HYPERVELOCITY INTACT CAPTURE IN MULTIPLE-LAYER FILMS

P. Tsou, Jet Propulsion Laboratory, Pasadena, California
S. T. J. Peng, Jet Propulsion Laboratory, Pasadena, California
A. L. Albee, California Institute of Technology, Pasadena, California

INTRODUCTION Encouraging experimental results in intact capturing of hypervelocity projectiles with commercially available underdense polymer foams [1] have shown the definite possibility for intact capturing of cometary coma material at hypervelocity flyby encounter speeds [2]. To increase the range of intact hypervelocity capturing speeds, new types of collectors, such as multiple layer films, have been explored. In parallel, even better underdense foams are being developed.

MOTIVATION Underdense polymer foams have performed well as hypervelocity intact collectors at around 7 km/s; however, polymer foams have complex microstructures that make controlled experiments on microstructure parameters difficult. An ideal laboratory controllable simulator of underdense foams is multiple layers of thin films. The thickness of the film, which is analogous to foam cell-wall thickness, and the separation distance between films, which is analogous to foam cell size, can be controlled in the laboratory. Hypervelocity capturing experiments on multiple-layer films can help our understanding of the complex microstructural interactions of underdense foams.

The recent intact recovery of extraterrestrial particles from the Solar Max thermal blanket [3] provided further motivation to explore multiple-layer films as a possible type of collector for the intact capture of hypervelocity cometary particles. A summary of the hypervelocity impact experimental results on multiple-layer films are presented here.

EXPERIMENT Polyvinylidene chloride, polyethylene, polystyrene, polyester, and organic tissue films were used in the experiments. The films were wrapped between pins inserted on a base board predilled with evenly spaced holes. In the span of 1.52 meter, as much as 1200 layers were wrapped, and the film thickness varied from 200 um to 1.5 um. Due to the static clinging effect of thinner polymer films and the difficulty of ensuring even film tension during wrapping, a constant and equal film separation spacing could not be maintained; often films would bunch together in various sections.

The projectiles used were mostly polished aluminum spheres 1.6 to 4.8 mm in diameter. At the NASA Ames Vertical Gun Range, the projectiles were accelerated with a two-stage light-gas gun up to 6.8 km/s and with a powder gun for speeds below 3 km/s. The integrity and the speed of the projectiles were ascertained by three-stage shadow polaroid photographs and counters triggered by the projectile's interruption of light beams. Due to the limitation of the range in the target tank, foams were used to ensure the capture of the projectile at the end of the multiple-film layers. All capture experiments were performed under vacuum around 7 mm of mercury.

RESULTS Of all the films tested, systematic data were obtained only with polystyrene and polyester films that were impacted by 1.6- and 3.2-mm-diameter aluminum projectiles for speeds less than 7 km/s. Polystyrene film was selected because it shares the parent material of the styrofoams, for which we have a good data base. Polyester films were used for the ready availability of wide range of film thickness, 10 to 1.5 um.

Data on projectile recovery with respect to projectile speeds for the two types of film material are shown in Figures 1 and 2. For the same film
thickness, higher mass recovery for larger projectile size is shown in Figure 1 curves A and B, as well as in Figure 2 curves A and B. Thinner films yielded higher projectile mass recovery for the same projectile size, as evident from Figure 2 curves B and C. Since larger projectiles require longer range to capture, the target chamber height limited the recovery range and, in turn, prevented lower-speed data for the 3.2 mm projectile with 1.5 μm films.

FINDINGS The A curves and B curves of Figures 1 and 2 are nearly overlapping, which indicates that film thickness dominates film material properties in projectile recovery; this is significant since the material properties varied widely:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Polystyrene</th>
<th>Polyester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting Point, [°C]</td>
<td>105</td>
<td>250</td>
</tr>
<tr>
<td>Tensile Strength, [MPa]</td>
<td>34</td>
<td>193</td>
</tr>
<tr>
<td>Density, [g/ml]</td>
<td>1.1</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Our preliminary experiments also show that film thicknesses greater than 1.5 μm yielded very poor projectile mass recovery as compared to that of underdense foams. The mass recovery curve C in Figure 2 comes close to that of the recovery in polystyrene foams [4]. This may indicate that hypervelocity recovery with about 1-μm-thick multiple-layer films of around two thousand layers are equivalent to around 13-mg/ml underdense polymer foams for projectile speeds at least less than 7 km/s.

Figure 1. Polystyrene Films
Figure 2. Polyester Films

Further experiments and analyses will be performed to better define and understand the hypervelocity capture by multiple-layer films and the equivalence of this capture to that of underdense polymer foams.

ACKNOWLEDGEMENTS The cooperative support of the NASA Ames Vertical Gun Range and its crew is much appreciated. This work was carried out, in part, by the Jet Propulsion Laboratory, California Institute of Technology, under NASA contract.

REFERENCE