Development of a high temperature black coating for space application

MAP: G. Sierra, D. Sacramento, S. Solé
CNES: P. Nabarra, S. Perraud, M. Fuxan, S. Remaury
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MAP is a SME company of 34 people
We are located in south of France close to Toulouse
We are involved in space since 1986
We design, produce and apply coatings for satellites and launchers
Our products are evaluated or qualified by European organizations like CNES, ESA, according to space standards
Organizations such as JAXA, NASA and scientific institutes also selected our coatings for testing
The space industrialists worldwide have been trusting us for over 30 years, by allowing us to participate in the thermal regulation of their satellites
1. Company overview

**White TCC:** SG121FD, PCBE, SCK5
Radiators, Antennas, Waveguides, Back side of solar panels, Manned flights

**Black TCC:** PU1, PUK, MAP® AQPU1 & AQ PUK, PNC...
Internal wall, Electronic boxes, Optical Baffles

**Adhesives:** MAPSIL® QS1123 range
Heat transfer, OSR and Cover glass bonding

**Lubricants:** MAPLUB range
Deployment mechanism

**Silicone conformal coatings:** MAPSIL® 213-B, MAP® ATOX 41-B
PCBs protection
Use of high temperature materials and coatings

2. Context

Scientific missions:
• Solar Orbiter
• Bepicolombo

Telecom satellites:
• Close to the electric thruster
• ...

http://sci.esa.int/solar-orbiter/55751-artists-impression-of-solar-orbiter/
https://www.esa.int/Our_Activities/Space_Science/BepiColombo_overview2
3. Specifications

Technical specifications of a black coating...

Maximal temperature:
400°C

Thermo-optical performances:
\( \alpha_s > 0.9 \)
\( \varepsilon > 0.8 \)

Main needs:
Low outgassing (ECSS-Q-ST-70-02C)
Thermal cycling under vacuum at high temperature
ESD compliance (ECSS-E-ST-20-06)

Technical performances:
Mechanical hardness
Cleaning ability
Adhesion on metallic substrates

Environmental needs – GEO and LEO orbit:
UV radiation
Charged particles (e-, p+)
ATOX
3. Specifications

... in a world space industry environment

- High competition in space industry
- Need of performance
- Need of sustainability
- Need of cost reduction
- Need of more services

- Coatings with a flight heritage
- Sustainable process that limits the risk of vagaries
- Improved product-process combination to save time on the critical path stages
- REACH compliance and ITAR Free
Properties of MAP® HT1607 coating

- 2K Silicone coating based on a T resin
- Polycondensation mechanism
- Good adhesion without primer
- High temperature curing

Properties of MAP® HT1607 coating

- Thickness: 20 to 40 µm
- Curing cycle: 1) 48 h at 23°C
  2) 1h at 300°C

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base / Hardener mixing ratio (w. %)</td>
<td>99.5/0.5</td>
<td>-</td>
</tr>
<tr>
<td>Solid contents mix (%)</td>
<td>38</td>
<td>ISO 3251</td>
</tr>
<tr>
<td>VOC rate (g/L)</td>
<td>466</td>
<td>ASTM D3960</td>
</tr>
<tr>
<td>Thickness (µm)</td>
<td>20 - 40</td>
<td>NF EN ISO 2360</td>
</tr>
<tr>
<td>Dry film weight (g dry /m² / µm)</td>
<td>1.52</td>
<td>Theoretical calculation</td>
</tr>
<tr>
<td>Solar absorptance (αS)</td>
<td>0.96</td>
<td>ECSS-Q-ST-70-09C</td>
</tr>
<tr>
<td>Infrared emittance (εh)</td>
<td>0.89</td>
<td>ECSS-Q-ST-70-09C</td>
</tr>
<tr>
<td>Total Integrated Scatter</td>
<td>4.5%</td>
<td>CNES method</td>
</tr>
<tr>
<td>Electrical surface resistance (Ω/□)</td>
<td>&lt; 10⁶</td>
<td>MAP 006/AQ/92/NI</td>
</tr>
</tbody>
</table>
Outgassing results

System:
- MAP HT1607 on aluminium alloy (without primer)
- Curing cycle: 1) 48 h at 23°C
  2) 1h at 300°C

<table>
<thead>
<tr>
<th>System</th>
<th>TML</th>
<th>RML</th>
<th>CVCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAP® HT1607</td>
<td>0.29%</td>
<td>0.10%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

→ Very low RML and no CVCM

Intespace report M19042
Ageing tests

Damp heat test

Temperature: 50°C
Humidity rate: 95%
Duration: 8 days

Thermal vacuum cycling

100 cycles: -170°C → 400°C
Pressure: $10^{-5}$ hPa
Cycle duration: 182 minutes (cold step = hot step = 20 min, heating and cooling slope 8°C/min)
4. Results

**Damp heat test + thermal vacuum cycling**

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Adhesion</th>
<th>After DH</th>
<th>After DH + TVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>304L</td>
<td>0/5</td>
<td>0/5</td>
<td>0/5</td>
</tr>
<tr>
<td>Inconel 600</td>
<td>0/5</td>
<td>0/5</td>
<td>0/5</td>
</tr>
<tr>
<td>TA6V</td>
<td>0/5</td>
<td>0/5</td>
<td>0/5</td>
</tr>
</tbody>
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<tr>
<th>Substrate</th>
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<td>TA6V</td>
<td>0.89</td>
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<tr>
<th>Substrate</th>
<th>Electrical surface resistance (kΩ/□)</th>
</tr>
</thead>
<tbody>
<tr>
<td>304L</td>
<td>1.1</td>
</tr>
<tr>
<td>Inconel 600</td>
<td>1.2</td>
</tr>
<tr>
<td>TA6V</td>
<td>1.1</td>
</tr>
</tbody>
</table>

→ No change in adhesion, thermo-optical properties and electrical surface resistance after ageing tests
Environmental simulation at ONERA lab

Simulation of 3 years GEO:

1. UV \[1112\text{ESH (Equivalent Sun hours)}\]
2. Electrons \[400 \text{ keV @ } 1 \times 10^{15} \text{ at/cm}^2\]
3. Protons \[240 \text{ keV @ } 2 \times 10^{14} \text{ at/cm}^2\]
4. Protons \[45 \text{ keV @ } 2 \times 10^{15} \text{ at/cm}^2\]

Test condition:
\[\alpha_s \text{ measurement under vacuum at each step of irradiation}\]

Study performed by T. Paulmier
Environmental simulation at ONERA lab: 3 years GEO

Stability of solar absorptivity under simulated GEO environment
ESD tests

✓ SIRENE facility

✓ 1\textsuperscript{st} test – Monoenergetic flux:
  ✓ Electron beam \([20\text{keV} - 250\text{ pA/cm}^2]\) – 3h
  ✓ Surface potential measurement at 25\(^\circ\)C, -80\(^\circ\)C and -150\(^\circ\)C
  ✓ Discharge of the samples between each irradiation (2h up to 25\(^\circ\)C)

✓ 2\textsuperscript{nd} test – Multienergetic flux
  ✓ SIRENE standard spectrum
  ✓ \([25\text{ keV} - 250\text{ pA.cm}^{-2}] \& [(0-400)\text{ keV} - 50\text{ pA.cm}^{-2}]\) – 3h
  ✓ Surface potential measurement at -150\(^\circ\)C

→ NO ESD sensibility due to the antistatic property of the coating
6. Conclusion

- Validation of a new coating for high temperature needs: MAP® HT1607
- Environmental stability (3 years GEO simulation & ESD test)
- ATOX exposition test at ESA planned by end of 2018
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Thank you for your attention!