Materials for Space Exploration

Polymer Science and Technology Lab
Materials Science Division
Engineering Directorate
Kennedy Space Center, Florida

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Lab Overview

Mission

To develop and apply new technologies in polymer and material chemistry that benefit NASA's programs and mission

Team

2 NASA scientists, 1 co-op, and 4 contractors

Areas of Expertise

Polymer Nanocomposites
Next Generation Wire Materials
Carbon Nanotube and Nanofiber Materials
Conductive Polymers
Polymer Processing
Fire and Polymers
Foam and Insulation Materials

Numerous Collaborative Efforts

NASA Centers (JSC, LaRC, MSFC, GSFC, GRC)
KSC Directorates (Shuttle, Ares, Orion, Ground support operations)
Academia (Alberta, FIT, GT, Harding, Illinois-Urbana Champagne, UCF, UF, USF)
Industry Space Act Agreements (Thermax, DeWAL, Sharklet, Crosslink, Sabic, Amalgam)
Industry Contracts (ARCnano, Epner)
Testing and Processing Equipment

• Fire Testing
  – Cone Calorimeter
  – Oxygen Index**
  – UL94 fire test
  – NASA Std 6001 fire test
  – Radiant Panel*
  – NBS Smoke Chamber*
  – Two foot tunnel*
  – Glow wire ignition*

• Cryogenic Materials Testing
  – Cryogenic moisture uptake (CMU)**
  – Brittleness/Impact test **
  – Liquid helium cold finger test**
  – Single Pin-Socket Krytox Contamination Electrical Characterization under Cryogenic Conditions**

• Specialty Test Equipment
  *in collaboration with Cryogenics Test Laboratory
  **in collaboration with Florida Tech

• Cellular Solid Analysis
  – Pycnometer (closed/open cell)**
  – Surface area measurement**

• Thermal Analysis
  – Thermogravimetric analysis (TGA)
  – Differential Scanning Calorimetry (DSC)
  – Dynamic Mechanical Analysis (DMA)

• Physical Testing
  – Tensile Test
  – Compressive Test
  – Pull/Peel Test

• Electrical Testing
  – 4-point probe
  – Surface /Volume resistance

• Polymer Processing capabilities
  – Extrusion
  – Injection molder
  – Fiber spinning equipment
  – Melt, ball, and high intensity mixers
A patent-pending irreversible color changing H₂ gas sensor was developed at KSC in partnership with UCF and ASRC.

Changes color from a light tan to black in the presence of H₂.

Can be manufactured into any polymer part, tape, fiber, or fabric material for unlimited potential uses.
- Paint, Gloves, Coveralls, PPE

Operates under ambient and cryogenic temperatures.
Chemochromic Hydrogen Sensors

STS-129 Transfer Line

LPA OMBUU Deployment for STS 117, 118, 120, 122, 123
Orion Potable Water
5 Inconel 718 Tanks (14.3 gal)
Miles of Titanium water lines

- Efficacy studies after 21 days decreases biofilm formation
- Easy to imprint during manufacture of polymer articles through a coining process
- Can be used in conjunction with antimicrobial polymers
Microgravity Flight Experiments

BIOLOGICAL ANALYSIS

Confirm efficacy of *Pseudomonas fluorescens* bacteria species with Sharklet® topography coupons and different surface treatments

- How well does it work in μG and lunar G compared to 1G?
Wire System Materials

Insulation and Repair Materials
CNT Ink formulations

Replace Ink with CNT Solution

Journal of Nanoscience and Nanotechnology, 6, 2006
Screen printed polymer-composite material

Line thickness and width increases conductivity

50 Ohm resistance able to measure damage to circuits
• Foam insulation materials
  – AeroFoam (patent pending)
  – Syntactic foams

• Ice release coatings
  – Shuttle Ice Liberation Coating (SILC)
  – Dow UCAR 439 and 627
  – Luna Innovations icephobic coating

• Structural aerogel composites
  – AeroPlastic (patent pending)
    • Polyamides
    • Polyetherimides
    • Polyolefins
Fire and Polymers

- Flame retardant strategies
  - Polymethoxyamide derivatives for high temperature engineering polymers (patent issued)
  - Carbon nanotube synergistic FR properties
  - Polyhedral Oligomeric Silsesquioxanes (POSS) FR properties

- Fire risk consultation
  - Wire insulation
  - Thermal insulation
  - Ablator

- Fire standards and risk
  - Ares I
  - Ares V
  - Orion

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\begin{align*}
\text{Formula 1} & \quad \text{Formula 2}
\end{align*}
\]
# The Importance of Lighting

## Electric Lamp Options

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>Conversion* Efficiency</th>
<th>Lamp Life* (hrs)</th>
<th>Spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent/Tungsten**</td>
<td>5-10%</td>
<td>2000</td>
<td>Intermd.</td>
</tr>
<tr>
<td>Xenon</td>
<td>5-10%</td>
<td>2000</td>
<td>Broad</td>
</tr>
<tr>
<td>Fluorescent***</td>
<td>20%</td>
<td>5,000-20,000</td>
<td>Broad</td>
</tr>
<tr>
<td>LEDs (red and blue)****</td>
<td>25%</td>
<td>100,000 ?</td>
<td>Narrow</td>
</tr>
<tr>
<td>Metal Halide</td>
<td>25%</td>
<td>20,000</td>
<td>Broad</td>
</tr>
<tr>
<td>High Pressure Sodium</td>
<td>30%</td>
<td>25,000</td>
<td>Intermd.</td>
</tr>
<tr>
<td>Low Pressure Sodium</td>
<td>35%</td>
<td>25,000</td>
<td>Narrow</td>
</tr>
<tr>
<td>Microwave Sulfur</td>
<td>35-40%+</td>
<td>?</td>
<td>Broad</td>
</tr>
</tbody>
</table>

* Approximate values.

** Tungsten halogen lamps have broader spectrum.

*** For VHO lamps; lower power lamps with electronic ballasts last up to ~20,000 hrs.

**** Green LEDs ~10% efficient.
Electric Lighting Systems

Fluorescent

High-Pressure Sodium

LEDs

Microwave Sulfur
LED for Plant Growth

Red...photosynthesis
Blue...photomorphogenesis
Green...human vision

John Sager, KSC, Testing Prototype Flight Plant Chambers with LEDs
Carbon Nanotube Fiber Filaments

Dry Spinning of MWCNT Forests

Wet Spinning of WMCNTs

A

Pressure

suspension

spinneret

Coagulation bath

fibre

fibre

30 μm

300 nm

5 μm

50 μm

500 nm
Carbon Nanotube Fiber Filaments

Spectrum of CFL bulb

Spectrum of Wet CNT fiber