Evaluation of Two Ionic Liquid-Based Epoxies from the MISSE-8
(Materials International Space Station Experiment-8) Sample Carrier

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Materials International Space Station Experiment-8*

- Deployed May 20, 2011 on STS-134
- Located on Express Logistics Carrier-2 (ELC-2)
- Retrieved July 9, 2013
- Returned to Earth May 2014 on SpaceX Dragon CRS-3

MSFC flew two passive sample trays on nadir side.
Total of 96 samples.

Atomic Oxygen Fluence

$3.6 \pm 0.1 \times 10^{19}$ atoms/cm$^2$

Determined by mass loss and thickness loss of Kapton HN

Very low fluence due to nadir location and ISS shielding

Ultraviolet Radiation Exposure

Exact dose unknown at this time

UV darkening observed on beta cloth, IL epoxy samples, others

This suggests a minimum of 500 equivalent sun hours (ESH).

Ionic fluid samples – Flight

Control
Environmental Conditions
- 2 years and 2 months Nadir Exposure
- A O Fluence $3.6 \pm 0.1 \times 10^{19}$ atoms/cm$^2$
- 12,500 cycles between $\sim-40^\circ C$ and $+40^\circ C$
- High Vacuum Environment, Radiation

<table>
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<tr>
<th></th>
<th>Pre-flight weight (g)</th>
<th>Post-flight weight (g)</th>
<th>Delta</th>
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<tr>
<td>ILEP 15</td>
<td>2.35486</td>
<td>2.3547</td>
<td>-0.00016</td>
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<tr>
<td>ILEP 17</td>
<td>2.32939</td>
<td>2.32902</td>
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Initial Observations
- Negligible Weight Change
- Continued Strong Adherence
Color change likely a result of ultraviolet (UV) radiation
Nano-scale Dimpling

Referencing the MISSE Database for similar surface structures

Note: Air Curing Epoxy results in an oxidation layer, scales may be similar
ESCA (Electron Spectroscopy for Chemical Analysis)

ILEP-13 Ground

ILEP-17 ISS

IL Epoxy Ground Test Samples
- Smooth – Exposed during cure
- Cut – Interior bulk material

Epoxy Monomer + Curing Agent = Epoxy

1,3-bisglycidylimidazolian

Bis-Aminophenoxybenzene (APB)

ILEP-2
O 1s (normalized)

- Cut
- ILEP 17
- ILEP 13
- Smooth

Binding Energy (eV)

537 535 533 531 529 527 525
Summary of IL Epoxy Exposure on MISSE-8

- No weight change
  - Extremely low vapor pressure

- Continued strong adherence to aluminum base
  - No cracking, de-bonding, or other observable deformations

- Nano-scale dimpling on surface
  - Not resolved

- ESCA results
  - Some bond breaking of the N molecules on the surface
  - No obvious O changes
  - C variance probably due to contamination
    → Analysis ongoing

Appears to well tolerate the harsh environment of space
Other Ionic Liquid Epoxy Properties

- Strong ionic bonding
- Very small coefficient of thermal expansion
- Hydrophobic

Applicable to Fabricating Carbon-fiber Composite Tanks for Cryogenic Liquid Containment
CSR: Impact test results

Plot of impact test results with increasing percentages of CSR for room and liquid nitrogen temperatures.

Comparable Improvement in Tensile Test Results
Cryogenic Testing in LOX and LH2

LOX: Potential Fuel Candidate, Much more Reactive than LN2
LH2: Potential Fuel Candidate, Much Colder (~20K) than LOX (~90K) or LN2 (~77K)

As-Fabricated Cylinder Section
After two dunks in LOX
After LOX plus two 1 hour Soaks in LH2

14 Samples Tested: High power microscopy and some fluorescent dye penetrant showed no degradation, cracking, or delamination

Epoxy is cured at 150°C (423K), 423K-20K (LH2) = ΔT = 403K!
Fabricate Composite Overwrap Pressure Vessels (COPV)

Wrapping

Curing

Epon 828 Resin with Huntsman T-403 Curing Agent
IL Resin (no CSR) with APB Curing Agent
Conclusions

- Ionic liquid-based epoxy well tolerates the space environment
- Other properties suggest application to fabricate carbon-fiber composite tanks for cryogenic liquid containment
- Testing/evaluation will continue
Acknowledgments

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