New Developments for Mass Production of Epoxy Automotive Composites

Presented by Cedric Ball
Business Development Manager – Automotive
Hexion Inc.
GALM Detroit 2016
Hexion is a specialty chemicals company with a leading position in the development and production of systems, products and services for the global energy, transportation and construction markets.

At a glance …
Columbus, Ohio USA
US$5.2 billion
5000 Employees
60 Global Production & Technology Sites

Technology Platforms
Epoxy
Phenolics
Versatics™
Formaldehyde

Automotive Applications
Lightweight Composites
Exterior
Structural
Suspension
Under-the-hood
Braking
Coatings
# Global Leadership Positions Across Our Range of Industries and Technologies

<table>
<thead>
<tr>
<th>Leading Market Positions</th>
<th>Blue Chip Customers</th>
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<tbody>
<tr>
<td><strong>Epoxy Resins</strong></td>
<td><strong>BASF</strong></td>
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<tr>
<td>Global</td>
<td><strong>ASHLAND</strong></td>
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<td><strong>PORSCHE</strong></td>
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<tr>
<td><strong>Phenolic Specialty Resins</strong></td>
<td><strong>Schlumberger</strong></td>
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<tr>
<td>Global</td>
<td><strong>WEYERHAUSEN</strong></td>
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<td><strong>COVestro</strong></td>
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<td><strong>CORNING</strong></td>
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<td><strong>Valspar</strong></td>
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<td><strong>Versatic™ Acids &amp; Derivatives</strong></td>
<td><strong>LAMBORGHINI</strong></td>
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<tr>
<td>Global</td>
<td><strong>3M</strong></td>
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<td><strong>DUPONT</strong></td>
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<td><strong>MASISA</strong></td>
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<td><strong>Sinoma</strong></td>
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<td><strong>Mercedes-Benz</strong></td>
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<td><strong>Forest Product Resins</strong></td>
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<tr>
<td>Global</td>
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<tr>
<td><strong>Oilfield Proppant Resins</strong></td>
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<tr>
<td>Global</td>
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Products for Automotive Composite Applications

- **BAKELITE® Engineering Thermosets / Molding Compounds**
  - Water pump housings
  - Vacuum pump housings
  - Oil pump shaft, piston
  - Variety of powertrain components

- **EPIKOTE® Resins and EPIKURE® Curing Agents**
  - Exterior panels
  - Body structure
  - Suspension components
  - Driveshafts
  - LPG, CNG and H₂ tanks

3rd Generation Volkswagen-Audi Water Pump for 1.8/2.0 L EA 888 Engines

Audi R8/R10 CFRP “Sideblade”
Produced Using HP-RTM Process
Auto Industry Imperative: Lightweighting to Meet Emission & Fuel Economy Regulations

Source: BMW Group
Composite Materials Face Perception of Low Manufacturing Volumes and High Cost
Composite Technology Developments Have Enabled Mass Production of Automotive Parts
Composite Technology Innovations Offer Cost-Efficient Lightweighting

**Composites:**
Offer highest weight reduction opportunities in automotive applications

**Innovative Processing Technologies:**
Enable mass production of automotive parts
**Carbon Fibre Reinforced Plastics (CFRP)**

Have the highest weight reduction potential

<table>
<thead>
<tr>
<th>Material</th>
<th>% of steel</th>
</tr>
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<tbody>
<tr>
<td>Steel</td>
<td>100</td>
</tr>
<tr>
<td>HSS</td>
<td>80</td>
</tr>
<tr>
<td>Plastics</td>
<td>80</td>
</tr>
<tr>
<td>Aluminum</td>
<td>60</td>
</tr>
<tr>
<td>Carbon fiber</td>
<td>50</td>
</tr>
</tbody>
</table>

**Typical Cost Build-Up**

**50% Material**
- 40 - 45% carbon fiber
- 5 - 10% resin

**50% Processing**
- Quicker curing matrix
- Process optimization
- Near-end-contoured preforms
- Automation

BMW 7-Series “Carbon Core” Illustrates Body-in-White Mixed Material Use

BMW 7-Series SOP: 2015
Various CFRP Parts using Hexion resins e.g. roof arc and tunnel reinforcement

Benefits
• 40 kg weight reduction vs. steel in the Carbon Core body structure
• Fast curing cycle enabled by Hexion latest resin technology
• Multi material usage: engineered for performance

Source: BMW Group
Composite Technology Innovations Offer Cost-Efficient Lightweighting

**Composites:**
Offer highest weight reduction opportunities in automotive applications

**Innovative processing technologies:**
Enable mass production of automotive parts
Epoxy CFRP with Resin Transfer Molding (RTM) Technology for Structural Applications

Audi R8 Coupe and Lamborghini Huracan (MSS Platform) CFRP Transmission Tunnel
ACE Advanced Composite Engineering GmbH
EPIKOTE™ Resin TRAC 06150/
EPIKURE™ Curing Agent TRAC 06150

Benefits
• 30% lighter than aluminium
• Short cycle time production
RTM Technology Enables Fast Production of Highly Complex Structural Parts

Lay-up binder stabilized fabric

Heating and some pressure
- Fast handling
- Textile stability
- Controlled permeability

Mold closing and resin injection
- Thermal latency
- Low viscosity
- Rapid fiber wetting

Curing
- Fast conversion
- Isothermal
- Low exotherm

Opening and de-molding
- Easy de-molding
- Part quality
- Reproducibility
Epoxy Binders Address Preforming Challenges in Fast RTM

Benefits

- Faster handling / positioning of preform
- Controlled permeability and lay-up definition
- Textile stability at mold temperature during injection
Part Size and Equipment Determine the Material Processing Window

80% of Molded Parts

Part Shot Weight (g)  Resin Injection Rate (g/sec)

100 g/s  80 g/s  60 g/s

Injection Time (sec)

EP TRAC 06170  EK TRAC 06170  33 sec

EP TRAC 06150  EK TRAC 06165  45 sec

EP TRAC 06150  EK TRAC 06150  95 sec
High Pressure RTM / LCM Process
In-Production Examples

• **In-Production Examples**
  - BMW M Series
  - BMW i-Series
  - BMW 7 Series
  - Porsche 911 GT3 CUP
  - Porsche Boxter
  - Audi R8
  - Lamborghini Aventador
  - Volkswagen XL1

• [https://youtu.be/qZrOxQ1V6bQ](https://youtu.be/qZrOxQ1V6bQ)

*Resin cure time is no longer a limiting factor for support of series production.*
Epoxy CFRP with RTM & LCM Technology for Structural Applications

**BMW 7-Series CFRP Roof Arc**
EP TRAC 06000/
EK TRAC 06130

**Benefits**
- Designed to the shape of the car body
- Fast curing cycle with HP-RTM
- Outstanding weight / performance ratio

**BMW 7-Series CFRP Tunnel Reinforcement**
EP TRAC 06000/
EK TRAC 06130

**Benefits**
- Local reinforcement enhances torsional stiffness
- Fast curing cycle with LCM
**LCM: Preforming is Simplified and Direct**

**Liquid Resin Application Shortens Cycle Time**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lay-up dry fabrics</td>
<td></td>
</tr>
<tr>
<td>Liquid resin application</td>
<td>- Tailorable latency</td>
</tr>
</tbody>
</table>
| Transfer wet lay-up into mold | - Controlled viscosity build  
                                |   - Fast conversion  
                                |   - Low exotherm        |
| Curing                       |                                                                             |
| Opening and de-molding       | - Easy de-molding                                                           |
Liquid Compression Molding (LCM) is Increasing Attractive for Complex Parts

![Graph showing the comparison between RTM and LCM in terms of Cost, Preform Requirements, and Process Complexity. For low part complexity, RTM has lower cost and higher preform requirements compared to LCM. As part complexity increases, both methods show an increase in cost and process complexity, but LCM maintains a lower cost compared to RTM.]
Part-to-Part Cycle Time of <1 Minute
Demonstrated w/ Liquid Compression Molding
Epoxy CFRP with Prepreg Technology (PCM) for Semi-Structural Applications

Forward Light Holders
CMP GmbH - UBC GmbH
EP TRAC 06425/
EK TRAC 06465

Mini Front Wings
CMP GmbH - UBC GmbH
EP TRAC 06425/
EK TRAC 06465

Performance Benefits
- Lightweight versus steel
- Short cycle time (90 sec or 3–5 min)
- High mechanical performance
- High Tg

Processing Benefits
- Long shelf life at room temperature
- Easy and versatile molding
- In house prepreg as viable approach to further reduce cost
High Mechanical Performance is Achieved with Prepreg Technology

<table>
<thead>
<tr>
<th>Process</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impregnation</td>
<td>• Low viscosity&lt;br&gt; • No VOC&lt;br&gt; • No preforming</td>
</tr>
<tr>
<td>Fiber or Prepreg Placement</td>
<td>• Easy fiber positioning&lt;br&gt; • Stable band width&lt;br&gt; • Good fiber wetting</td>
</tr>
<tr>
<td>Cutting &amp; Molding</td>
<td>• Low scrap rate&lt;br&gt; • Hybrid reinforcement&lt;br&gt; • Functionalization</td>
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<tr>
<td>Pressing</td>
<td>• Short in-mold cycle times&lt;br&gt; • Controlled flow&lt;br&gt; • Net shape</td>
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<tr>
<td>Part de-molding</td>
<td>• Low shrinkage&lt;br&gt; • Mechanical performance&lt;br&gt; • Reproducibility</td>
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EPIKOTE™ Resin Systems Have Benefits in SMC

Epoxy Benefits versus Vinyl Ester and Unsaturated Polyester Resins

- VOC and styrene free
- Inherently low shrinkage
- Better mechanical strength properties
- Good adhesion to glass and carbon fibre
- Compatible with other epoxy material technologies
- Higher Tg
- Higher fatigue / durability performance
**Improved Cost Efficiency of SMC Technology: Net Shape Molding without Preforming**

<table>
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<tr>
<th>Process</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component Mixing</td>
<td>• Low Viscosity&lt;br&gt;• No VOC (styrene free)</td>
</tr>
<tr>
<td>SMC Compounding</td>
<td>• Good fibre wetting&lt;br&gt;• Potential use recycled fibre&lt;br&gt;• Fast maturation</td>
</tr>
<tr>
<td>SMC Cutting &amp; Molding</td>
<td>• Lower scrap rate&lt;br&gt;• Hybrid reinforcement&lt;br&gt;• Functionalization</td>
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<td>• Low shrinkage&lt;br&gt;• High strength/modulus&lt;br&gt;• Reproducibility</td>
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Optimum CFRP Performance and Cost ... depend upon all 3 factors:

Design
- Equipment Suppliers
- Reinforcement & Preforming
- Part Design and Modeling
- Process Design and Simulation
- Tool Construction

Materials
- Epoxy Resins:
  - Liquid Resins
  - Hot Melts
  - Perform Binders
  - Mold Release Agents
  - Prototyping Systems
- Phenolic ETS Compounds

Process
- HP-RTM
- Injection Molding
- LCM Compression Molding
- Prepreg
- Towpreg
- Performing
- SMC
- FiWi
Optimum CFRP Performance and Cost ... depend upon all 3 factors:

- **Design**
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- **Process**
  - Injection Molding
  - LCM Compression Molding
  - HP-RTM
  - SMC
  - Towpreg
  - FiWi

- **Prepreg**
Epoxy Glass and Carbon Fibre Reinforced Composites:
Highest weight saving potentials

New generation resin systems:
Faster cure cycles, easier demolding and more process versatility

Comprehensive component design and development:
Will continue to decrease the cost of weight saving
Automotive Application Centers
Come visit us!

Composite Application Technologies

- Preforming
- RTM (HP-/LP-RTM)
- Prepreg
- CM / SMC / LCM
- Prototyping
- Tooling

- HP-3K Dosing
- Cannon ESTRIM System

- RTM Tooling
- 2500 ton press

Duisburg, Germany

London, ON

South Hampton, UK
Additional Questions?
Contact:

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Thank You!

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