Advancements in Composite Resin Systems for Electric Vehicle Applications

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Dan Dowdall – Business Development Manager
Advancements in Composite Resin Systems for Electric Vehicle Applications

1 – Overview: INEOS Composites

2 – Composites for Electric Vehicles
   - Applications & Value Propositions

3 – Advanced Composite Resin Technologies
   - Lower Mass, Improved Sustainability, Greater Performance

4 – Summary & Future Work
Introduction: INEOS Composites
INEOS GROUP at a glance

SAFETY FIRST
(SHE is our highest priority)

SALES
$60bn

SITES
168

22,000
PEOPLE

TOP 50 COMPANY
FORBES

54 MILLION TONNES
OF CHEMICALS CAPACITY

SUPPLYING MILLIONS OF
UK HOMES WITH GAS

UK'S LARGEST
PRIVATE COMPANY
INEOS Solutions for the Transportation Industry

INEOS Automotive: Launched the Grenadier 4x4 SUV in 4Q22

INEOS Styrolution: PS, ABS, SAN, ASA, SMMA, Styrene

INEOS Olefins & Polymers: PP, HDPE, Olefins

INEOS Composites: Thermoset Resins, Gelcoats, & Additives
INEOS COMPOSITES (formerly Ashland Performance Materials)

- Unsaturated Polyesters
- Epoxy Vinyl Esters
- Gelcoats
- Additives
- SMC, BMC, LCM
- RTM/Infusion
- Sprayup/Layup
- Pultrusion
- Prepregs
- Castings
- Transportation
- Marine
- Corrosion
- Building/Construction
- Wind Energy
- Infrastructure

Global Leader in Thermoset Resins ... for Multiple Composite Processes ... serving Key Markets.

SALES
$1bn

SITES
20+
HQ in Dublin (OH), USA

1,000+
PEOPLE

(SHE is our highest priority)
Composites for Electric Vehicles: Applications & Value Propositions
EV Composite Applications: A Look Back!

1996 GM EV-1

SMC: hood, roof, doors, decklid, quarter panels
GF-PP: battery carrier
RRIM: fenders, fascias

WHY?
✓ Mass Reduction
✓ Low Tooling Investment
✓ Aerodynamics
✓ Dent & Corrosion Resistance
**EV Composite Applications: Body Panels & Structure**

**Value Proposition**
- Mass Reduction
- Ability to Package Electrical Components
- Class-A Appearance
- Low Tooling Investment

*Sources: Teijin Automotive Technologies, IDI Composites International, Plastics Omnium, TPI Composites*
EV Composite Applications: Stowage Systems

Value Proposition
- Mass Reduction
- Impact & Corrosion Resistance
- Low Tooling Investment
- Ability to Form Large Complex Shapes
- Mold-in-Color

Sources: Teijin Automotive Technologies, A&PS
EV Composite Applications: **SMC Battery Enclosures**

- **Chevy Volt**
- **Ford Mustang Mach-E**
- **Chevy Bolt**
- **Fiat 500e**
- **SAIC EV E50**
- **Ford F150 Lightning**

**Value Proposition**
- Mass Reduction
- Electrical Insulation
- Flame, Heat, Impact, & Corrosion Resistance
- Low Tooling Investment
- Ability to Form Large Complex Shapes

_Sources: Teijin Automotive Technologies, Core Molding Technologies, Hanwha, IDI Composites International, Magna Exteriors_
Advanced Composite Resin Technologies

- Lower Mass
- Improved Sustainability
- Greater Performance
INEOS Composites’ SMC Resins & Additives

- **AROTRAN**
- **AROPOL**
- **ENVIREZ**
- **DERAKANE**

**Arotran™ Technology**

- **VOC**
- **Sustainable**
- **Low Odor/VOC**
- **Structural**
- **Weatherable**

**Resins & Additives**

- **805/2805**
- **2502**
- **600**
- **Envirez**
- **300**
- **700**
- **900**

**Applications**

- Mold-in-color truck beds
- Watercraft hulls / wells
- Painted truck beds
- Inner panels/reinforcements
- Underbody shields
- EV battery enclosures
- Vehicle interiors
- Bio- and recylcate-based resins
- General purpose applications
- Structural assemblies
- Reinforcements
- Underbody shields
- Class A surfaces
- Body & closure panels
- Reinforcements/prepregs
Electric Vehicles: Material & Product Requirements

**Customer Needs**

- Ultra-low mass body panels
- Environmentally-friendly *(and affordable)* raw materials
- High-strength high-stiffness frame & chassis components
- Weather-resistant high-strength beds, stowage systems & frunks
- Impact/heat/fire-resistant battery enclosures

**INEOS Resin Systems**

- **Arotran 700 series for Low-density Class-A SMCs**
- **Envirez Resins with Bio- and Recyclate content**
- **Arotran 800 series for Mold-in-color (no paint) SMC**
- **Arotran 300 series for Carbon Fiber SMCs**
- **Arotran 800 series for Mold-in-color (no paint) SMC**
- **Derakane & Arotran 2500 series for Structural SMCs**
Arotran 700 Series for Low-Density Class-A SMCs

Body panels 50% lighter than sheet metal

AT771 Tough Class A Body Panels

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>wt %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resins and Additives</td>
<td>40</td>
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<tr>
<td>Glass Microspheres</td>
<td>14</td>
</tr>
<tr>
<td>Calcium Carbonate</td>
<td>4</td>
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<tr>
<td>Fiberglass Reinforcement</td>
<td>42</td>
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Mechanical Properties of Cured SMC Plaques

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>1.20</td>
<td>g/cm³</td>
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<tr>
<td>Tensile Strength</td>
<td>84</td>
<td>MPa</td>
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<tr>
<td>Tensile Modulus</td>
<td>7.9</td>
<td>GPa</td>
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<tr>
<td>Flexural Strength</td>
<td>270</td>
<td>MPa</td>
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<tr>
<td>Flexural Modulus</td>
<td>12.5</td>
<td>GPa</td>
</tr>
<tr>
<td>Shrink (negative = expansion)</td>
<td>-0.13</td>
<td>%</td>
</tr>
</tbody>
</table>
Bio-based Envirez Composite Resins

- **INEOS Envirez 1807** introduced in 1999 – the first unsaturated polyester resin to use a significant amount of **soybean oil and corn-based ethanol** in its production.

- **25% wt** of Envirez 1807 is from grain-derived organics.

- Each 17 MT batch of resin saves 10 barrels of crude petroleum and **removes 15 MT CO₂** from the environment.

- Current commercial applications include include **large SMC panels and covers** for John Deere and CNH agriculture equipment.

Sources: Teijin Automotive Technologies, Ashley Industrial Molding
Recycled-PET-based Composite Resins & Additives

- rPET-based INEOS Composites products include:
  - Aropol Q6266 unsaturated polyester resin
  - Neulon 2432 low profile additive
- Aropol Q6222 contains approximately 22% wt of post-industrial recycled PET.
- Current (and future) commercial applications include LCM stowage assemblies, HLU saunas, pultruded ladder rails, and SMC body panels.
Arotran 300 Series for Carbon-Fiber SMCs

Affordable CFRPs

<table>
<thead>
<tr>
<th>AT300 Carbon Fiber Structural SMC</th>
<th>Ingredient</th>
<th>wt %</th>
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<tbody>
<tr>
<td></td>
<td>Resins and Additives</td>
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<td>Carbon Fiber Reinforcement</td>
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<tr>
<th>Mechanical Properties of Cured SMC Plaques</th>
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<th>Value</th>
<th>Units</th>
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<tr>
<td>Specific Gravity</td>
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<td>Tensile Strength</td>
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<td>MPa</td>
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<tr>
<td>Tensile Modulus</td>
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<td>GPa</td>
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<tr>
<td>Flexural Strength</td>
<td>480</td>
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<tr>
<td>Flexural Modulus</td>
<td>30</td>
<td>GPa</td>
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**Arotran 800 Series UV Resistant SMC Resin**

Weatherable Mold-in-Color Frunks, Stowage Boxes, Truck Beds,…

### SMC Formula

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>wt %</th>
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<tbody>
<tr>
<td>Resins and Additives</td>
<td>37</td>
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<tr>
<td>Alumina Trihydrate</td>
<td>10</td>
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<tr>
<td>Glass Microspheres</td>
<td>0</td>
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<tr>
<td>Fiberglass Reinforcement</td>
<td>53</td>
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### Mechanical Properties of Cured SMC Plaques

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Units</th>
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</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>1.78</td>
<td>1.55 g/cm³</td>
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<td>Tensile Strength</td>
<td>152</td>
<td>140 MPa</td>
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<tr>
<td>Tensile Modulus</td>
<td>12.7</td>
<td>11.5 GPa</td>
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<tr>
<td>Flexural Strength</td>
<td>270</td>
<td>266 MPa</td>
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<tr>
<td>Flexural Modulus</td>
<td>12.5</td>
<td>11 GPa</td>
</tr>
<tr>
<td>Shrink (negative = expansion)</td>
<td>0.013</td>
<td>- 0.02 %</td>
</tr>
<tr>
<td>Delta E (2000 hrs accelerated)</td>
<td>&lt; 2.0</td>
<td>&lt; 1.5</td>
</tr>
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</table>
Arotran 2500 Series for EV Battery Enclosures

High-strength Fire-resistant Impact-resistant Battery Enclosures

SMC Formula

<table>
<thead>
<tr>
<th>Ingredient</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Resins and Additives</td>
<td>18</td>
</tr>
<tr>
<td>Alumina Trihydrate</td>
<td>32</td>
</tr>
<tr>
<td>Fiberglass Reinforcement</td>
<td>50</td>
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</table>

Mechanical Properties of Cured SMC Plaques

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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<tbody>
<tr>
<td>Specific Gravity</td>
<td>1.98</td>
<td>g/cm³</td>
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<tr>
<td>Tensile Strength</td>
<td>115</td>
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<td>Tensile Modulus</td>
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<td>GPa</td>
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<tr>
<td>Flexural Strength</td>
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<tr>
<td>Flexural Modulus</td>
<td>11.8</td>
<td>GPa</td>
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<tr>
<td>Shrink (negative = expansion)</td>
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<td>%</td>
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<tr>
<td>UL 2596 FR Rating</td>
<td>Pass</td>
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Box Thermal Runaway Test for EV Battery Enclosures

UL 2596 Testing of Arotran 2502 based SMC:
Samples passed at 2.5mm thickness and 250 kPa pressures.
Summary & Future Work
Advancements in Composite Resin Systems for Electric Vehicle Applications: Summary & Future Work

- Composites’ properties (low density, high strengths, electrical/thermal insulation, inexpensive tooling) make them good candidate materials for EV applications, including exterior body panels, battery enclosures, stowage systems, and structural reinforcements.

- New resin systems from INEOS Composites can affordably enable products with even lower mass, higher performance, and improved sustainability.

- Continuing work is focused on improving processing methods, lowering costs, and optimizing physical properties.

- Questions & Discussion.
Advancements in Composite Resin Systems for Electric Vehicle Applications

For additional info, please visit: https://www.ineos.com/businesses/ineos-enterprises/businesses/ineos-composites/

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dan.dowdall@ineos.com