication Laboratory, using wafer processing techniques common to the semiconductor industry. To create the membranes, silicon wafers (200 and 500 μm thickness) were first deposited with low-stress nitride (Si_3N_4), and then subjected to a series of photolithography and etching processes to create the Si_3N_4 grid mesh. Each membrane was manually separated from the silicon wafer and inspected under the microscope for defects. A total of ~300 membranes were made in five grid sizes, labelled A through E (Fig. 1): A=500μm; B=250μm; C=125μm; D=60μm; and E=30μm.

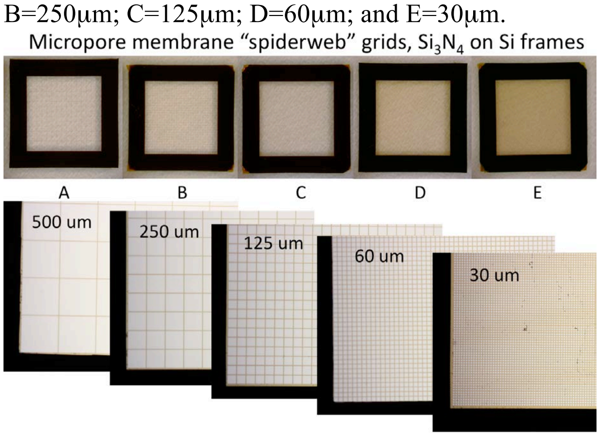

Fig. 1. Sample images of the silicon nitride membranes of each grid size, prior to dust capture experiments.

Sample holders were made of delrin, and were designed to hold stacks of ~25-30 individual membranes (Fig. 2). Approximately five membranes of each grid size were stacked such that the smallest grids were at the bottom of the collector, and the largest at the top.

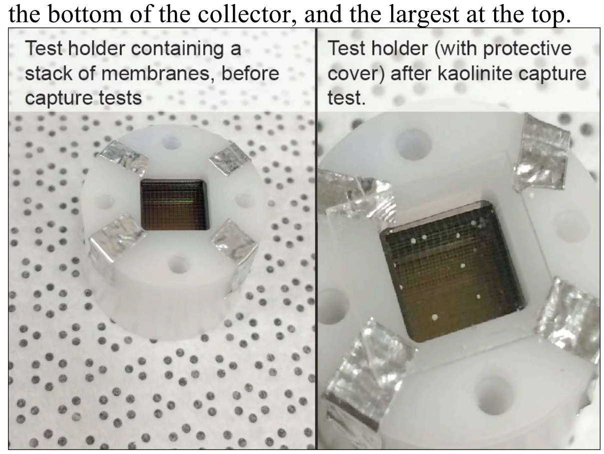

Fig. 2. Photographs of the spiderweb holder, before and after a kaolinite capture experiment (test 3).

We conducted analog capture experiments at the Istituto di Astrofisica e Planetologia Spaziali in Italy, in a class 100 clean lab to minimize contamination. We conducted eight capture tests in total (see Table 1), four at 1 m/s and four at 30 m/s to simulate the potential dust velocity extremes in the cometary coma [e.g., 6]. The low speed set-up was a simple drop procedure of a defined number of particles from a well. For the high speed setup, the particles were shot by connecting a high pressure chamber (which contained the particles) to the testing vacuum chamber containing the spiderwebs. All tests were performed at room temperature, and in a vacuum of 8.6×10^{-3} mbar. Three different materials were used to test the capture efficiency of the spiderwebs: glass spheres (100 μm), single-crystal olivine particles (20-50 μm and 100-250 μm), and kaolinite aggregates (20-50 μm and 100-250 μm). Kaolinite and olivine were chosen as useful analogs for IDPs and asteroid-like material seen in comet Wild 2 [1, 7], as they represent a variation in texture (single crystal vs. fluffy aggregate) and composition (anhydrous vs. phyllosilicate).

Results and Discussion: Quantitatively, tests 1 and 3 were the only tests in which the number of particles was counted before and after the shot. The capture rate was over 95%, with only 1 glass sphere remaining unaccounted for from test 1, and all large olivine grains captured in the membranes during test 3. For tests with a large number of grains, counting was impractical, and therefore only a qualitative assessment was conducted. For the capture tests using kaolinite, the aggregates were often fragmented upon capture, and therefore we could not provide an accurate quantitative measurement of capture efficiency.

Test #	Velocity (m/s)	Material	Grain Size (μm)	# Particles Shot
1	1	glass spheres	100	21
2	1	Kaolinite	20-50	1 scoop
3	1	olivine kaolinite	20-50 100-250	30 ~30-35
4	1	olivine	100-250	36
5	30	olivine	20-50	1 scoop
6	30	olivine	100-250	1 scoop
7	30	olivine olivine	20-50 100-250	1 scoop 1 scoop
8	30	kaolinite kaolinite	20-50 100-250	1 scoop 1 scoop

Table 1. Summary of capture experiments. 1 scoop contained ~100 small particles.

Qualitatively, the membranes were excellent at capturing the sample materials. The stacked membrane grids acted as a sieve, sorting the shot material by grain size. During the low-velocity tests, the large olivine grains and kaolinite aggregates were trapped primarily on the first C grid, being small enough to be sorted through the A and B grids. Smaller grain sizes were captured on the first D and E-sized grids. Since most of the material was caught on the first grid of each size, having five membranes of each size may have been overly cautious; stacks of two or three membranes of each size may have sufficed. For the high-velocity tests, olivine grains were similarly captured (Fig. 3). The kaolinite aggregates, however, were disaggregated either from the high-speed shot process, or from fracturing upon impact. The result was a fine kaolinite powder that was dusted on all of the membranes, and many of the aggregates broke up into smaller clusters of <60μm and were captured on the E-sized grids.

Each material behaved differently upon capture, due to the variations in crystal size, density, and surface roughness. The 100 μm glass spheres from test 1 were nearly all deposited on the first D grid. The glass spheres statically "adhered" to the Si_3N_4 grid, and did not shift or roll around when dismounting the grid from the holder. In contrast, the olivine grains and kaolinite aggregates were much less "sticky". The larger (>50μm) particles were caught and trapped (Fig. 2b), but rolled around if jostled. The smallest grains (<50 μm) statically remained in place.

The Si_3N_4 membranes were mechanically robust throughout the tests. The only damage occurred during test 7, where the high velocity, large olivine particles damaged the top two grids A1 and A2 (out of a stack of 25). In this case, some of the Si_3N_4 membranes were broken, but the majority of the damage was actually from the olivine grains impacting the edges of the brittle Si frames and cracking them. Despite this minor damage, the assemblages still captured and trapped grains efficiently (Fig. 3).

This first capture test demonstrates the capability of the Si_3N_4 spiderwebs as a collection medium for small cometary-like particles. Designs for the holder are still in development, and future models will take into account the results of this test. The final holder design will be improved to retain loose particles that are not attached to the membranes, to allow for disassembly without tilting the frames, and to mitigate Si frame breakage by protecting them from bombardment. Future tests will also explore more impactor compositions and textures.

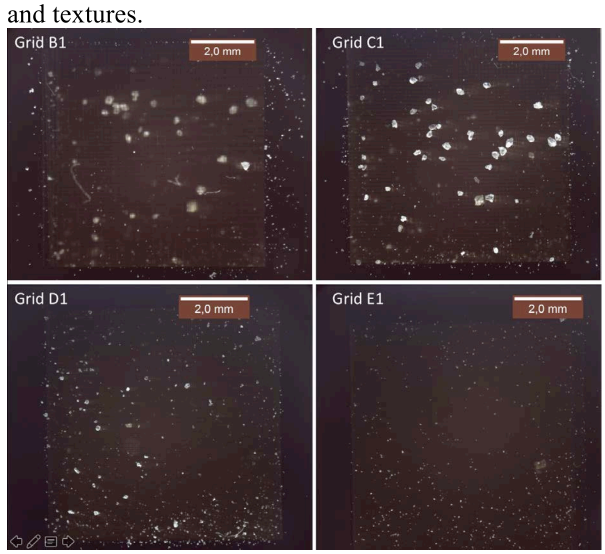

Fig. 3. Photomicrographs of grids B1, C1, D1, and E1 mounted in the holder after high velocity olivine test 7. Olivine grains were 20-50 and 100-250 μm.

References: [1] Brownlee D. et al. (2012) *Meteorit. Planet. Sci. 47*, 453-470. [2] Clemett S. J. et al. (2010) *Meteorit. Planet. Sci. 45*, 701-722. [3] Leroux H. et al. (2008) *Meteorit. Planet. Sci. 43,* 97-120. [4] Westphal A. J. et al. (2004) *Meteorit. Planet. Sci. 39*, 1375-1386. [5] Rotundi A. et al., (2015) *Science 347,* aaa3905. [6] Dealla Corte et al. (2016) *MNRAS* 462, S210–S219. [7] Ferrari M. et al. (2014) *Planet. Space Sci., 101,* 53-64. **Acknowledgements:** We thank M. Daal and X. Fan for assistance with microfabrication processing at the Marvell Nanolab.