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EUREKA!! AEROGEL CAPTURE OF METEOROIDS IN SPACE

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Light gas gun studies have shown that 6 km/s solid mineral and glass test particles can be successively captured in 0.05 g cm^{-3} aerogel without severe heating or fragmentation. In spite of this work, there has been uncertainty in the performance of aerogel for hypervelocity capture of real meteoroids. Natural impacts differ from simulations in that the particles are likely to be structurally weak and they typically impact at higher velocity that can be simulated in the laboratory. We are fortunate now to have had two successful capture experiments using aerogel exposed in space. These experiments provide fundamental data for the assessment of the value of silica aerogel for capture of hypervelocity meteoroids from spacecraft. The first experiment used 0.02 g cm^{-3} aerogel flown on the lid of a Shuttle Get Away Special canister [1]. During its 9 day exposure, the 0.165 m^2 of aerogel in this Sample Return Experiment (SRE) captured two long "carrot-shaped" tracks and one highly fractured bowl shaped "crater". The second collection was with 0.04 m^2 of 0.05 g cm^{-3} aerogel exposed on ESA's Eureca freeflying spacecraft that was exposed for 11 months before recovery by the Shuttle. The Eureca aerogel exposure consisted of four 10cm X 10cm module trays that were part of the TiCCE meteoroid collector built by the University of Kent at Canterbury[2]. To date we have found ten "carrot-shaped" tracks and two "craters" on this experiment. The longest tracks in both exposures are over 2 mm long.

The typical impacts on these experiments produced classic carrot shaped tracks that begin with entry holes as big as 100μm and taper to a point with a cone angle of only a few degrees. In every case the projectile can be clearly seen at the end of the track. Under low angle illumination the tracks can easily be located with a stereo microscope and the larger tracks can be seen with the naked eye with appropriate lighting. The first three tracks in the Eureca experiment were found with only 10 minutes of scanning. Unlike simulations, the carrot shaped tracks caused by true meteoroids show no obvious evidence of fracturing. This difference may be due to the higher speed of the natural impacts or differences in the aerogel. Even near the end of the tracks, where the projectiles have slowed down, there is no visual evidence of fracturing. The tracks are simply clean, hollow, carrot-shaped holes in the aerogel with a particle in the end. The particles are rounded objects with high reflectance. Few stratospheric IDPs are light colored and it is likely the apparent brightness of the captured particles as well as their rounded shape is due to a thin coating of compressed aerogel. Most of the larger projectiles have an apparent in-situ diameter of ≈ 10μm, the size of particles expected for the [time]X[area] exposure product of the collectors. At their widest points, the cone shaped cavities are a order of magnitude wider than the projectile diameters and it is probable that the carrot width is determined by jetting at the projectile-aerogel interface, The cone angles and deviation from perfect cone shape vary between

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tracks. It is likely that the track geometry can be used to estimate the velocity of non-fragmenting projectiles. The carrot walls are quite distinct and are presumably composed of either compressed or fused aerogel. The tracks are very straight and would provide a highly accurate record of the meteoroid trajectory if the orientation of the aerogel was known at the time of impact. Most of the carrot tracks are spectacular and simple features and there is no evidence that the projectile fragmented. In a few cases, however, one or more shorter tracks branch from the main carrot and are evidence for fragmentation. In these cases the secondary tracks are faint, short and only slightly deviate from the path of the bulk of the projectile mass.

Two of the TiCCE modules had a 0.1μm Al film suspended a millimeter above the aerogel. On these modules several of the projectiles fragmented during passage through the film producing fields of carrot shaped tracks from the resulting miniature "meteor" shower. The smallest tracks seen in these clusters are only 20μm long and apparently were made submicron fragments. Most of the tracks in these showers have observable particles at their ends.

One of the SRE impacts and two of the TiCCE impacts are essentially bowl shaped craters surrounded by extensive conchoidal fractures. These are remarkably different from the more common carrot-shaped tracks because they are shallow, large, surrounded large fracture zones and they retain no evidence of a surviving projectile. The biggest of these craters is 800μm in diameter, 8 times the diameter of the largest track. Most of these craters are nearly two orders of magnitude larger than the most likely size of the largest projectiles expected to impact either experiment. TiCCE also contains an impact that appears to be a intermediate case between a carrot track and a crater. It could be considered either a short carrot or a deep crater. It is has a depth /diameter ratio of about 4 and it is surrounded by extensive fractures. The origin of these large, shallow and barren craters is a mystery. It is conceivable that they are either low velocity impacts or impacts of very high velocity or very fragile particles. Either low specific momentum or an explosion on impact might prevent deep penetration to form a carrot track. If crater formation results from abnormally high speed impact, this would imply that the threshold for crater formation is exceeded by only 20% of 10μm meteoroids.

We have extracted one of the carrot track meteoroids and mounted it in epoxy for sectioning. We plan to present data on the TEM analyses of microtome sections of several samples at the meeting. This work will provide data on the composition of natural and space debris impacting spacecraft in low Earth orbit and will provide much needed information on the degree of alteration of bonafide meteoroids captured in low density aerogel. So far the examination of these 14 impacts suggests that low density aerogel is a magic and higly effective media for intact capture of hypervelocity particles in space. Typical meteoroids travel ≈ 100 projectile diameters in the aerogel before stopping and it obvious that typical projectiles remain intact throughout their penetration. The tracks are easily found, there is no ambiguity in their distinction from artifacts and they clearly provide an excellent record of the particle trajectory. If velocity can indeed be determined from track geometry then this would provide a novel method of determining orbital parameters of collected particles. References: [1] Tsou, P. et al. LPSC XXIV, 1333, 1993, [2] McDonnell, J.A.M., LPSC XXV, 1994.