Passive Nano- and Micro-Textured Dust-Mitigation Surfaces in Space-Grade Materials Made with a Highly Scalable Fabrication Process

LSIC Lunch Meeting January 20, 2022

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Team: Nichole Cates and Lauren Micklow

University of Texas, Austin:
Dr. Chih-Hao Chang (co-PI), Asst. Prof. of Mech. Engr.
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Team: Samuel Lee, Suarav Mohanty, and Kun-Chieh Chien
Agenda

• Project goals
• Summary of achievements
  – Surface textures
  – Fabricated surfaces
  – Dust mitigation performance
• Proposed future work
NASA SBIR Phase I Project

Passive Nano- and Micro-Textured Dust-Mitigation Surfaces in Space-Grade Materials Made with a Highly Scalable Fabrication Process (5/19/21 – 11/19/21)

Smart Material Solutions

Dr. Stephen Furst (PI)
Founder and CEO
PhD in Mechanical Engineering
specialized in precision engineering

Dr. Nichole Cates
Senior Scientist
PhD in Materials Science
specialized in electronic materials

Lauren Micklow
Mechanical Engineer
BS in Mechanical Engineering

UT Austin

Dr. Chih-Hao Chang (co-PI)
Associate Professor Mechanical Engineering
Nanostructures and Nanomanufacturing Lab

Students
Samuel Lee, Suarav Mohanty, and Kun-Chieh Chien

NASA

Glen King, Chris Wohl, and Lopamudra Das
NASA Langley Research Center
Objective: Use our scalable process to imprint “space grade materials” with passive structured surfaces that reduce dust adhesion.

Tasks:
1. Texture Optimization
2. Flexible Mold Fabrication
3. Replication and Metrology
4. Chemical Treatment and Testing
Concept

Check out our Blog! [www.smartmaterialsolutions.com/blog](http://www.smartmaterialsolutions.com/blog)
Enabling Technology

Nanoimprint lithography molds
• Seamless, roll-to-roll
• Batch, thermal embossing
Nanopatterning Process

1. Diamond die
2. High speed indenting
3. Imprinting

Nanocoining

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Thermal NIL

Materials of Interest
- Polycarbonate (Markrofol N)
- ETFE (Tefzel 280)
- CoC (Zeonor)
- PET (Mylar)
- Polyimide (Kapton)
- PTFE (Teflon)

Key challenge – complete imprints into space grade polymers
Drum Mold with Test Patterns
# Molds and Replicas

<table>
<thead>
<tr>
<th></th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mold</td>
<td><img src="image1" alt="Mold Sample 1" /></td>
<td><img src="image2" alt="Mold Sample 2" /></td>
<td><img src="image3" alt="Mold Sample 3" /></td>
</tr>
<tr>
<td>PC Replica</td>
<td><img src="image4" alt="PC Replica Sample 1" /></td>
<td><img src="image5" alt="PC Replica Sample 2" /></td>
<td><img src="image6" alt="PC Replica Sample 3" /></td>
</tr>
</tbody>
</table>
Example Patterns

Current capabilities: **250 nm to 5 µm pitch and 0.5 height:pitch**

<table>
<thead>
<tr>
<th>Rounded</th>
<th>Irregular</th>
<th>Sharper</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Rounded Pattern" /></td>
<td><img src="image2" alt="Irregular Pattern" /></td>
<td><img src="image3" alt="Sharper Pattern" /></td>
</tr>
</tbody>
</table>

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Testing at UT Austin

• Lunar Dust Simulant: Exolith Labs LMS-1
• Polycarbonate substrates w/ and w/out silane coating
• Procedure:
  1. Heap dust on surface
  2. Tilt to 90 degrees
  3. Take micrograph
  4. Spin on spin coater, 3G
  5. Take another micrograph
  6. Image analysis
Particle Counting

Visible Microscope

- Raw image
- Enhanced contrast

Particle counting

Particle identification

Laser Confocal

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Effect of Silane Treatment

No Silane Treatment

<table>
<thead>
<tr>
<th></th>
<th>Before Spinning</th>
<th>After Spinning</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>39.5 ± 3.5</td>
<td>37.0 ± 3.0</td>
</tr>
<tr>
<td>B</td>
<td>38.0 ± 3.1</td>
<td>37.0 ± 3.0</td>
</tr>
<tr>
<td>C</td>
<td>37.0 ± 3.3</td>
<td>17.3 ± 2.3</td>
</tr>
<tr>
<td>D</td>
<td>37.0 ± 3.0</td>
<td>37.0 ± 3.0</td>
</tr>
<tr>
<td>E</td>
<td>35.3 ± 2.5</td>
<td>35.5 ± 2.5</td>
</tr>
</tbody>
</table>

With Silane Treatment

<table>
<thead>
<tr>
<th></th>
<th>Before Spinning</th>
<th>After Spinning</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2.4 ± 0.2</td>
<td>2.2 ± 0.2</td>
</tr>
<tr>
<td>B</td>
<td>7.4 ± 0.4</td>
<td>7.4 ± 0.4</td>
</tr>
<tr>
<td>C</td>
<td>18.3 ± 1.8</td>
<td>34.5 ± 1.8</td>
</tr>
<tr>
<td>D</td>
<td>20.6 ± 1.6</td>
<td>24.9 ± 1.9</td>
</tr>
<tr>
<td>E</td>
<td>15.6 ± 1.5</td>
<td>35.0 ± 1.5</td>
</tr>
</tbody>
</table>

93% Improvement!
Particle Distribution

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Particle Size (μm)

Count

Before Spinning
After Spinning

Smooth

Textured

Before Spinning
After Spinning

1/20/2022
Seam: Transmission Microscopy

Smooth

Textured

Smooth

Textured
Seam: Electron Microscopy

Smooth | Textured

Smooth | Textured

100 µm
Dust on Smooth Polycarbonate
Dust-Mitigating Surfaces

Smooth    Textured

4x Speed

https://youtu.be/FBWk1OCg5dc
Roll to Roll Imprinting

- 6.5” drum with 300 nm features (SMS)
- Thermal NIL into PC, 1.5 m/min (MiCon)

https://youtu.be/2WzndwDG9SY
Proposed Phase II Work

1: Adhesion Physics
- What geometric characteristics matter?
- Will low surface energy materials demonstrate the dust-mitigating effect without a silane coating?
- What happens if we increase the excitation force?

2: Scale and Form Factors
- Roll-to-roll imprinting
- Pattern transfer to PTFE, polyimide, PET, FEP via imprinting and etching
- Application to solar cells, radiator strips, food bags, and camera optics

3: Relevant Testing
- Vacuum, temperature, static charge, and humidity
- Repeated dust loading cycles
- Abrasion and thermal stress testing