Innovations in Automotive Plastics “Materials and Processes/Enabling Technologies”

Based on SPE Awards

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Transportation Industry Megatrends

- Efficient Energy Use
- Environmental Protection
- Competition
- Legislation
- Customers
- Risks / Prices
Fuel efficiency, emissions, light-weighting and regulatory drivers are automotive industry opportunities where innovations in plastics are key enablers.
What we hear from the industry:

- Weight Reduction
- Perceived Quality & Appearance
- Turbo/Super-charging
- Emissions/Mileage Regulations
- Electrification
- Infotainment
- Functional Integration
- Safety Systems Improvement
- Localization
- Lighting Solutions
Transportation Megatrends

Safer, Cleaner Transportation
- CO₂ emission / fuel consumption
- Sensors / driver assisted operation
- Occupant protection
- Stricter regulations

Human Factors
- Connectivity/Infotainment
- Quality, Appearance, Comfort, Style
- Car sharing

Electrical Power Management
- EVs & HEVs: Battery technology
- Autonomous vehicles
- Lighting solutions

Innovations in Plastics have to continue to meet megatrends

Plastics Enabling Technologies

Light - Weighting
- Metal replacement
- Parts consolidation
- Paint elimination

Cost Reduction
- Metal replacement
- Parts consolidation
- Paint elimination

Appearance
- Perceived quality / comfort

E&E / Sensors
- Heat management
- Higher temperature environments

Safer, Cleaner Transportation

Human Factors

Electrical Power Management

Innovations in Plastics have to continue to meet megatrends
Plastics Enabling Technologies

% of 2016 Innovation Award Finalists

- Light-weighting: 64%
- Cost Reduction: 58%
- Appearance: 33%
- E&E / Sensors: 15%

Many finalists fall within multiple enabling technologies
“Mark my words: a combination airplane and motorcar is coming. You may smile, but it will come.”
– Henry Ford, 1940
The goals of this project were to develop a high-biomass-content thermoplastic polyester blend for window panels and steering-wheel bezels using biomass-based PETG -- reportedly the first application in the world.

The optimized PETG/ABS composition was used to replace a PC/ABS blend. Benefits include a 57% reduction in carbon emissions (145 tons/year), an 88% reduction in VOCs, and a significant increase in molded part chemical resistance. By weight, the biomass content is 25% and by C14, the biomass content is 14%.
Selection of Biomaterials

- Drawback of Bio Plastics (for Automotive)
  - High Cost
  - Poor Thermal Stability
  - Weak Durability
  - Poor Mechanical Properties

▶ Need Renewable Bio Materials to Overcome Current Issues

⇒ Bio PETG

※ PETG: Poly cyclohexanedicarboxylate terephthalate glycol modified

BIO PETG Process

Sugar manufacture

Corn or sugarcane

Waste

Grinding

Hydrolysis

Fermentation

Distillation

Purified and dried

Strong acid treatment

And polymerization

Bio-ester

⇒ SPE ANTEC® Anaheim 2017 / 365
Why PETG?

What is PETG?

- Amorphous Polymer (Transparent)
- Composition: TPA, CHDM, EG + Transformed bio-mass based raw material (from corn)
- Biomass: up to 30% (weight %) and 15% C\textsuperscript{14} content

※ PETG: Poly cyclohexanediimethylene terephthalate glycol modified

PETG

- Chemical Resistance
- Impact Strength
- Thermal Stability

- HDT (1.82MPa)
- Notched Impact (1/4")

Requirements for Interior Parts

1. Impact strength
2. Heat Stability
3. Chemical resistance

Most Suitable solution for Interior Parts
**Molecular difference**

- **<Polycarbonate>**
  - Twist structure (stable state of PC)
  - Easy to penetrate

- **<PETG>**
  - Linear structure (stable state of PETG)
  - Hard to penetrate

**Molding Difference (in Process)**

- **<Polycarbonate>**
  - Surface: Linear (unstable state)
  - Inside: Twist structure (stable)
  - Residual Stress

- **<PETG>**
  - Surface: Linear (stable state)
  - Inside: Linear structure (stable)

Imbalance between Surface and Inside

Balance between Surface and Inside
This innovative, multi-stakeholder, cost-neutral recycling project protects the environment, grows local economies, creates jobs, and helps people in a sustainable manner.

Water bottles collected at GM operations and from the Flint, Michigan area are directed into a supply chain that recycles the material into nonwoven fleece for specific applications including engine manifold cover insulation, insulation for coats that convert to sleeping bags for the homeless and are made by formerly homeless women as part of a jobs program, and air filters that purify the air at numerous GM and other manufacturing operations. Already 3.5-million water bottles have been repurposed.
Do Your Part: GM Gives Recycled Water Bottles a New Life

- **7 Bottles**: Insulation covering the Chevrolet Equinox V6 engine
- **31 Bottles**: Insulation in empowerment plan coats for the homeless
- **6 Bottles**: Air filtration component for GM plants
Recycling Water Bottles is Good Business

GM supply web gives material a second life

Supply web

GM Orion Assembly

GM RenCen

GM Warren Technical Center

GM Flint Tool & Die

GM Flint Engine

HARRAMACK RECYCLING
PREPARES BAILS

UNIFORM MANUFACTURING INC.
RECYCLES INTO RESIN

WASHES & FLAKES

WIN-I. BURNETT & CO.
TURNS FIBER INTO FLEECE

CARHARTT
CUTS TO SIZE

THE EMPOWERMENT PLAN
SEW INSULATION INTO COATS

FILTERATION SERVICES GROUP
WORKS WITH NEW LIFE CENTER TO MAKE PANELS

GM plants
INSTALL THE AIR FILTERS

EXO-S
ATTACHES FLEECE TO ENGINE COVER

GM CAMI Assembly
INSTALLS PART ON CHEVROLET EQUINOX

The Empowerment Plan
DONATES COATS TO THE HOMELESS
Because aluminum body panels expand at twice the rate that steel ones do, a new baffle sealing package was needed that would maintain adhesion to the substrate during thermal expansion of the aluminum.

It also needed to reduce or eliminate NVH throughout the vehicle to improve driver comfort through a quieter interior.

A new EVA expandable sealer with a blowing agent that activates during e-coat and produces an innovative elastic cross-linking network was developed to improve hot-tear strength and elongation vs. previous materials.

The EVA foam is injection overmolded onto a PA substrate.
• Project goals were to achieve a unique MIC color space that looks luxurious but appeals to today's generation.
• It involved using the first transparent pigment-based interior color deliverable across 76 base resins for the vehicle interior.
• Once the color was mastered, early attempts showed it was prone to metamerism with a red/green directional hue shift.
• Numerous attempts to achieve color consistency bidirectionally with standard pigment adjustments did not solve the problem.
• Finally, the color was remastered using a non-TIO2 system that did not exhibit hue shift, eliminating the need to paint and creating a calming, cool color environment.
Rhapsody Blue Environment
A new, lighter weight TPO bumper cover was developed using high-crystallinity PP, ethylene-octane rubber, and a combination of nano-size talc and micron-size whisker fillers similar to magnesium oxysulfate.

The material provides high mechanical performance, improved dimensional stability, and low CLTE thanks to the high aspect ratio filler. Weight is reduced 7-10% (7.5kg vs 6.9kg) and the material is cost neutral vs. the material it replaced. Additionally, 6 patents have been obtained on the development.
Development of New Material

- Technological Approach: Polypropylene with Rubber and Filler

<table>
<thead>
<tr>
<th>Polypropylene</th>
<th>Rubber</th>
<th>Filler (Whisker / Nano sized talc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Polypropylene Image]</td>
<td>![Rubber Image]</td>
<td>![Filler Image]</td>
</tr>
</tbody>
</table>

- High crystallinity PP
- Isotatic index above 96%

- Ethylene – octane rubber

- Whisker
  - Av. length: 15 μm
  - Av. dia.: 0.5 μm
  - Aspect ratio: 30
  - Density: 2.3

- Nano sized talc
  - D_{50}: 0.5 μm
  - Density: 2.7
A high-performance thermoplastic was needed for vacuum brake tubing to replace reinforced rubber. It needed broad temperature performance (-40-150C), chemical resistance, burst strength to 60 bar min. and flexural strength to 50 N min.

- It also had to resist vacuum collapse after 2 hr @ 150C and provide impact retention after 336 hr @ 150C.
- The design was changed to use a smaller diameter, thinner wall to simplify engine/undercarriage routing and eliminate heat shields plus allow quick connects.
- A TPC-ET elastomer with high thermal oxidative stability was developed. It is 30% lighter, less costly, and eliminates brackets.
Challenge:

• General Motors wanted a high performance thermoplastic for heavy duty (Type B) vacuum brake tubing.
• GMW 14640, Type B Materials, requirements:

  ✓ Operating Temperature, -40 to 140 °C, Peak Temperature 150 °C
  ✓ Vacuum Collapse Resistance, after 2 hr. @ 150 °C
  ✓ Burst Pressure, min. 60 bar
  ✓ Flexural Strength, min. 50 N
  ✓ Chemical Resistance, Under hood environment

Application & Function

The brake assist booster uses vacuum from the engine to multiply the force that your foot applies to the master cylinder.

Figure 5-1. Vacuum-booster master cylinder assembly (Bendix).
Arnitel® CM622 Exhibits Higher Long Term Thermal Performance
### Design Evolution

#### MY 2013 Chevy Silverado
Reinforced Rubber

- Larger Diameter (20 mm)
  - Requires more space, routing restrictions
- Rubber/Reinforcement Matrix
- Hose clamps (non-ergonomic)
- Hose & clamps (170g)
- Cost (Baseline)

#### MY 2015 Chevy Silverado
Arnitel CM622

- Smaller Diameter (12.5 mm, >35% smaller)
  - Simpler engine/undercarriage routing
- TPC (homogenous monolayer)
- Quick connects (ergonomic)
- Hose & quick connects (80g, >50% reduction)
- Lower cost

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Bulky Design

- Larger Diameter (20 mm)
  - Requires more space, routing restrictions
- Rubber/Reinforcement Matrix
- Hose clamps (non-ergonomic)
- Hose & clamps (170g)
- Cost (Baseline)

Elegant Design

- Smaller Diameter (12.5 mm, >35% smaller)
  - Simpler engine/undercarriage routing
- TPC (homogenous monolayer)
- Quick connects (ergonomic)
- Hose & quick connects (80g, >50% reduction)
- Lower cost
• The zipper clip is a plastic solution that gives the holding benefits of a stud-and-nut combination while reducing production limitations.
• Ideal for use where a nut is desired but not feasible, this is the first stud insert with 4 ratcheting control features and a self-centering 2-way locator that holds over 120 lb/54.43 kg of weight while it requires low ergonomic effort (5.11 lb/2.32 kg) for assembly.
• The design reduces spring back as well as weight and cost and eliminates the need for assembly equipment as well as an isolator, since it protects the stud from corrosion.

**Zipper Clip**

**OEM/Vehicle**
General Motors Co.
2017 Chevrolet Malibu

**System Supplier**
3 Dimensional Services Group

**Material Processor**
3 Dimensional Services Group

**Material Supplier**
Celanese Corp.

**Resin**
Celcon M90 Acetal

**Tooling/Equipment Supplier**
3 Dimensional Services Group
Features

The Zipper Clip - a plastic (Acetal) solution that gives the attachment benefits of stud and nut while greatly simplifying assembly.

The Zipper Clip:

• Used where a nut is desired but access is not possible
• Is a rust Isolator (stops galvanic corrosion)
• Independently engaging zipper fingers
• Self centers to hole and allows 2-way location
• Removes all assembly equipment
The Zipper Clip can do it all

Standard Stud

Substrate

Zipper Clip

Metal

License Plates

Supply lines and wiring

Panels

Ext. Trim

Interiors

Additional uses: lighting, appliques, planes, trains, home appliances
Zipper Clip: The Benefits

Assembly Time & Tools: Time is $$$

- No tools needed!
- $1.00 (resist per stud) Savings!
- $0.36 (Assembly time savings)
- $1 Million+ savings annually

It’s an Isolator

- Isolates interfacing metals COMPLETELY
  - No RUST/Galvanic Corrosion!

Easy Serviceability

- Easily removed by compressing retention wings

...continued on next slide
The Benefits Continued

**Reduced Warranty**
- No loose nut...as there are No nuts!
- No more rust (especially chrome)

**Easy Loading**
- Underside access never required

**Mass**
- Reduced!
- 4.5 Grams saved per nut deleted

**Patent Pending** P035218-US-NP
**GM ATW** (Advanced Technology Work) Award Winner
• Hot-gas welding joins both halves of this 35% GR-PPA thermostat housing assembly.
• The part has a small welding-flange footprint but high weld strength because there is no fiber/material degradation during the joining process.
• In fact, it is the only welding process that permits bridging of glass across the joint. The weld distance is held within 0.1 mm, enabling parts to package into very limited spaces with tight tolerances.
• Since the part is not touched during welding, there is no sticking. Versus previous aluminum solutions, the PPA assembly is 30% lighter and 40% less costly.

OEM/Vehicle
Ford Motor Co.
2017 3.5L V6 Cyclone TiVCT
GTDi engines
System Supplier
Plastic Tec - Bocar Group
Material Processor
Plastic Tec - Bocar Group
Material Supplier
DuPont Automotive
Resin
Zytel HTN51G35HSLR BK420 PA
Tooling/Equipment Supplier
Schweiger GmbH & Co. KG
Thermostat housing design

1. Connector
2. Upper Housing
3. Lower Housing
4. Welding area

Aluminum and Plastics Thermostat Housing
Challenge and innovation

Requirements:

- Operation at -40 to 120 °C
- Chemical resistance
- 3.3 bars peak system pressure
- Safety factor x3
- No dust in coolant circuit
- Assembly to cylinder head and front cover across the weldline

-> high precision/quality weld line

Innovative solution:

Hot gas welding of PPA material
Hot gas welding process

- Contactless heating with 500 °C Nitrogen
  - very low oxidation
  - no milling of glass fibers
  - no dust generation

- Single axial joining
  - high precision of joint in all 3 axis
  - height tolerance < 0.1 mm
Hot gas welding process

- High weldline strength
  - Burst pressure average: 20 bars
  - No leakage after > 240,000 cycles of pressure cycle testing (100 °C, 3.3 bars)
A redesigned capacitive touch lens produced via 2-shot molding eliminates molding defects while maintaining an ideal bonding surface and clear aperture for best light intensity.

Eliminating a second tool, the Fresnel pattern is molded into the core of the first shot, which becomes the cavity of the second shot as the latter is layered over the former, keeping both outer surfaces smooth.

Using 2 grades of PC with a 40°C difference in HDT solves the problem of the second shot melting the first during overmolding. Eliminating a tool reduced costs 25%.

**OEM/Vehicle**
Ford Motor Co.
2017 Lincoln Continental

**System Supplier**
Flex Auto (Flextronics)

**Material Processor**
Flex Auto (Flextronics)

**Material Supplier**
SABIC

**Resins**
Lexan 143R, HFD1830 Polycarbonate

**Tooling/Equipment Supplier**
Flex Auto (Flextronics)
Original 2-shot design called for injecting the second shot (clear polycarbonate resin) directly into the white polycarbonate first shot.

With such similar material properties between the two shots, several poor molding conditions were observed.
Develop all-new lens which meets styling and appearance requirements and eliminates molding defects from previous design, while still maintaining ideal bonding surface for capacitive trace sensor and optically clear aperture for best light intensity.

- Ability to contain decorative pattern within a dual layered design
- Eliminates need for textured B side surface in tooling
- Effectively hides “guts” of lens if optics are not styled. Only opening is light aperture
- Layered 2-shot design preserves optic grade first layer with effective geometry
• Requires “layering” shots on top of each other

• Fresnel pattern contained on one side of 1st shot, interfacing side of 2nd shot.

• Normally Fresnel is contained on B side surface. (See CD391 design)

• HDT Material Selection Critical - 1st layer melt temp (polycarbonate SABIC Lexan 143R-111) must be greater than 2nd shot (SABIC Lexan HFD1830-WH96415) to avoid melting the clear for appearance
Shot order sequence - Shoot clear first with pattern on core. White fills in peaks and valleys of clear. Normally white is first shot and pattern is filled in by clear. Clear shot must happen first due to optical requirements - See HDT explanation

Inserting Fresnel in between 2 layers - Fresnel pattern normally on back of lens. Flat surface for capacitive sensor needed so multiple layers are necessary. Also hides sensor traces. HDT material selection - 1st shot melts hotter than 2nd. Appearance parts require flawless physical quality.
• This tool-less, single-lever, self-locking underhood bussed electrical center (UBEC) guarantees proper connections for 4 connectors from 4 different wire harnesses using 1 hand and low assembly effort.

• There is no need to re-orient the UBEC to install mating connectors during OEM assembly.

• The result is a robust, high-circuit-capacity design that is ergonomically friendly to assembly-line workers.

• Additional benefits are a 7% weight savings, 8% additional spare electrical content, 10% reduction in overall footprint, better water-ingress protection, and 30% less assembly time.
A hydraulic punch and sonic welding operation was replaced by robotic laser cutting and welding of a Class A exterior fascia.

Unlike other welding processes, it is not necessary to thicken wallstock in weld areas to prevent read-through with robotic laser welding of brackets on the backside of the part, and that reduces weight slightly.

It also eliminates the need for contoured horns and punches. Clean cuts can be made in 1 sec on the painted side of the part. The dual-function process provides greater flexibility between programs and reduces floor space and tooling costs.
Benefits of Laser Cutting and Welding

Laser Cutting
• Increased flexibility through the cell
  • No contoured horns or punches
  • Not limited on punch/die sizes – Ability to change holes sizes on the fly with simple programming change
  • Fast cutting – 1 sec per RPA hole (18.3mm)

Laser Welding
• No A-surface read-through of welds
  • Capable of welding 2.6mm wallstock with no read through. Mass savings on total assembly
  • Able to use less weld area and achieve higher pull off forces
• Reduced bracket foot prints, better packaging ability – Smaller flanging needed for laser welding
• Allows welding of dissimilar materials – (e.g. ASA to TPO)
Laser vs. Punch & Weld

Flexible cells eliminate the need for unique punch/weld fixtures for each fascia design on lower volume programs and for service business

*Investment and Floorspace Savings*
Camaro ZL1 Fascia

Front Fascia

- Brackets Welded to Fascia Skin

- Added slots for Dive Plane attachment

Rear Fascia

- Added slots for lower valance attachment
Thanks to integrated composite designs, this "perfect position seat" suspension system delivers tuned suspension to optimize occupant comfort by cradling the upper back and providing side-torso support, which flexes to accommodate various occupant sizes.

Special attachment features facilitate assembly and service time.

The design also creates a robust dynamic crash-energy management system for rear-impact protection.

Molded-in-color is used for A surfaces and craftsmanship. The system, for which 83 patents have been filed, reduces total seat weight by 8% and cost by 15% despite adding more features.
Detroit Section & Automotive Division

- Local Technical Meetings
- Training Programs
- Technical Resources
- Scholarships
College for Creative Studies Design Project
The PlastiVan™ Program

2009-2016

Over $100,000 in scholarships to over 40 students

Vanderbilt University
Kettering University
University of Michigan
Ferris State University
Michigan State University
Johns Hopkins University
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