Further Analysis of MISSE Polymeric Materials at MSFC

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Many different spacecraft materials were flown as part of the Materials on International Space Station Experiment (MISSE). MISSE was exposed to the low Earth orbital environment of atomic oxygen, ultraviolet radiation, thermal cycling, and hard vacuum. A number of polymer samples did not survive the atomic oxygen attack. Mass and thickness loss measurements indicate the durability of the remaining polymeric materials to withstand the space environment. Results from the one-year exposure on MISSE-3 and MISSE-4 are compared to those from the four-year exposure on MISSE-1 and MISSE-2. Solar absorptance and infrared emittance measurements are given for thermal control materials. Transmission measurements are given where appropriate.

A wide variety of polymeric materials were flown on MISSE, ranging from extremely thin films for solar sails to bulk materials. Some of the candidate solar sail materials were flown underneath magnesium fluoride windows to eliminate atomic oxygen effects and allow the study of ultraviolet radiation damage. Exposed seal materials include Viton®, silicone, and fluorosilicone. Multi-layer insulation materials were flown, including atomic oxygen-resistant polymers. Also flown were candidate inflatable materials for a High Altitude Airship or inflatable lunar habitat. Polymer materials being flown on MISSE-6 are discussed.
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Further Analysis of MISSE Polymeric Materials at MSFC

- Environment
- Results
  - DC93-500 films
  - CP1 films
  - Transhab candidate materials
  - Seal materials
  - Other polymeric materials
- Summary
## Overview of Environmental Exposure

<table>
<thead>
<tr>
<th></th>
<th>Duration</th>
<th>Atomic Oxygen (atoms/cm²)</th>
<th>UV (ESH)</th>
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</thead>
<tbody>
<tr>
<td>MISSE-1</td>
<td>4 years</td>
<td>Ram $\sim 9.5 \times 10^{21}$</td>
<td>Ram 5400 – 6400</td>
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<tr>
<td></td>
<td></td>
<td>Wake 1.1 – 1.3 $\times 10^{20}$</td>
<td>Wake 4500 – 5600</td>
</tr>
<tr>
<td>MISSE-2</td>
<td>4 years</td>
<td>Ram 6.8 – 9.1 $\times 10^{21}$</td>
<td>Ram 5000 – 6700</td>
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<tr>
<td></td>
<td></td>
<td>Wake 1.4 – 2.0 $\times 10^{20}$</td>
<td>Wake 4800 – 6200</td>
</tr>
<tr>
<td>MISSE-3</td>
<td>1 year</td>
<td>Ram 1.2 – 1.3 $\times 10^{21}$</td>
<td>Ram 1695 – 1750</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wake 1.9 $\times 10^{20}$</td>
<td>Wake 655 – 790</td>
</tr>
<tr>
<td>MISSE-4</td>
<td>1 year</td>
<td>Ram $\sim 2.1 \times 10^{21}$</td>
<td>Ram 1200 – 1600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wake 3.6 $\times 10^{20}$</td>
<td>Wake 825 – 1000</td>
</tr>
</tbody>
</table>
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ENTECH DC93-500 Thin Silicone Films
- Used in refractive photovoltaic concentrator systems
- Four samples flown on MISSE-2 wake side
  - Two with UV-rejection coating
  - Two without coating
- Three samples flown on MISSE-4 wake side
  - Two with UV-rejection coating
  - One without coating
- Consistent results between flights
  - Samples without coating darkened
  - Samples with UV-rejection coating maintained similar transmission
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Typical coated sample

Typical uncoated sample
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Further Analysis of MISSE Polymeric Materials at MSFC
NeXolve Corporation CP1 Films
• Used in solar sails, solar concentrator systems, large antennas
• One sample exposed for one year on ram side
  • CP1 with aluminum and SiOx coating
• Four samples exposed for one year on wake side
  • CP1 with and without aluminum
  • CP1 with aluminum and SiOx coating and ripstop fiber
• Four samples exposed for four years on wake side
  • CP1 without aluminum, with butt joint and lap joint
  • CP1 with aluminum
  • CP1 with aluminum and SiOx coating and ripstop fiber
1 mil CP1 with aluminum and SiOx coating

- Exposed to $1.3 \times 10^{21}$ atoms/cm$^2$ AO
- Some erosion through film
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1 mil CP1 with aluminum coating
- Some oxidizing of aluminum coating noted
5 micron CP1 with Al and SiOx coating and ripstop

- Some oxidizing of aluminum coating noted
- Ripstop intact
1 mil CP1 with aluminum coating

- CP1 side exposed
- AO erosion evident – emittance dropped from 0.65 to 0.61
Transhab Materials
• Candidate materials for inflatable module
• Program cancelled, but development continued with Bigelow Aerospace Genesis and Nautilus spacecraft
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Polyurethane foam, Combitherm bladder material, Kevlar felt, Kevlar webbing
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Polyurethane foam, Combitherm bladder material, Kevlar felt, Kevlar webbing
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Nextel cloth, Kevlar webbing, Kevlar felt, polyurethane foam
Transhab Materials

- Foam and bladder materials heavily eroded
  - No AO reactivity calculated
- Kevlar materials, including thread intact, after four years
- Nextel intact (one year exposure)
- Sizing appears to be removed
Seal Materials

Fluorosilicone

- Little mass loss
  - 1.5 mg (0.13%) for four-year exposure
- Darkened due to UV
- Some glassification
Seal Materials
   Silicone S383
   • Mass increase with the formation of SiOx
   • Cracking evident
Seal Materials
Viton 835
- Some mass loss
  - 3.7 mg (0.32%) for one-year exposure
- Calculated AO reactivity
  $0.26 \times 10^{-24} \text{ cm}^{-3}/\text{atom}$
Other Polymeric Materials
Boeing Dielectric Film
Withstood AO attack, too brittle for much analysis
Conclusions and Future Research

- UV-rejection coatings worked as intended
- CP1 films performed better on wake side
- Transhab foam and bladder materials heavily eroded by AO
- Kevlar and Nextel performed as expected
- Seal samples should be evaluated for permeability
- MISSE-6 returning on STS-128
  - Germanium/Kapton
  - L’Garde materials incl. ripstop and grounding patch
  - Ballute materials Upilex and PBO
  - NeXolve CORIN, EP2550, conductive CP1