New Transparent OSU-Compliant Polycarbonate Copolymers

LEXAN* FST

International Aircraft Fire & Cabin Safety Research Conference

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Transparent OSU-Compliant Polycarbonate Copolymers

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GE Global Research

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SABIC Innovative Plastics

Karen Hills, Gregory Bell

The Boeing Company
Special Thanks To

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Herb Curry Lab
Scott van Wormer

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Vasan Sundaram, Hank Lutz, Joel Peterson, Pete Guard, Jim Griffing, Kjersta Larson, Steve Moffitt
Plastics in Aircraft Applications

Highly regulated market
FST Tests Required by FAA & OEMs

**Ignitability, Melting/Dripping**
- 60-sec vertical Bunsen burner
- 6” burn length
- 15-s specimen extinguishing time
- 3-s drip extinguishing time

**Heat release**
- Ohio State Univ calorimeter
- 65 kW • min/m² total (during first 2 min)
- 65 kW/m² peak rate (during first 5 min)

**Smoke release**
- National Bureau of Standards smoke chamber
- Specific optical density < 200 (during 4-min test)
- Toxicity (OEM): CO, HCN, HF, HCl, SO2, NOX

**OSU 65/65 most challenging requirement**
Need for transparent OSU compliant polymer

OSU Test

**OSU 65/65**
- 65 kW • min/m² total (during first 2 min)
- 65 kW/m² peak rate (during first 5 min)

Existing commercial materials all opaque:
- Polyetherimide, polysulfone

Heat Release Rate

Time
New Transparent Polycarbonate Copolymers

OSU 40/35

t = 0.08”
for aircraft dust cover application

Heat release capacity & char forming controlled at molecular level
OSU Performance: Flame & Heat Applied

Heat & Flame Applied

$t=0$
OSU Performance: Start of burning & char

$t=30$ sec

Key factors:
- Low fuel value
- Formation of char
- Rheology

Sample starts to char with low heat release
OSU Performance: Full Burning

$t=2 \text{ min}$

Key factors:

- Char layer forming
- Char layer needs good integrity
- Low sagging & running
- No exposure of fresh fuel

Polymer composition and structure key to char layer integrity
OSU Performance: Burning stops

Char layer slows burn rate & holds sample in place

First halogen-free transparent materials to meet OSU
FR Performance of New Copolymers

Validated at Boeing labs
## FR Performance of New Copolymers

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>Peak HRR (kW/m²)</th>
<th>2-min HR (kW-min/m²)</th>
<th>NBS Smoke Density (4Dm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLEAR/TRANSPARENT</td>
<td>1.5</td>
<td>37</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
<td>39</td>
<td>29</td>
</tr>
</tbody>
</table>

**Source:** Non-halogen Fire Resistant Plastics for Aircraft Interiors, Rich Lyon, FAA, Oct 2007
**Smoke, Vertical Burn, Toxicity**

### Smoke Density (3 sample avg.)

<table>
<thead>
<tr>
<th>Smoke Generation</th>
<th>Max</th>
<th>New Mat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Ds) @ 4 min</td>
<td>200</td>
<td>23.15</td>
</tr>
</tbody>
</table>

### 60 Second Vertical Burn (3 sample avg.)

- Burn length
- Drip extinguishing time

#### Toxicity

**Component** | Max (ppm) | New Mat. |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>HF</td>
<td>200</td>
<td>1</td>
</tr>
<tr>
<td>HCl</td>
<td>500</td>
<td>0</td>
</tr>
<tr>
<td>HCN</td>
<td>150</td>
<td>1</td>
</tr>
<tr>
<td>H2S</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Nox</td>
<td>100</td>
<td>1</td>
</tr>
<tr>
<td>HBr</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>PO4</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>SO2</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

**Component Max (ppm) New Mat.**

<table>
<thead>
<tr>
<th>Vertical Burn</th>
<th>Max</th>
<th>New Mat.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extinguishing Time</td>
<td>15 sec</td>
<td>2.3</td>
</tr>
<tr>
<td>Burned Length</td>
<td>6 inches</td>
<td>0.6</td>
</tr>
<tr>
<td>Drip Extinguishing Time</td>
<td>3 sec</td>
<td>no drips</td>
</tr>
</tbody>
</table>

**Exceeding FAA requirements**
### Beyond Fire, Smoke, Toxicity Performance

<table>
<thead>
<tr>
<th>Optical</th>
<th>Mechanical</th>
<th>Physical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Transmission</td>
<td>Tensile</td>
<td>Density</td>
</tr>
<tr>
<td>Haze</td>
<td>Flex</td>
<td>Specific Gravity</td>
</tr>
<tr>
<td>Color/Yellowness</td>
<td>Impact</td>
<td>Molecular Weight</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Aging</th>
<th>Thermal</th>
<th>Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV Resistance</td>
<td>Glass Transition</td>
<td>MFI</td>
</tr>
<tr>
<td>Temp/Humidity Cycling</td>
<td>CTE</td>
<td>Capillary Rheology</td>
</tr>
<tr>
<td></td>
<td>HDT</td>
<td>Dynamic Rheology</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solvent Sensitivity</th>
<th>Abrasion Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discoloration</td>
<td></td>
</tr>
<tr>
<td>Crazing</td>
<td></td>
</tr>
</tbody>
</table>

New copolymers extensively tested across mechanical, chemical, optical and rheological properties
Injection molding, sheet and film extrusion
Thermal forming, profile extrusion…

Extruded sheet of new copolymer (GE Plastics)
Visible Spectrum

Light Transmission
(0.060" thickness)

Light transmission close to BPA-PC
Color Space

Low color & high transmission expand color space
Gardner Impact & Reverse Scratch

Production-quality coated sheets with varying levels of UV protection evaluated

Boeing Specification = No scratch 80 in-lbs min/
Scrapped reverse impact 26 in-lbs min

New material = no scratch 172-210 in-lbs/
Scratch reverse Impact 144-170 in-lbs

MRAC = no scratch 174 in-lbs/
Scratch reverse impact 170 in-lbs

Strong performance, well above minimum requirements
## Physical Properties

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>Units</th>
<th>Method</th>
<th>PC</th>
<th>OSU Resin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MECHANICAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tensile Stress at Yield, 50 mm/min</td>
<td>MPa</td>
<td>ASTM D 638</td>
<td>62</td>
<td>74.2</td>
</tr>
<tr>
<td>Tensile Stress at Break, 50 mm/min</td>
<td>MPa</td>
<td>ASTM D 638</td>
<td>66</td>
<td>72.8</td>
</tr>
<tr>
<td>Tensile Elongation at Yield, 50 mm/min</td>
<td>%</td>
<td>ASTM D 638</td>
<td>7</td>
<td>6.9</td>
</tr>
<tr>
<td>Tensile Elongation at Break, 50 mm/min</td>
<td>%</td>
<td>ASTM D 638</td>
<td>110</td>
<td>99</td>
</tr>
<tr>
<td>Tensile Modulus, 50 mm/min</td>
<td>MPa</td>
<td>ASTM D 638</td>
<td>2,351</td>
<td>2,510</td>
</tr>
<tr>
<td>Flexural Modulus 1.27 mm/min</td>
<td>MPa</td>
<td>ASTM D 790</td>
<td>2,344</td>
<td>2,480</td>
</tr>
<tr>
<td>Flexural Stress@Yield, 1.27mm/min</td>
<td>MPa</td>
<td>ASTM D 790</td>
<td>93</td>
<td>116</td>
</tr>
<tr>
<td><strong>IMPACT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notch Izod Impact, 23°C</td>
<td>J/m</td>
<td>ASTM D 256</td>
<td>801</td>
<td>719</td>
</tr>
<tr>
<td><strong>THERMAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDT, 0.455MPa</td>
<td>°C</td>
<td>ASTM D 648</td>
<td>138</td>
<td>131</td>
</tr>
<tr>
<td>HDT, 1.82MPa</td>
<td>°C</td>
<td>ASTM D 648</td>
<td>127</td>
<td>120</td>
</tr>
<tr>
<td>Tg</td>
<td>°C</td>
<td>DSC</td>
<td>150</td>
<td>140</td>
</tr>
<tr>
<td><strong>PHYSICAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melt Flow Rate, 300°C/1.2 kgf</td>
<td>g/10 min</td>
<td>ASTM D 1238</td>
<td>10.5</td>
<td>6</td>
</tr>
</tbody>
</table>

Polycarbonate-like physical properties
Chemical Resistance

Production-quality coated sheets with varying levels of UV protection evaluated

✓ Solvent Sensitivity (per BMS8-246):
  All pass
  ✓ No visible response to acetone, toluene, and IPA

Chemical resistance better than BPA-PC
Hardcoat Adhesion

✓ Adhesion- Wet & Dry:
  All perform excellently
  (10s on scale of 0-10)

Ground-Air-Ground Cycling: All pass

Numerical Ratings are per Boeing BSS7225 w Class 5 Cross-hatches (6 x 3 mm at 45°)

- 10
- 5
- 3
- 1

No coating left on panel

Worse
Weathering resistance good compared to current product
Hard Coating

- Good adhesion with standard BPA-PC hard coat
- Improved scratch resistance
- Same fire performance
- Good light transmission
- Works with commercial coating for BPA-PC

“Drop in” for existing process
Special Thanks To

*Goodness Gracious*
*Great Balls of Fire !!!*

Gary “Hell Fire” Davis
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