Revolutionary Polymer for Metal Replacement in Automotive Applications

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General Motors Corporation
Outline

- Introduction
  - Material needs in the automobile industry
- QLP Materials
  - Basic Material Concepts and Relevance to Automotive Applications
- Material Properties & Comparison
- Computer simulations of Fascia Bracket
- Materials roadmap for automotive industry
Materials Needs

- Very Low CLTE = to steel
- Stiffness > 10,000 MPa
- Tensile Elasticity, +/- aluminum, approaching steel
- Paint-ability – Class “A” Surface
- Compatibility w/metals, high bond strength
- Chemical resistant
- Injection moldable, thermo formable, extrusion
- High Heat Resistant, >250°C
Potential Applications

- Structural parts, support brackets, etc.
- High heat applications, under hood
- Painted applications, exterior
- Very low CLTE applications, gap control
QLP Background

- Founded in December 2002
- Headquartered in Wilmington, Massachusetts
  - 32,000 sq. ft. manufacturing facility in Massachusetts
  - 16,000 sq. ft. manufacturing facility in California

- Venture Capital:

- Strategic Investor: SUMITOMO CHEMICAL

- Strategic Partnerships
  - DuPont
  - CMC Interconnect Technologies

- Materials Company with first products in semiconductor packaging
Quantech™
Material Innovation

- Semiconductor Assembly - High Reliability
- Technology focused on Solving Current LCP Limitations

<table>
<thead>
<tr>
<th>Traditional LCP Limitations</th>
<th>QLP Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation Issues</td>
<td>Isotropic Properties</td>
</tr>
<tr>
<td>• TD CLTE &gt; 80 ppm/C</td>
<td>High Temperature (&gt;400°C)</td>
</tr>
<tr>
<td>Temperature Limitations</td>
<td>Adhesion to Metals</td>
</tr>
<tr>
<td>No Adhesion</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Traditional Structural Materials</th>
<th>QLP Formulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforced with long fibers (glass/carbon)</td>
<td>Micro and nano fillers for reinforcement</td>
</tr>
<tr>
<td>Anisotropic properties</td>
<td>Isotropic structural properties</td>
</tr>
</tbody>
</table>
Quantech™
Material Innovation

- High Performance Polymer For Ceramic/Metal Replacement: Semiconductor Packaging
- Next generation Polymer Technology solves current LCP Limitations
  - Tailor-able Material Properties
  - CTE Matching Metals
  - Isotropic Mechanical Properties
  - Dimensional Stability
  - High Temperature Stability
  - Outstanding Moisture Resistance
  - Excellent Adhesion to Metals
Linear and Low CLTE matching steel

- Steel CLTE = 14x10^-6/°C to 19x10^-6/°C
- End gated plaque, 3” x 5”

**Flow Direction**

**Cross-Flow Direction**

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Corrected Expansion</th>
</tr>
</thead>
<tbody>
<tr>
<td>-40</td>
<td>-5.00E-03</td>
</tr>
<tr>
<td>-20</td>
<td>-4.00E-03</td>
</tr>
<tr>
<td>0</td>
<td>-3.00E-03</td>
</tr>
<tr>
<td>20</td>
<td>-2.00E-03</td>
</tr>
<tr>
<td>40</td>
<td>-1.00E-03</td>
</tr>
<tr>
<td>60</td>
<td>0.00E+00</td>
</tr>
<tr>
<td>80</td>
<td>1.00E-03</td>
</tr>
<tr>
<td>100</td>
<td>2.00E-03</td>
</tr>
<tr>
<td>120</td>
<td>3.00E-03</td>
</tr>
<tr>
<td>140</td>
<td>4.00E-03</td>
</tr>
<tr>
<td>160</td>
<td>5.00E-03</td>
</tr>
<tr>
<td>180</td>
<td>6.00E-03</td>
</tr>
</tbody>
</table>

**CLTE**

-30 to 30: 1.07E-05
-30-100: 1.21E-05
Pts: 1.19E-05

- CLTE: 1.09E-05
- Pts: 1.35E-05
- 1.36E-05
Adjustable Melt Temperatures

320°C – 360°C

Peak = 328.72 °C
Area = 25.996 mJ
Delta H = 5.9623 J/g

Peak = 344.20 °C
Area = 6.712 mJ
Delta H = 1.5841 J/g

Peak = 353.99 °C
Area = 7.140 mJ
Delta H = 1.6320 J/g

Peak = 358.17 °C
Area = 27.450 mJ
Delta H = 6.2033 J/g
High Temperature Stability and Linearity

TGA
(Low Outgassing: Stability to 500C)

No discernable Tg
DMA (-200C – 500C)
Permeability Comparable to Glass

Permeability of Quantech™
Quantech™ Suitability
Manufacturing Structural Parts

- 100% Crystalline material
- Extremely low heat of fusion
  - Fast Cycle Times
  - Excellent dimensional stability
- Very Low Viscosities
  - Can fill complex geometries
- Very Low Shrinkage
  - Minimum sink marks
Rheology

Extremely Low Viscosity

![Viscosity vs Shear Rate](image)

- Viscosity vs Shear Rate
- Extremely Low Viscosity
- Shear Rate (1/s)
- Viscosity (Pa-s)
- Temperature: T=360[C], T=370[C], T=380[C]
<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Density</td>
<td>• Lighter Weight vs Al and Steel</td>
<td>1.75 g/cc</td>
</tr>
<tr>
<td></td>
<td>• Weight Savings &gt;30%</td>
<td></td>
</tr>
<tr>
<td>CTE Matching metals</td>
<td>• Minimizes Gaps up on Expansion</td>
<td>10-40 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Near-Zero Shrinkage</td>
<td>• Dimensionally stable</td>
<td>&lt;0.05%</td>
</tr>
<tr>
<td></td>
<td>• Improves alignment during assembly processes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• No Warpage</td>
<td></td>
</tr>
<tr>
<td>High Stiffness</td>
<td>• Excellent structural strength and rigidity</td>
<td>&gt;1GPa</td>
</tr>
<tr>
<td>High Temperature Stability</td>
<td>• Under-the-hood applications</td>
<td>420 C HDT</td>
</tr>
<tr>
<td>Extremely Fast Injection Cycle Time</td>
<td></td>
<td>&lt;90s</td>
</tr>
<tr>
<td>Environmentally Friendly</td>
<td></td>
<td>ROHS and Green Compliant</td>
</tr>
</tbody>
</table>
### Quantech™ Key Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>QLP Quantech™ Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLTE - isotropic Tailorable</td>
<td></td>
<td><strong>X13017</strong> (electronics) <strong>X13094</strong> (High Stiffness)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>X</td>
<td>10⁻⁶ /°C</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>10⁻⁶ /°C</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>Mpa</td>
<td>13,620</td>
</tr>
<tr>
<td>Tensile Modulus</td>
<td>Mpa</td>
<td>14,177</td>
</tr>
<tr>
<td>Density</td>
<td>g/cc</td>
<td>1.75</td>
</tr>
<tr>
<td>Water Uptake</td>
<td>%</td>
<td>0.08</td>
</tr>
<tr>
<td>Shrinkage</td>
<td>%</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Heat Deflection</td>
<td>°C</td>
<td>320</td>
</tr>
</tbody>
</table>
Quantech™ Suitability
Lightweight Structural Applications

- **Strength/Weight (s.g.) Ratio**
  - Quantech™: 90
  - Cast Aluminum: 80
  - Cast Steel: 50
  - Cast Nodular Irons: 39-42

- **CLTE**
  - Tailored to match Metals
  - Isotropic
Quantech™ Suitability
Lightweight Structural Applications

Quantech™ Addresses
- Moisture Issues with Current Plastics
- Shrinkage and Dimensional Stability
- Anisotropy
- Warpage

Water Absorption vs. Material

- **Nylon Glass Reinforced**
- **Polyolefin**
- **Quantech**

Water Absorption (%) vs. Shrinkage (%)
Bracket Moldflow studies - Glass Filled Nylon vs Quan Tech™

- Warpage
- Cycle Time
- Ability for thin walls
- Part Weight
- Clamp Tonnage
Warpage Comparisons
Glass Filled Nylon vs Quantech™

Lower wall thickness and warpage 1/10 of Nylon

Quantech™
Wall Thickness = 0.090”
Warpage = 0.044”

Nylon
Wall Thickness = 0.135”
Warpage = 0.489”

1/10 Warpage of Nylon @ 30% Thinner Wall Thickness
Warpage Comparison
Glass Filled Nylon vs Quantech™

White—Quantech™

Yellow—Glass-filled Nylon
Pressure & Clamp Tonnage
Glass Filled Nylon vs Quantech™

Pressure and Press Tonnage Comparison

18,728 psi
8,687 psi

>50% Less Pressure
>20% Less Press Tonnage
Summary of Bracket

- Warpage is 1/10 that of glass filled nylon.
- Molding pressure < 50% of molding pressure of Nylon.
- Thinner wall (0.090”) vs, Nylon 0.135”.
- Part weight is 15% (minimum) less than Nylon.
- Cycle time is ½ of glass filled nylon
  - Nylon 20 seconds
  - Quantech™ 10 seconds
- Clamp Tonnage
  - Nylon 800 tons
  - Quantech™ 525 tons
QLP/GM Molded
World’s Largest LCP Part

- Husky Molding Facility
  - Novi, Michigan

- 1350 Ton Molding Press

- 24X24 Inch x 3 test plaque
  - 4.1 lb part
  - Largest LCP part ever molded
Materials Roadmap

- Impact Resistance
  - High Elongation Materials
  - Greater Ductility
- Paint-ability
- Very Low CLTE
Materials Roadmap
High Ductility

Stress-Strain Characteristics

Current Elongations ~ 2.0%

Future Goal > 8.0%

Improved Ductility-
Quantech™
Paintability

- QLP paint-able LCP technology
  - Typical LCPs are not paint-able
- Cross-Hatch Test Results
  - Excellent Adhesion
SUMMARY

Unique material properties of Quantech™ enables direct metal replacement and weight reduction

- Tailored CTE—Matching Metals
- Excellent Strength and Stiffness
- Low Density
- Outstanding Moisture Resistance
- High Temperature Stability
- Excellent Chemical Resistance/Permeability
- Materials Roadmap for automobile Industry