Advancements in Composite Resin Systems for Electric Vehicle Applications

May 2023

Tom Skelskey – Technical Group Leader
Dan Dowdall – Business Development Manager

INEOS Composites

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

INEOS Composites


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 Composites

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)*

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

- *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*

INEOS Composites

Composites for Electric Vehicles:
Applications & Value Propositions

INEOS Composites

EV Composite Applications: A Look Back!

1996 GM EV-1

SMC: hood, roof, doors, decklid, quarter panels

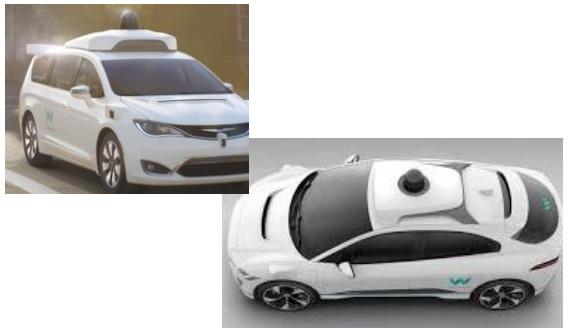
GF-PP: battery carrier

RRIM: fenders, fascias

WHY?

- ✓ Mass Reduction
- ✓ Low Tooling Investment
- ✓ Aerodynamics
- ✓ Dent & Corrosion Resistance

EV Composite Applications: Body Panels & Structure



WAYMO Gen-1 Roof Modules

Proterra Bus Body Structure Assembly

Lucid Air Decklid & Roof

Ford F150 Lightning Tailgate Work Surface

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

Ford F150 Lightning
Hood-Waterfall & Frunk

Tesla Model-3 SMC Frunk

Rivian R1T Bed Assembly & Stowage Trunk

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

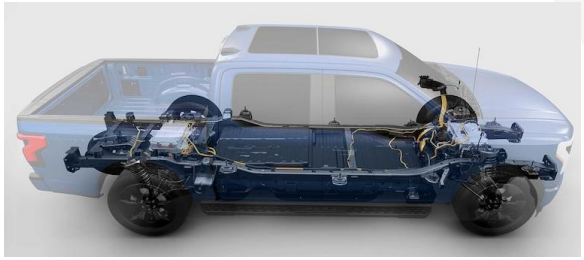
Chevy Volt

Ford Mustang Mach-E

Chevy Bolt

Fiat 500e

SAIC EV E50



Ford F150 Lightning

Value Proposition

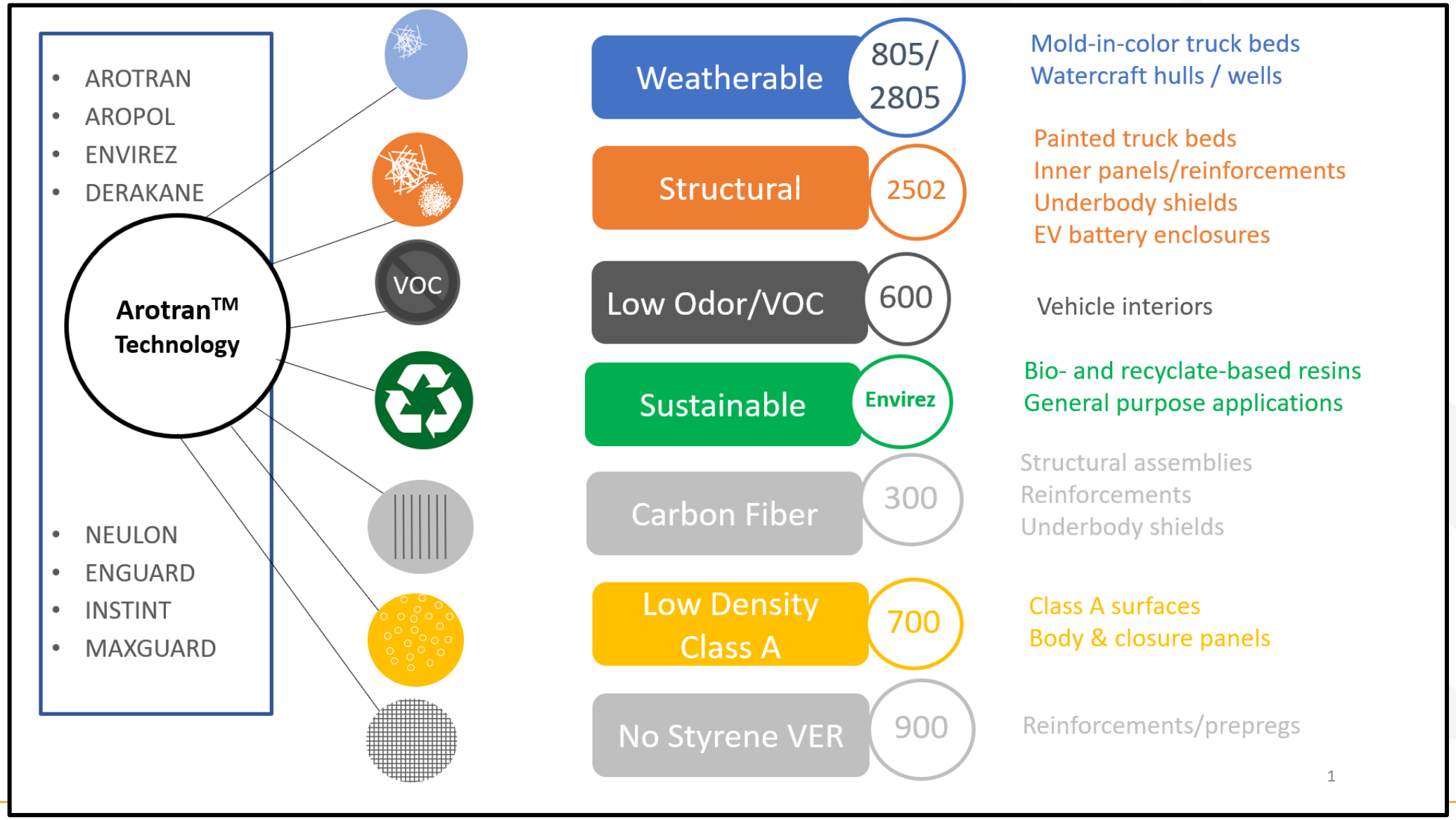
- ✓ Mass Reduction
- ✓ Electrical Insulation
- ✓ Flame, Heat, Impact, & Corrosion Resistance
- ✓ Low Tooling Investment
- ✓ Ability to Form Large Complex Shapes

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



INEOS Composites

Electric Vehicles: Material & Product Requirements

Customer Needs	***INEOS Resin Systems***
• Ultra-low mass body panels	***Arotran 700 series for Low-density Class-A SMCs***
• Environmentally-friendly *(and affordable)* raw materials	***Envirez Resins with Bio- and Recyclate content*** ***Arotran 800 series for Mold-in-color (no paint) SMC***
• High-strength high-stiffness frame & chassis components	***Arotran 300 series for Carbon Fiber SMCs***
• Weather-resistant high-strength beds, stowage systems & frunks	***Arotran 800 series for Mold-in-color (no paint) SMC***
• Impact/heat/fire-resistant battery enclosures	***Derakane & Arotran 2500 series for Structural SMCs***

Arotran 700 Series for Low-Density Class-A SMCs

LOWER MASS

Body panels 50% lighter than sheet metal

AT771 Tough Class A Body Panels	
Ingredient	wt %
Resins and Additives	40
Glass Microspheres	14
Calcium Carbonate	4
Fiberglass Reinforcement	42

Mechanical Properties of Cured SMC Plaques		
Property	Value	Units
Specific Gravity	1.20	g/cm^3
Tensile Strength	84	MPa
Tensile Modulus	7.9	GPa
Flexural Strength	270	MPa
Flexural Modulus	12.5	GPa
Shrink (negative = expansion)	- 0.13	%

INEOS Composites

Bio-based Envirez Composite Resins

SUSTAINABILITY

Sources: Teijin Automotive Technologies, Ashley Industrial Molding

- **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 CO_2** from the environment.
- Current commercial applications include include large **SMC panels and covers** for John Deere and CNH agriculture equipment.

INEOS Composites

Recycled-PET-based Composite Resins & Additives

SUSTAINABILITY

- 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.**

INEOS Composites

Arotran 300 Series for Carbon-Fiber SMCs

Affordable CFRPs

HIGHER STIFFNESS

AT300 Carbon Fiber Structural SMC	
Ingredient	wt %
Resins and Additives	45
Carbon Fiber Reinforcement	55

Mechanical Properties of Cured SMC Plaques		
Property	Value	Units
Specific Gravity	1.40	g/cm^3
Tensile Strength	200	MPa
Tensile Modulus	35	GPa
Flexural Strength	480	MPa
Flexural Modulus	30	GPa

INEOS Composites

Arotran 800 Series UV Resistant SMC Resin

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

IMPROVED DURABILITY

SMC Formula		
Ingredient	wt %	
Resins and Additives	37	35
Alumina Trihydrate	10	0
Glass Microspheres	0	4
Fiberglass Reinforcement	53	61

Mechanical Properties of Cured SMC Plaques			
Property	Value		Units
Specific Gravity	1.78	1.55	g/cm^3
Tensile Strength	152	140	MPa
Tensile Modulus	12.7	11.5	GPa
Flexural Strength	270	266	MPa
Flexural Modulus	12.5	11	GPa
Shrink (negative = expansion)	0.013	- 0.02	%
Delta E (2000 hrs accelerated)	< 2.0	< 1.5	

INEOS Composites

Arotran 2500 Series for EV Battery Enclosures

High-strength Fire-resistant Impact-resistant Battery Enclosures

IMPROVED FR

SMC Formula	
Ingredient	wt %
Resins and Additives	18
Alumina Trihydrate	32
Fiberglass Reinforcement	50

Mechanical Properties of Cured SMC Plaques		
Property	Value	Units
Specific Gravity	1.98	g/cm^3
Tensile Strength	115	MPa
Tensile Modulus	12.5	GPa
Flexural Strength	225	MPa
Flexural Modulus	11.8	GPa
Shrink (negative = expansion)	0.006	%
UL 2596 FR Rating	Pass	

INEOS Composites

Box Thermal Runaway Test for EV Battery Enclosures

IMPROVED FR

<u>UL 2596 Testing of Arotran 2502 based SMC:</u>
Samples passed at 2.5mm thickness and 250 kPa pressures.

INEOS Composites

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.

Thank You!

INEOS Composites

Advancements in Composite Resin Systems for Electric Vehicle Applications

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

Or send us a note:
thomas.skelskey@ineos.com
dan.dowdall@ineos.com

INEOS Composites