SILICON NITRIDE SPIDERWEBS FOR COMETARY COMA DUST CAPTURE. A. J. Westphal[1], J. Blum[2], Z. Gainsforth[1], A. T. Lee[3], S. A. Sandford[4], [1]*Space Sciences Laboratory, U. C. Berkeley, Berkeley, CA, USA,* [2]*University of Braunschweig, Braunschweig, Germany,* [3]*Physics Department, U. C. Berkeley, Berkeley, CA, USA,* [4]*NASA/Ames, Moffet Field, CA, USA*.

Introduction: A cometary surface sample return (CSSR) mission was identified by the Planetary Science NRC Decadal Review as one of the five key missions to be considered for the New Frontiers program. The primary goal of this mission would be to collect a surface sample, but it will be critically important to also collect complementary samples from the coma of the same comet. Recent evidence[1, 2] strongly suggests that comets are internally heterogeneous and indeed may record the history of the early solar system in stratigraphic layers in much the same way that Antarctic and Greenland ice has preserved a record of the Earth's climate. Material from cometary jets samples material is deeper and probably more primitive and volatile-rich that a surface sample, which will have had long exposures to the space thermal and radiation environment. Here we describe an entirely passive cometary coma dust collector that will sample cometary coma dust onboard a cometary surface sample return mission. The basic technology is already flight-proven on the Planck cosmic microwave background mission.

Lesson learned from Stardust: CSSR is the natural next step in the exploration of the early solar system after the spectacularly successful Stardust mission. Stardust vividly reminded the community of the importance of sample return. We learned several important lessons from Stardust that will guide the next generation comet sample return mission.

- Hypervelocity capture in aerogel and in aluminum foils strongly compromised the fine-grained and organic components of the cometary samples;
- A suite of complementary capture media is critical for maximizing the science yield after recovery;
- Within the constraints imposed by flight requirements, capture media should be as compatible as possible with the instruments to be used for analysis of samples after recovery — that is, it is vitally important to consider the post-recovery analyses as part of the mission design.

Spiderweb collector technology: We are developing a capture cell technology for the next-generation comet sample return mission, based on silicon nitride "spiderweb" bolometers with flight heritage on cosmic microwave background (CMB) missions, most recently Planck. Such a capture cell technology would address the lessons learned from Stardust. Capture cells based on silicon nitride spiderwebs would have several other important advantages over wire mazes and metal felts that were studied during CCRSR Phase A[4]:

- As demonstrated repeatedly in synchrotron experiments using silicon nitride windows in wet cells[5], silicon nitride is chemically inert and so would induce no changes in the chemistry, mineralogy or composition of captured particles.
- A capture cell consisting of silicon nitride "spiderwebs" would be easily disassembled after recovery, and mounted directly in the instruments that would be used in the preliminary characterization and surveys of returned cometary samples. Si_3N_4 is a low-Z material that would be essentially invisible in hard x-ray microprobe surveys of capture cells
- Samples and the silicon nitride spiderwebs on which they were captured could be directly embedded in epoxy and ultramicrotomed for subsequent TEM, STXM, and SIMS analyses
- Silicon nitride spiderwebs are robust and have flight heritage. Silicon nitride is extremely stong: thin silicon nitride windows are used on the ends of vacuum beam pipes at synchrotrons, so can support 1 atmosphere of pressure
- Silicon nitride membranes are extremely pure and clean. They are used routinely as a mounting medium for synchrotron x-ray microprobes, where cleanliness and purity are strong requirements
- Except for extremely rare, tiny and isotopically anomalous Si_3N_4 pre-solar grains[3], Si_3N_4 is not naturally occurring so will not be confused with the returned cometary samples in post-recovery analyses

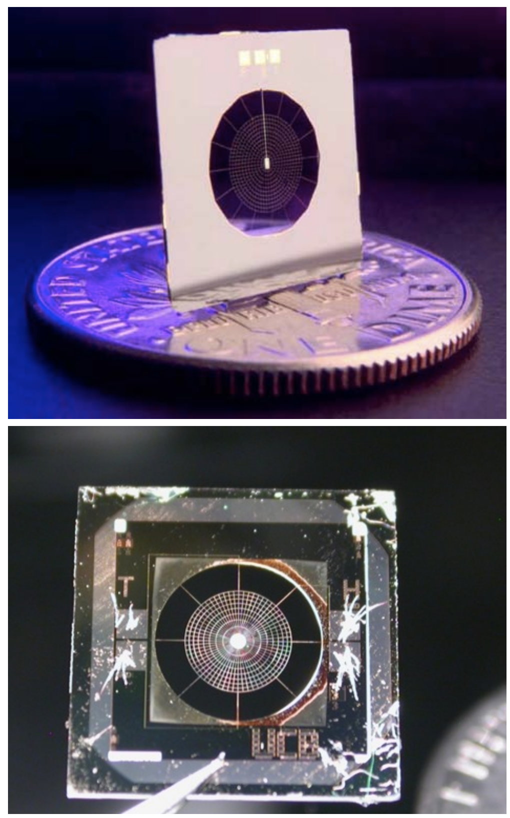

Fig. 1: (top) A silicon nitride "spiderweb" bolometer used by experimental cosmologists to measure the spectrum and anisotropy of the Cosmic Microwave Background. This bolometer was flight qualified for the Planck mission. (bottom) A spiderweb bolometer manufactured by the Lee group at UCB.

Laboratory heritage: We have extensive experience using Si_3N_4 windows in the analysis of Stardust samples and IDPs.

In particular, we have already demonstrated that silicon nitride membranes are directly compatible with the most likely suite of analytical techniques that would be used on returned cometary samples: Synchrotron-based FTIR, XRF, XRD and STXM; SEM/EDX; FIB; epoxy embedding and ultramicrotomy, TEM, and, SIMS. The Stardust Interstellar Preliminary Examination (ISPE) is currently ongoing. The central effort of the ISPE is the identification of candidate interstellar particles through automated digital microscopy and a massively distributed search, followed by the extraction of candidates and subsequent sample preparation for synchrotron-based infrared and x-ray microprobe analysis. We have found that silicon nitride "sandwiches" are ideal for mounting interstellar dust candidate samples. The sandwiches completely enclose the sample, so protect them from loss, damage and contamination. They are very clean, so introduce essentially no background in x-ray fluorescence microprobe measurements. They exhibit a faint, diffuse ring in x-ray diffraction, which is easily subtracted from XRD data. They are transparent over a wide range in the infrared, showing only one narrow absorption band at $\sim 800\ \mathrm{cm}^{-1}$.

Using Si_3N_4 windows as an enabling technology, we have developed a sample preparation technique that enables high precision O isotope measurements in small particles in potted butts, but preserves the samples for further rounds of ultramicrotomy and analyses after SIMS analysis[6]. We use a C-coated conductive 200nm-thick Si_3N_4 window with a $\sim$50-100μm hole, made using an ion mill with a pinhole mask. The flat geometry makes a uniform electric field above the sample. Micromanipulators are required for the precise three-dimensional alignment of the mask with the sample. We prepare samples using the Si_3N_4-window technique to preserve the particles as much as possible for subsequent analyses. This technique was applied for analysis of Iris[7].

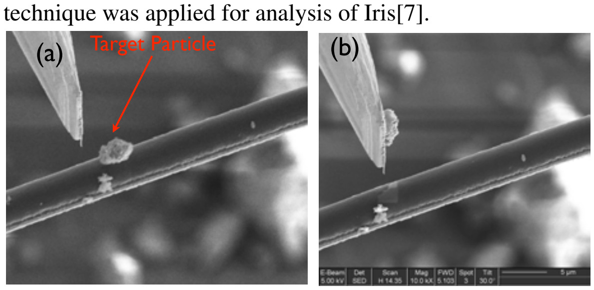

Fig. 2. A $\sim 4\mu$m particle transferred from a spiderweb onto a W needle in a dual-beam FIB at the National Center for Electron Microscopy for further sample preparation.

Capture cell design: A straightforward design (the "crossed picket fence") is one in which silicon nitride strips, taking up $\sim$25% of the area of each layer, are stacked in such a way that each layer is oriented at right angles to the layers above and below it. Half of the particles incident on the cell penetrate deeply into the cell down "tunnels" in the capture cell, but because the aspect ratio of the tunnels is very high, particles will eventually encounter the edge of the tunnel and stop.

Another design has almost no open area, but uses flexible "fingers" to allow particles to pass but to prevent them from escaping after capture, so effectively has $\sim$ 50% open area for large particles. We have estimated the capture efficiency of such a "flytrap" capture cell by comparing the kinetic energy of the projectile to the flexure energy of the finger. The result is shown in figure 3, in which we plot the capture probability for particles impacting the finger region against particle size and velocity.

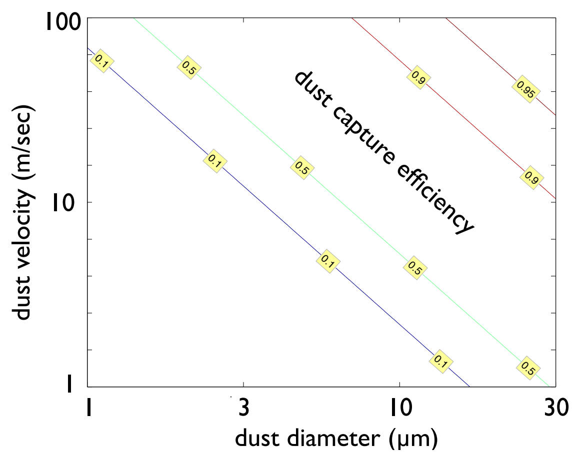

Fig. 3: Estimate of the single-layer capture probability for particles impacting the finger region of a "flytrap" layer, plotted against particle size and velocity.

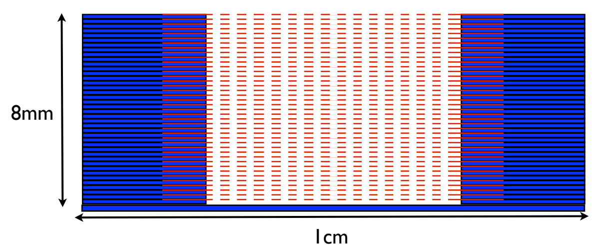

Fig. 4: Schematic of a capture cell comprising a stack of Si_3N_4 spiderwebs.

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