Specular Black Coating For Starshade Razor Edges (second progress update)

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Range of Solar angles for Starshade Optical Edge

Coat from this direction so that the sag angle is < 11.25 deg.

Exoplanet

Target Star

Sun

40° 85° 58.75°

Telescope

Only this part of the edge needs AR coating.
Incident angle on edge is 47.5 to 70 deg.

Starshade petal edge.
Petal comes out of the page.
Curve here represents the terminal edge of the petal.
Starshade blade
ZeCoat’s 2.4-meter coating chamber with integrated motion-controlled evaporation system
<table>
<thead>
<tr>
<th></th>
<th>JPL stated goals</th>
<th>ZeCoat expected performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>wavelength range</td>
<td>425-nm to 1000-nm</td>
<td>425-nm to 1000-nm</td>
</tr>
<tr>
<td>reflectance</td>
<td>&lt;5% 47.5 deg to 70 deg.</td>
<td>R&lt;2% 0-45deg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R&lt;5% 0-62-deg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R&lt;11% @70-deg</td>
</tr>
<tr>
<td>thermal cycle</td>
<td>TBD</td>
<td>10 cycles; -85C to +150C</td>
</tr>
<tr>
<td>humidity</td>
<td>TBD</td>
<td>80C/80%RH, 48-hrs</td>
</tr>
<tr>
<td>adhesion</td>
<td>TBD</td>
<td>tape adhesion MIL PRF13830B</td>
</tr>
<tr>
<td>abrasion</td>
<td>TBD</td>
<td>moderate abrasion MIL PRF13830B</td>
</tr>
<tr>
<td>cleanability</td>
<td>TBD</td>
<td>alcohol, acetone, First Contact</td>
</tr>
<tr>
<td>space radiation</td>
<td>TBD</td>
<td>GEO, 5-years (protons, electrons, UV)</td>
</tr>
</tbody>
</table>
Measured reflectance for first two delivered coating designs deposited on edges

- **BEC-4** (~300-nm thick, measured 8-deg. SOC)
- **BEC-1** (~200-nm thick, measured 8-deg. GSFC)
Reflectance vs. Wavelength; BEC-2 for several AOI's

<table>
<thead>
<tr>
<th>AOI</th>
<th>Reflectance (S)</th>
</tr>
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<tbody>
<tr>
<td>70-deg</td>
<td>18</td>
</tr>
<tr>
<td>65-deg</td>
<td>14</td>
</tr>
<tr>
<td>55-deg</td>
<td>10</td>
</tr>
<tr>
<td>45-deg</td>
<td>6</td>
</tr>
<tr>
<td>8-deg</td>
<td>2</td>
</tr>
</tbody>
</table>

wavelength (nm)
visible and IR reflectivity - BEC-4

solar absorption ($\alpha$) = 0.93
thermal emissivity ($\varepsilon$) = 0.28
$\alpha/\varepsilon = 3.3$
Edge temperature determined by $\alpha/\varepsilon$ ratio

\[ T = \left( \frac{a}{\varepsilon} \cdot \frac{1400}{e \cdot 5.67 \times 10^{-8}} \right)^{1/4} = \left( \frac{a}{\varepsilon} \right)^{1/4} \cdot \left( \frac{1400}{5.67 \times 10^{-8}} \right)^{1/4} \]

Temperature on edge in sunlight $\sim 200^\circ C$

Note: preliminary ZeCoat calculation, JPL to verify

$\alpha/\varepsilon = 0.93/0.28 = 3.3$
STATUS TASKS

Complete 1. Apply BEC-1 and BEC-2 coatings to customer-supplied amorphous sample blades and measure scatter and collect micrographs at JPL

Half complete (February) 2. Determine optical constants n,k for the amorphous metal substrate and for select coating materials, and optimize black interference coating designs for high AOI

Complete 3. Scale coating process with linear motion to coat 1-meter piece and perform calibration single-layer coating runs with linear motion system.

March 4. Make and test optimized designs on small amorphous blade sample.

April 5. Coat 1-meter full-size starshade blade

April 6. Environmental testing
Enter @ TRL-2 parallel paths

TRL-3
Fabricate and test BM-1 baseline coating
Optimize coating designs

TRL-4
Modify large coating System for 1-meter blade
Perform calibration coating For 1-meter blade
Coat 1-meter blade
Test coatings in relevant space environments
To TRL-5
QUESTIONS?