**Cutting Silica Aerogel for Particle Extraction** P. Tsou[1], D.E. Brownlee[2], R. Glesias[3], C. P. Grigoropoulos[4], M. Weschler[5], [1]Jet Propulsion Laboratory, California Institute of Technology (peter.tsou@jpl.nasa.gov), [2]Astronomy Department, University of Washington, [3]U. S. Laser Corporation, [4] University of California, Berkeley, [5]TFEI Company.

**Introduction:** The detailed laboratory analyses of extraterrestrial particles have revolutionized our knowledge of planetary bodies in the last three decades. This knowledge of chemical composition, morphology, mineralogy, and isotopics of particles cannot be provided by remote sensing. In order to acquire these detail information in the laboratories, the samples need be intact, unmelted. Such intact capture of hypervelocity particles has been developed in 1996[1]. Subsequently silica aerogel was introduced as the preferred medium for intact capturing of hypervelocity particles [2] and later showed it to be particularly suitable for the space environment [3]. STARDUST, the 4th NASA Discovery mission to capture samples from 81P/Wild 2 and contemporary interstellar dust, is the culmination of these new technologies [4].

In early laboratory experiments of launching hypervelocity projectiles into aerogel, there was the need to cut aerogel to isolate or extract captured particles/tracks [5]. This is especially challenging for space captures, since there will be many particles/tracks of wide ranging scales closely located, even collocated. It is critical to isolate and extract one particle without compromising its neighbors since the full significance of a particle is not known until it is extracted and analyzed. To date, three basic techniques have been explored: mechanical cutting, lasers cutting and ion beam milling. We report the current findings.

**Cutting Requirements:** The evaluation criteria of cutting aerogel for the processing of captured particles include the following:

1), amount of contamination/damage to the sample or its neighbors.

2), extent of alteration to the aerogel medium, i.e., swath width.

3), degree of optical clarity preservation.

4), processing speed/complexity.

The surface condition of silica aerogel can be grouped into three categories: optical, clear and obscured. A cleaved silica aerogel surface is near optical quality; however cleaving silica aerogel is a random process. A good casting will produce very good clear quality surface allowing clear optical viewing. Lastly, mechanical processed aerogel usually results in optically obscurity along with considerable shedding of silica grains.

**Mechanicals:** The techniques to physically disrupt the aerogel lattice to cause separations are many: wire diamond saw, blade saw, vibrating disruption and perforation. Table 1 shows the tradeoffs of various mechanical techniques.

| | Wire saw | Blade saw | Vibration | Perforation |
|---|---|---|---|---|
| Contamin. | diamonds | little | little | little |
| Alteration | mms | blade width | tool width | tool diameter |
| Visibility | obscured | obscured | obscured | obscured |
| Speed | 10s minutes | seconds | 10s minutes | hours |

The cut path of wire saw tends to wobble and the up and down wire motion makes holding aerogel a challenge, worst if the aerogel piece is small or irregular; furthermore, impregnated diamonds and wire shreds do come off. Flat blades cut aerogel very well and fast but can cause severe shatter of aerogel in mishaps. Vibrating blade or core works well for mm paths but would not work well for cm depths. Keystoning has proven to work very well for small near the surface particles [6]. Manual cutting with a blade produce the best visible surface by cleavage, but without reliable control of the direction of cleavages. To date, cutting STARDUST's 2x4x3 cm cells safely and controllably is still a challenge.

**Lasers:** The primary motivation in using laser to cut aerogel was to achieve vaporization. First, 200 W continuous $CO_2$ laser was used; the cut was easy and fast but also produced large amounts of molten glass and obscured cut surface. Then we shortened the laser wave lengths to UV; total vaporization was not achieved but with smaller molten glass beads. We then went to pulsed femtosecond laser hoping to deliver high power but melting still took place.

| | CW $CO_2$ | UV | Pulsed |
|---|---|---|---|
| Contamination | melts, coloration | little | little |
| Alteration | Many mms | 10s µm | 10s µm |
| Visibility | obscured | obscured | obscured |
| Speed | seconds | minutes | 10s minutes |

Lasers can make coarse cuts over large cm dimensions so long as the surface damage will not affect the near by samples.

**Ions:** Then ionization was thought be used to advantage in achieving aerogel vaporization. Aerogel can be ion milled, but ion milling requires surface preparation such as discharge coating. The equipment is sophisticated, and aerogel has to be in a vacuum chamber. Our test showed that the penetration depth is very limited and the resultant surface is still obscured. The speed of cut can be very slow. An example of ion milling is shown in Figure 1.

**Conclusion:** Specific techniques for specific objectives in aerogel cutting have been demonstrated. It is likely that different techniques will be used for cutting STARDUST aerogel cells. Total vaporization of aerogel by laser has not been achieved to date. To safely cut STARDUST's 2x4x3 cm cells while leaving a clear surface is still a challenge to be realized. Undoubtedly, if an aerogel polishing technique is developed, cutting aerogel with precious embedded particles can be made more routine.

**References:** [1] Tsou P., et al., (1986) *LPI Tech. Report 85-805*, [2], Tsou P., et al., (1988) *LPSC 19$^{th}$* [3] Tsou, P. (1995) *J. Non-Cryst. Solids 186*. [4] Brownlee D. E. et al. (2003) *JGR 108 E10*,. [5] Tsou P., et al., (1990) *LPSC 20$^{th}$*. [6] Westphal et al. (2003) *Lunar .Planet. Sci. 34$^{th}$*.

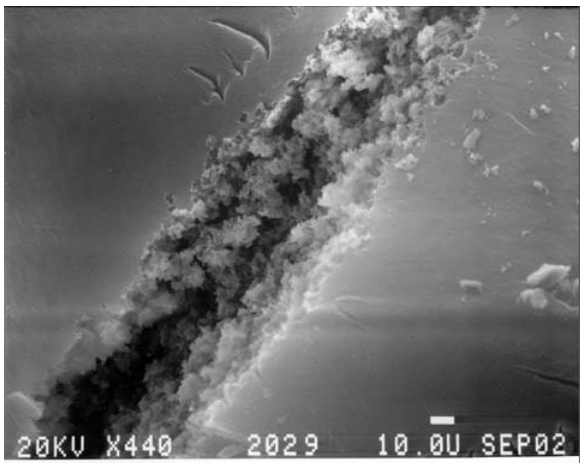


Figure 1. Femtosecond cut of aerogel. Note the resultant rough surface.

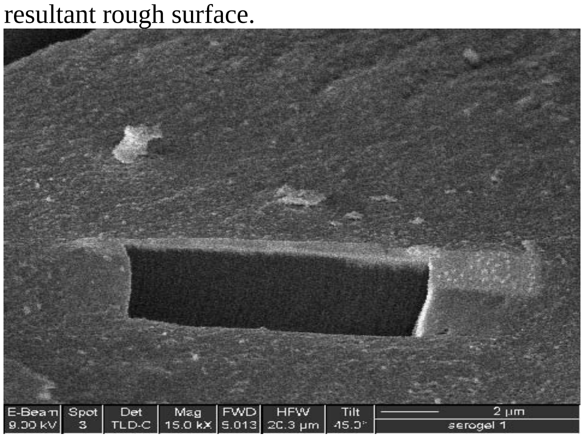


Figure 2. Ion milling of aerogel. Note the swath marks about .2 µm wide. Aerogel may have warped due to the milling process.