CAPTURING OF HYPERVELOCITY PARTICLES

P. Tsou, Jet Propulsion Laboratory, Pasadena, California
D. E. Brownlee, University of Washington, Seattle, Washington
A. L. Albee, California Institute of Technology, Pasadena, California

INTRODUCTION Experiments indicating the possibility of intact capturing of cometary particles while flying through a comet coma at hypervelocities have been reported [1]. Aluminum projectiles were accelerated into graphite and Kevlar felts and expanded polystyrene foam and showed that polymer foam is more suitable as a capture medium. At about 6.5 km/s, more than 75% of the Al projectiles were recovered in whole pieces.

Additional experiments have been carried out with other types and densities of underdense media and varied sizes, types, and speeds of projectiles. Recovery of intact Al projectiles has been extended up to 7.9 km/s; comet-like projectiles have been recovered nearly intact up to 3.9 km/s and unmelted grain fragments have been recovered at 6.7 km/s.

EXPERIMENT A wide range of polymer foams, with both open and closed cell structures, was used as capture media. The foam densities varied from 9 to 528 mg/ml; both uniform density and combinations of densities were used. Several fibrous target materials with a density range from 36 to 430 mg/ml were also utilized, as were multiple layers of thin organic films. Most of the capturing experiments were performed under vacuum.

The projectiles used were mostly polished aluminum spheres of 3.2 mm diameter. These were accelerated with a two-stage light-gas gun up to 7.7 km/s at the NASA Ames Vertical Gun Range. In order to assess the effect on more fragile and comet-like particles, projectiles of 3.2 mm spherical Pyrex glass, and 3.2 mm diameter cylindrical Wellman meteorite, epoxy-bonded Allende meteorite powder, and epoxy-bonded olivine and FeS powder with hollow glass microspheres were used. The olivine mixture is closest to the expected mineralogical composition of cometary material. With the hollow glass microspheres, the bulk density of the projectile is reduced to about 1 g/ml as expected.

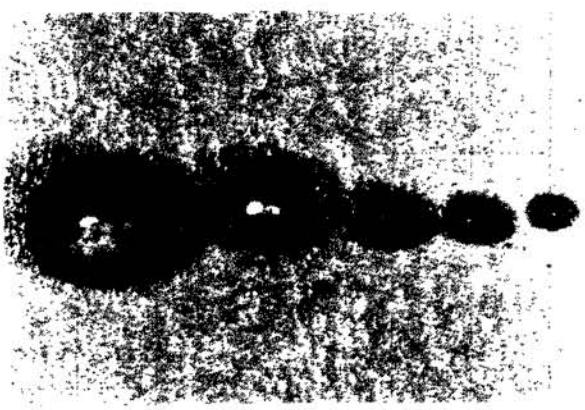
RESULTS Polymer underdense media are superior to either the fibrous or the multiple-film type media for capturing particles intact up to about 7 km/s. Fibrous materials tend to break up the projectiles. The typical track is characteristically carrot-shaped in either the foam, fiber, or multiple-film targets with two distinct sections: burn track and shear track. The burn track is typically marked with black residues from pyrolysis or melt of the foam media, and the diameter is very much larger than the projectile diameter. The width of the shear track, on the other hand, is nearly the same as the projectile diameter and is devoid of any burn residues.

The Al projectiles that are recovered in one piece retain the original spherical shape except for the frontal surface, which is ablated. Figure 1 shows a sample of the recovered Al projectiles. The Al projectiles come to the final stop with the polished and ablated surfaces oriented near orthogonal to the track, making it difficult to determine the attitude of the projectile during deceleration. However, several multiple-film experiments indicated that the ablated surface was on the forward side of the projectile. Note this is opposite to previously reported supposition.

The back surface looks undamaged under an optical microscope, indicating that the internal stress did not exceed those limits that would cause fragmentation. X-ray diffraction analysis of a cross-section of one

projectile was compared to NBS crystal structure data for Al. A series of X-ray pinhole photographs with 30 um spot size was used to assess changes in crystal structure. The interior region of the sample was typical of cold worked metal without recrystallization. The frontal ablated surface showed residual stress and clear evidence of recrystallization in the lattice, indicative of melting. Our hypothesis is that the frontal surface of the projectile ablates due to the heat generated as the projectile penetrates the medium.

The maximum speed of highest recovery for the five different sizes of Al projectiles is shown in the upper half of Figure 2. The number enclosed in parenthesis is the experiments performed with that projectile size. The percent of recovery refers to the ratio of the recovered mass in one piece for Al projectiles and in large chunks for comet-like projectiles to the original mass. However, the limited data for other than 0.125" projectile seem to indicate that a higher recovery ratio can be expected for larger projectiles.



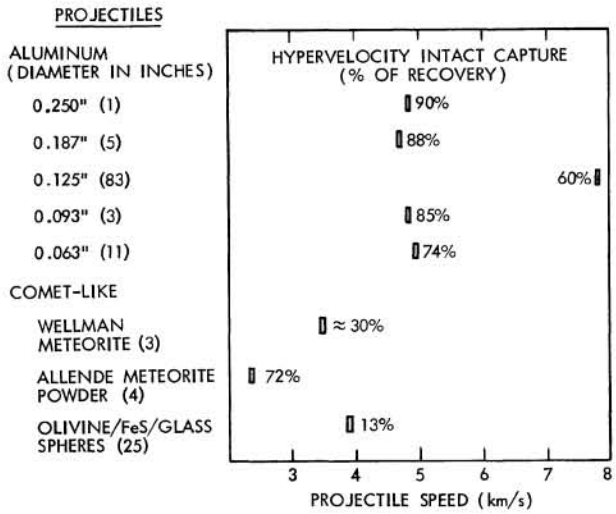


Fig. 1 Recovered Al Projectiles Fig. 2 Intact Projectile Recovery

For more fragile comet-like projectiles, the maximum speed of intact recovery record is shown in the lower half of Figure 2, up to 3.9 km/s. The recovered projectiles, unlike the Al projectiles are fragmented in mm sized chunks. Under SEM, no melting or shock damage in the interior of the recovered chunks has been found, indicating that the kinetic energy is removed through ablation and mechanical fragmentation. Further analyses will be to determine the energy removal processes. The 4 km/s intact recovery limit of olivine mixture may be an artifact due to the disintegration of the bonding Epoxy. In a foam slow-down experiment, micron-sized unmelted olivine and FeS grains have been recovered on a brass sheet after deceleration by a six-inch thick foam. Two 3.2 mm Pyrex glass shot into medium density foam at about 6.5 km/s were shattered with no large pieces recovered.

ACKNOWLEDGEMENTS Without the cooperative support of the NASA Ames Vertical Gun Range, this research would not have been possible. This work was carried out, in part, by the Jet Propulsion Laboratory, California Institute of Technology, under NASA contract.

REFERENCE

[1] Tsou, P. et al. (1984) Lunar and Planet. Sci. XV, p. 866-867.