EFFECT OF RAM AND ZENITH EXPOSURE ON THE OPTICAL PROPERTIES OF POLYMERS IN SPACE

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Abstract

The temperature of spacecraft is influenced by the solar absorptance and thermal emissivity of the external spacecraft materials. Optical and thermal properties can degrade over time in the harsh low Earth orbit (LEO) space environment where spacecraft external materials are exposed to various forms of radiation, thermal cycling, and atomic oxygen. Therefore, it is important to test the durability of spacecraft materials in the space environment. One objective of the Polymers and Zenith Polymers Experiments was to determine the effect of LEO space exposure on the optical properties of various spacecraft polymers. These experiments were flown as part of the Materials International Space Station Experiment 7 (MISSE 7) mission on the exterior of the International Space Station (ISS) for 1.5 years. Samples were flown in ram, wake or zenith directions, receiving varying amounts of atomic oxygen and their radiation exposure. Total and diffuse reflectance and transmittance of light and corresponding control samples were obtained post-flight using a Cary 5000 UV-Vis-NIR Spectrophotometer. Integrated air mass zero solar absorptance (ε0) of the flight and control samples were computed from the total transmittance and reflectance, and compared. The optical data are compared with similar polymers exposed to space for four years as part of MISSE 2, and with atomic oxygen erosion data, to help understand the degradation of these polymers in the space environment. Results show that prolonged space exposure increases the solar absorbance of some materials, knowing which polymers remain stable will benefit future spacecraft design.

Atmospheric Oxygen (AO)

- AO is the predominant species in LEO (180-650 km)
- At ram impact velocities (17,000 mph) the impact energy is 6.5 eV
- AO is formed when O2 is broken apart by energetic UV radiation
- AO oxidizes certain materials, producing gas - so the material erodes away...

Materials International Space Station Experiment 7

MISSE 7 Polymers Experiment

The MISSE 7 Polymers Experiment is a passive experiment with 45 samples flown in ram or wake orientations on MISSE 7B.

Objectives include:
1. Determine the LEO AO erosion yield (Ey), volume loss per incident oxygen atom, cm³/atom, of the polymers
2. Determine the effect of ram or wake space exposure on optical properties

Ram samples:
- 38 samples were flown in the ram orientation exposing them to high AO fluence and solar radiation
- 8 samples were flown for AO Ey and AO for tensile testing
- Kapton H polyimide was flown for AO fluoride determination
- Only 7 samples were appropriate for optical measurements (the wake samples were too small)

MISSE 7 Zenith Polymers Experiment

The MISSE 7 Zenith Polymers Experiment is a passive experiment with 25 samples flown in a zenith orientation on MISSE 7A.

Objectives include:
1. Determine the effect of solar exposure on the LEO AO Ey of fluoropolymers under high solar/low AO exposure
2. Determine the effect of zenith exposure on optical properties

Zenith samples:
- 14 out of 25 square samples were flown in the Z Tray and 10 "taped" samples were flown in handmade Al holders
- 18 samples were flown for AO Ey & 5 for tensile testing
- Kapton H polyimide was flown for AO fluoride determination
- 15 zenith samples were measured for optical properties

Solar Absorption of Select MISSE 7B Ram Samples

<table>
<thead>
<tr>
<th>Material</th>
<th>AO Fluence (atoms/cm²)</th>
<th>0.6</th>
<th>1.0</th>
<th>1.4</th>
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<tbody>
<tr>
<td>Kapton H</td>
<td>2.9E+21</td>
<td>0.85</td>
<td>0.70</td>
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<td>Polypropylene (PP)</td>
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<td>PVOH</td>
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<td>Teflon</td>
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<td>0.70</td>
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Materials International Space Station Experiment 7

MISSE 7 Ram Polymers Optimal Properties Data

<table>
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<tr>
<th>Material</th>
<th>Thickness (mm)</th>
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<th>1.0</th>
<th>1.4</th>
<th>2.0</th>
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<tbody>
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<td>Kapton H</td>
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</tbody>
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Summary and Conclusions

- MISSE 7 ram and zenith samples were characterized and compared to corresponding MISSE 2 samples
  - Optical properties were obtained on ram & 14 zenith MISSE 7 samples (all 12 zenith samples were repaired previously)
  - AO Ey data were compared
  - MISSE 7 ram AO Ey & AO fluence were very little change in optical properties indicating very low on-orbit contamination
  - The Oy for the MISSE 2 samples is greater than for the MISSE 7 samples (except PTFE & PVF)
  - The Ey of the MISSE 7 samples is greater than for the MISSE 2 samples (except PTFE & PVF) to a small increase
  - Understanding data on changes in polymers’ optical properties and Ey allows the determination of the most durable and best fit samples for spacecraft design
  - Samples with high increases in Ey should be better protected, when considering materials for thermal control or other exterior spacecraft applications

**Equivalents run hours (ESH): hours of sunlight**

- 1 year = 8760 hours
- 1 month = 720 hours
- 1 week = 168 hours
- 1 day = 24 hours

**Optical Procedures**

- Cary 5000 UV-Vis-NIR Spectrophotometer
- Total and diffuse reflectance (RR) and total and diffuse transmittance (TT, DT) were obtained from 250 nm to 2500 nm
  - Data was obtained post-flight on both the flight and control samples
- Specular reflectance (SR) and specular transmittance (ST) were computed using the following equations:
  - SR = TR - DR
  - ST = TT - DT
  - Solar absorptance (α) was determined through the equation: α = 1 - (TR + TT)
  - Data from the flight and control samples were compared to determine effect of LEO space exposure on the optical properties of the polymers