Comet dust analog capture experiments in silicon nitride membrane “spiderwebs”

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Motivation

For the Stardust mission, aerogel was used as a collection medium for capturing particles during a relatively high-speed (6.1 km/s) pass through the coma of comet Wild 2 [1]. While spectacularly successful at capturing hypervelocity particles, the aerogel has been a challenging capture medium for later extraction and analysis of the cometary material [2-4].

The motivation for this study is to develop a capture medium that is well-suited to low-speed coma dust capture. Measurements from GIADA indicate that the dust velocity in a comet nucleus ranges from ~2-10 m/s [5] reaching highest values of ~30 m/s at perihelion [6]. For this purpose, we have developed a new dust-capturing device made out of layered silicon nitride grids, a.k.a. “spiderwebs”.

Methods

Membrane fabrication @ UC Berkeley Marvell NanoLab

Process summary

- Deposition:
  - Double-sided Si₃N₄ deposition on Si wafer, nitride thickness variable between 0.7-1.1 μm
- Photolithography:
  - Coat wafers with photoreist
  - Expose w/ mask to create membrane patterns
  - Develop
- Etching:
  - SF₆ + He etching to remove Si₃N₄ from mesh (Fig. 1a)
  - KOH bath to etch Si wafers (Fig. 1b,c)

A total of ~300 membranes were made in five grid sizes, labeled A through E: A=500μm; B=250μm; C=125μm; D=60μm; and E=30μm (Fig. 2, below).

Results and Discussion

We conducted eight capture tests (Table 1) simulating the potential dust velocity extremes in the cometary coma [e.g., 6]. Kaolinite and olivine were chosen as useful analogs for IDPs and asteroid-like material seen in comet Wild 2 [1, 7], as they represent a variation in texture and composition.

<table>
<thead>
<tr>
<th>Test #</th>
<th>Velocity (m/s)</th>
<th>Material</th>
<th>Grain Size (μm)</th>
<th># Particles Shot</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Glass spheres</td>
<td>100</td>
<td>21</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Kaolinite</td>
<td>20-50</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>Olivine</td>
<td>100-250</td>
<td>36</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Olivine</td>
<td>100-250</td>
<td>36</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
<td>Olivine</td>
<td>20-50</td>
<td>1 scoop</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>Olivine</td>
<td>100-250</td>
<td>1 scoop</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>Olivine</td>
<td>20-50</td>
<td>1 scoop</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>Kaolinite</td>
<td>20-50</td>
<td>1 scoop</td>
</tr>
</tbody>
</table>

Fig. 3: Sample holders for capture tests made of delrin, designed to hold stacks of ~25-30 membranes. Approximately five membranes of each grid size were stacked such that the smallest grids were at the bottom of the collector, and the largest at the top, acting as a “sieve” for the collected dust.

Fig. 4: Image of well used for low-velocity drop experiments, here filled with kaolinite aggregates from test 2.

The glass spheres statically “adhered” to the Si₃N₄ grids. In contrast, the olivine grains and kaolinite aggregates were much less “sticky”. The larger (>50μm) particles were caught and trapped, but rolled around if jostled. The Si₃N₄ membranes were mechanically robust throughout the tests. The only damage occurred during high-speed test 7, where the large olivine particles damaged the top two grids (Fig. 6).

This first capture test demonstrates the capability of the Si₃N₄ spiderwebs as a collection medium for small cometary-like particles. Designs for the holder are still in development, and future models will take into account the results of this test.

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References: