INTACT CAPTURE OF HYPERVELOCITY MICROMETEOROID ANALOGS

P. Tsou,[1] D.E. Brownlee,[2] M.R. Laurance,[2] L. Hrubesh[3] and A.L. Albee[4]. [1]Jet Propulsion Laboratory, Pasadena, CA 91109, [2]Department of Astronomy, University of Washington, Seattle, WA 98195, [3]Lawrence Livermore National Laboratory, [4]California Institute of Technology.

For several years we have worked on the development of collection techniques suitable for "intact" (=unmelted mineral fragments) capture of hypervelocity meteoroids.[1] This capability is important both for meteoroid collection on a comet coma sample return mission and for Earth orbital collection missions such as the cosmic dust collection facility proposed for the space station. The laboratory development involves using the NASA Ames Vertical Gun Range to launch projectiles into low density capture media and then studying the recovered materials. With the Ames gun, the experiments are limited to speeds less than 7km s^{-1} and conventional projectiles larger than 1.6mm.

NEW LAUNCH TECHNIQUE. In-spite of previous successes in capturing 1.6mm and 3.2mm projectiles in polymer foams, there remained considerable uncertainty about the application of the collection techniques for real meteoroid capture. The laboratory projectiles were much larger than those that could be encountered in a realistic space experiment and in many cases the projectiles were made of materials such as aluminum that clearly are poor analogs to meteoritic material. In recent experiments we have successfully developed a technique to launch realistic meteoritic analog materials in the 10 μm to 200 μm size range.

The basic limitation at the Ames gun is that the speed measuring mechanism cannot be triggered by projectiles smaller than 1.6mm. To overcome this limitation, we developed a hybrid technique using the simultaneous launch of an aluminum disk along with a large number of meteoroid analog particles in the same sabot. The disk is placed in the front of the sabot and several thousand projectiles are packed into a cylindrical space behind it. The aluminum disk serves to trigger the speed counters and shadowgraph cameras. In-flight images show the disk leading the expanding cloud of particles (figure 1). The spread of the projectiles on the target is 4cm to 12cm depending on the speed of launch and state of cohesion of the particles. The Al disk passes through the center of the target and the thousands of meteoroid analog particles impact a matrix of target materials placed around this spot. One of the most important aspects of this technique is that one shot can test several materials using projectiles of identical velocity. When desirable, projectiles of different sizes and compositions can be launched simultaneously. We have successfully launched micron to $> 100\,\mu$m particles in this manner up to the full velocity range of the Ames gun. We have used irregular grains of olivine, soda lime glass and pyrrhotite and spheres of glass and olivine. The olivine spheres were made by flame spraying.

CAPTURE AND METEOROID ANALYSIS. The intact capture efficiency of the 25 μm to 200 μm mineral grains and spheres impacting silica aerogel and microporous polymer foams at 5-6km s^{-1} has been spectacular. Earlier experience with large metallic projectiles in coarse polymer foams suggested that small projectiles would not survive well. Another concern suggested by earlier tests was that location and analysis of small particles in the foams would be exceedingly difficult. On the contrary we found that capture of small mineral grains and glass was very efficient and that the particles and their tracks in the foam could be easily found. This was most dramatic in the 0.15g cm^{-3} aerogel targets. The aerogel is quite transparent and even projectiles 10 μm in diameter produced tracks that could easily be seen in an optical microscope (figure 2). A track consists of a cylindrical hole surrounded by fractures in the aerogel. At the end of each track, an intact captured particle can clearly be seen. Glass particles of 50 μm size produced tracks 1.5mm deep in the aerogel. SEM analysis of the the captured projectiles was accomplished by impregnation of the aerogel by low viscosity epoxy and subsequent grinding down to the particle. All of the projectiles examined had rims of compressed aerogel and the dynamic accretion and shedding of this target material may play an important role in reducing particle degradation during capture. Recovery of small projectiles in polymer foam was done by cutting out the section of foam that contains the track and then dissolving the foam in an appropriate solvent. The projectile fragments are then found in the water-clear plastic film that remains. Even micron-sized particles can be seen and recovered with this approach. Particles can be removed from the film with standard techniques and mounted for microtoming, probe analysis, etc.

FINDINGS. New materials and techniques have lead to the successful development of the technology for the capture of small hypervelocity meteoroids. Our studies have demonstrated that intact capture of mineral grains down to micron size is possible and rather straightforward at velocities up to at least 6km s^{-1}. Because entire grains are captured, contamination is not a significant problem. Within the boundaries of the particle there is no contamination. Collection of unmelted particles or fragments of particles in aerogel or polymer foams provides a very powerful technique for investigating comets that produce particles that can be intercepted by spacecraft.

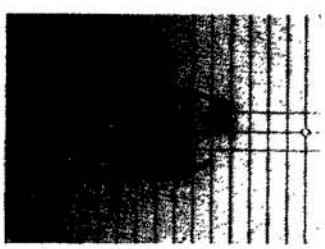

Figure 1. An in-flight image of an edge-on Al disk and cloud of thousands of glass spheres launched from the same sabot in the Ames vertical gun. Travel is from left to right and the velocity is 5km s^{-1}.

Figure 2. An optical micrograph of 20 μm and 40 μm glass projectles and their tracks in 0.15g cm^{-3} silica aerogel. The bright object at the end of each track is an intact particle that was successfully decelerated from 5.13km s^{-1}.

ACKNOWLEDGEMENTS. This work was carried out, in part by the Jet Propulsion Laboratory, California Institute of Technology, under NASA contract.

References: [1] Tsou, P. *et al.*(1986). ESA Sp 250, pp237-241., Tsou, P. *et al.*(1986). Lunar Planetary Science **17**, 903-904.