EFFECTS OF MEDIA MESOSTRUCTURE ON INTACT CAPTURE

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The ability to capture hypervelocity cosmic dust analogs intact in underdense media has been demonstrated [1]. Intact capture is important for both the capturing of fragments of cosmic dust in Earth orbital experiments on the Shuttle or the Space Station and for a comet coma flyby sample return mission using a low-cost free-return trajectory to intercept a comet's coma. Only with better understanding of the parameters governing intact capture will significant progress be made in improving intact capture. We report here the progress made in characterizing one of the key parameters affecting intact capture -- the mesostructure of the capture media. Laboratory capturing simulation data with varying mesostructures have been acquired.

DEFINITION Within an acceptable range of the capture media's bulk densities, the physical structure of the media dominates the degree of intact capture. The physical structure of underdense media can be ordered as the macrostructure, mesostructure, and microstructure. Macrostructure refers to the gross form of the material: thin films, fibers or foams; and microstructure refers to the molecular arrangements as single, double, or triple bonds; rings; or hybrids. Mesostructure refers to the intermediate level of the media's material groupings and distinguishes variations within a macrostructure, such as the shape of the foam cells, thickness of the cell wells, and the manner of connection among foam cells. By far, intact recovery with media foam macrostructure exceeds either multiple-film or fiber [2]. The significance of the media's microstructure on intact recovery is refined effects within higher order structural effects.

A mesostructure for capture media is a three-dimensional feature. A characterizing measure would require at least three parameters; however, a scalar measure would greatly simplify analysis and reference. A simple scalar mesostructure has been found to be useful by taking the product of the average width of the media material, t, and the average space between the consecutive material, x, in the line of capture: meso = t · x. A fine, microcellular mesostructure would be indicated by a small meso; a large cellular or more spacious mesostructure would be indicated by a large meso.

SAMPLE MESOSTRUCTURES Since the technology to fabricate a designated capture medium with a specified mesostructure is not readily available, we are restricted to studying the available media with given mesostructures. Fortunately, several varying mesostructures are available for selected underdense media, allowing measurable variations in intact capture. One of the first most dramatic sample mesostructures shows the variation of shape, size, and distribution of polystyrene rings, Figs. 1a, 1b, and 1c. The mesostructure in Fig. 1a shows on the average 2-μm rings with 0.4-μm x 0.3-μm ring cross sections (density 68 mg/ml), or a meso of 0.8-μm^2. As the rings become less defined, they merge into connected larger spheres, as shown in Figs. 1b to 1c (density 39 and 15 mg/ml), and the meso is increased to 25 to 200 μm^2, respectively. The more conventional mesostructure of foams (polyethylene) and aerogel are shown as a comparison in Figs. 2 and 3 (density 28 and 50 mg/ml) with mesos of 170 μm^2 and 25 nm^2, respectively.

EVALUATION CRITERION The foremost criterion useful to distinguish the effects of mesostructure on intact recovery is the ratio of intact mass recovery. Other measures are dimensional retention and the surface features of the recovered projectile. The amount of intact mass recovery is ascertained by determining the mass of the intact projectile before and after the simulation experiment. The condition of the recovered projectile is determined by measuring the shape of the projectile before and after capture and by examining the projectile surface with a scanning electron microscope (SEM).

The simulation experiments consist of launching standard 1.6-mm aluminum projectiles individually into the prepared capture media for speeds ranging from 2 to 6 km/s. Large 1.6-mm aluminum projectiles are used in these experiments to facilitate quantitative characterizations with a rapid turn-around time. With micron-sized projectiles, capture experiments must be performed with hundreds of projectiles, not an individual projectile, making data average a necessity. Furthermore, the time required to extract micron-sized silicate projectiles would be very long and would create a large uncertainty in the data because of the difficulty in maintaining uniformity in size, compensation of shape.

FINDINGS One would expect that the intact recovery of the three polystyrene foams (Figs. 1 a-c) with decreasing bulk density would produce an increasing recovery ratio; however, recovery ratios for the three meso structures are 95%, 87%, and 72% at 6 km/s, correlating with their mesos increasing from 0.8, 25 to 200 μm^2, respectively. This indicates clearly the dramatic dominance of the mesostructure over bulk density. The ablated surfaces of recovered projectiles in polystyrene, 1a, are specially smooth and free from pitting or pronounced facets, as compared to 1b and 1c.

At 6 km/s, polyethylene foams (meso 170 μm^2) produces 78% recovery and aerogel (meso 25 nm^2) produces about a 40% recovery. The scalar measure, meso, does not seem to be useful to characterize intact capture response for different capture media since the material's unique properties have not been accounted for. For the same media, the mesostructure measured by a scalar, a meso, is a useful parameter in determining the degree of intact recovery.

REFERENCES [1] Tsou, P. et al. (1988) LPSC 19th. [2] Tsou, P. et al (1987) LPSC 18th.4

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a._____5 μm   b._____10 μm   c._____50 μm

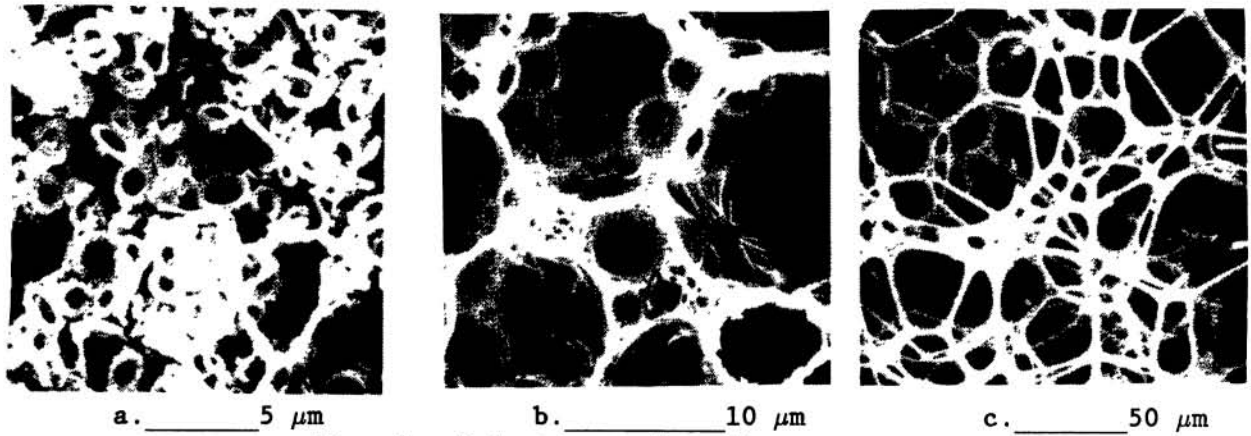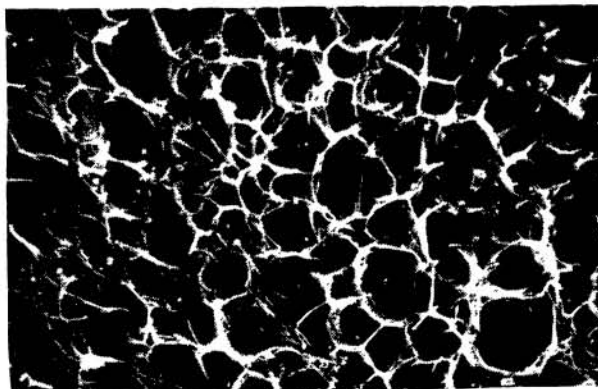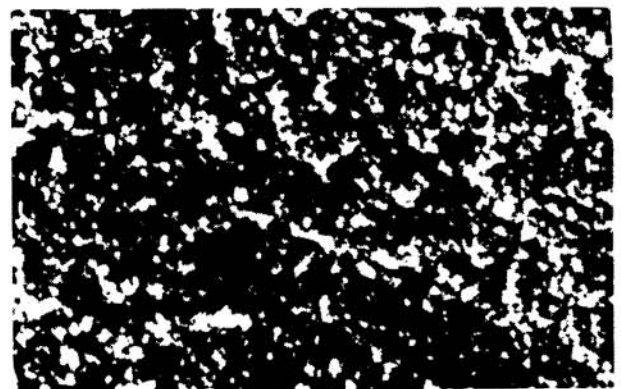Fig. 1.   Polystyrene Foam Mesostructures

2._____500 μm   3._____1 μm

Fig. 2.   Polyethylene Foam Mesostructure   Fig. 3.   Aerogel Mesostructure