AEROGEL DUST CAPTURE FOR IN SITU MASS SPECTROSCOPIC ANALYSIS. S. M. Jones[1], M. S. Anderson[1], A. G. Davies[1], J. P. Kirby[2], M. J. Burchell[3] and M. J. Cole[3]. [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109-8099 (Steven.M.Jones@jpl.nasa.gov); [2] Planetary Science Institute, Tucson, AZ: University of Washington, Seattle, WA; [3] Centre for Astrophysics and Planetary Sciences, University of Kent, Canterbury, Kent CT2 7NH, UK.

Introduction: The analysis of the ice and dust grains associated with interplanetary space is a significant source of information about the planets, their moons, asteroids and comets. The particles present in the exospheres of the Galilean and Saturnian moons are of particular interest, due to the fact that these particles provide information about their parent bodies, i.e., Enceladus, Io, Ganymede, Europa, Callisto. Dust analyzers have been flown on many missions, including Ulysses [1] Gallileo [2], Cassini-Huygens [3, 4] and Stardust [5]. These instruments were designed to provide information about the velocity, electric charge, mass and composition of these particles. The composition of the grains is determined by a time-of-flight mass spectrometer. The dust grains enter the instrument and impact a target plate. The kinetic energy of the dust grains is more than sufficient to break up the constituent components to form molecular and atomic ions. The ions are directed into the mass spectrometer by electromagnetic fields, where they are differentiated by their masses based on their time of flight.

A different approach would be to use cells of aerogel to capture the dust grains and then to desorb any volatile molecules from the grains for analysis in a mass spectrometer. This concept would be based on the capture of cometary grains in aerogel by the Stardust Mission. Cells of gradient density silica aerogels were the particle capture material in the cometary and interstellar particle collector grids for the Stardust Mission [6], which flew past comet 81P/Wild-2 at 6.1 km s^{-1} and returned cometary dust samples to Earth in 2006. Aerogels are extremely porous materials composed of submicron sized filaments that form a solid network. Since the filaments are so much smaller than the high velocity particles being captured, they are crushed and melted during the capture process, allowing for the capture of the particles largely intact [7, 8]. The cometary particles captured by the Stardust aerogel cells have provided information about the origin of our solar system [9]. In addition to minerals, the cometary particles captured by the Stardust aerogels were also found to contain polycyclic aromatic hydrocarbons (PAHs), as well as aliphatic hydrocarbons [10]. It was found that the aliphatic hydrocarbons present in some of the particles survived the highly energetic capture process, yet were sufficiently labile to have migrated from the captured particle into the surrounding aerogel where they were retained and eventually observed.

Advantages: By capturing the grains in aerogel, rather than having them impact a metal plate, the kinetic energy of the grains is dissipated over a longer duration and thus leaves much of the grain intact. It is clearly important to understand how these various organic materials can be captured in the aerogel and subsequently desorbed and analyzed. Therefore, to demonstrate that organic compounds from fine particles captured in aerogel can be detected and identified by mass spectroscopy, several laboratory impact tests were conducted. The organics used were polycyclic aromatic hydrocarbons (PAHs) and niacin. This study was intended to establish and validate the methodology, while later studies will examine a larger variety of organic compounds and the concentration limits at which they can be detected.

Particle Capture: In several tests done at the Advanced Vertical Gun Range (AVGR) at Ames research Center, porous silica particles containing PAHs were launched at 5.5 km s^{-1} and captured in silica aerogel. At the Light Gas Gun Facility at the University of Kent, niacin crystals were launched at 6.3 km s^{-1} and captured in silica aerogel. In both cases, the aerogel cells were returned to JPL for analysis.

Sample Preparation: Sample preparation consisted of compressing the section of aerogel containing the tracks and particles onto a glass slide. Since low-density aerogels are more than 99% pore volume, they can be flattened to a very small fraction of their original volume. This compression ensures that the full lengths of the tracks formed by the captured particles and the terminal particles themselves are brought close to the surface of the aerogel. This means that the analytes present in the captured particles are now at the surface of the aerogel.

Control spectra of the projectiles that were not impact tested were obtained by pressing them into Teflon and placing them in the metastable helium flow.

Sample Analysis: A Direct Analysis Real Time (DART) unit (IonSense, Danvers, Massachusetts, USA) and JEOL ACCUTOF high-resolution mass spectrometer were used to detect and identify the organics present in the captured particles. The

DART ionization source produces metastable helium (He*) that is used to provide soft ionization and enhanced desorption of molecules from a sample. Even relatively non-volatile molecules such as amino acid zwitterions may be detected [11]. The flow from the DART unit is a mixture of helium and neutral, long-lived He* that can be heated to enhance analyte desorption from a sample. Analyte ionization occurs when the He* impacts on sample surfaces placed in the gap between the DART outlet and the mass spectrometer sampling inlet orifice.

Results: A flow of He* from the DART source was directed at the aerogel, which ionized the analytes and swept them into the MS inlet. The ionized organic samples produce a signal predominantly from the parent ion mass (M) and the hydrogen adducts (M+1). Figure 1 is the spectrum obtained from the DART-MS analysis of one of the aerogel cells from one of the AVGR impact tests. M+1 peaks are seen for each of the PAHs present in the projectiles.
M and M+1 peaks for niacin were also observed for the aerogel tested at Kent.

Conclusions: The results show that using aerogel to capture hypervelocity particles preserves the integrity of the organic signature and are readily analyzed using DART-MS methods. An advantage of the hypervelocity dust capture mechanism is that samples can be concentrated over time and stored in the aerogel. The analysis can be performed at an optimal time for both spacecraft and instrument operations.

In a broader spacecraft mission context, the work presented here demonstrates the feasibility of in situ mass spectroscopic analysis of dust captured in aerogel. By capturing particles in aerogel, the thermal and mechanical alterations due to the very high energy, short duration impacts are minimized. This is a significant improvement over current flight mass spectrometers that use simple impactor plates that lose much of the molecular signature. This work expands the application of aerogel capture technology that has been established over the past three decades in laboratory experiments and on several space missions. The new methodology could be used to conduct chemical analyses of particles captured in the exospheres of planets and moons.

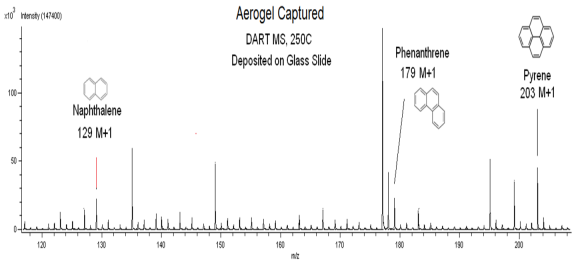

Fig. 1 – DART-MS spectrum of PAHs captured in aerogel at 5.5 km s^{-1}.

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