AUTO INTERIOR TPOs, TPEs, AND PPs:
EVOLVING TOWARD THE FUTURE

PRESENTED BY:
Robert Eller
Robert Eller Associates LLC
Phone: +1-330-670-9566
Email: bobeller@robertellerassoc.com
Web Site: www.robertellerassoc.com

PRESENTED AT:
SPE ENGINEERED POLYOLEFINS CONFERENCE 2017
DETROIT, MI USA
October 2, 2017

B/mydox/spe tpo 2017/eller presentation 050117
• Interior growth and diversification prospects

• TPO/TPE/PP compound inter-materials competitions

• Examine potential effects of:
  - Vehicle electrification
  - Autonomous/semi-autonomous vehicles

• Role of 3D (additive manufacturing) in:
  - filler modification
  - component fabrication

• Supply chain shifts

• Identify and examine vision of the future and future-oriented innovation strategies for interior TPOs, TPEs and PP compounds
## Factors Affecting NAFTA Automotive Interior TPO Demand

<table>
<thead>
<tr>
<th>Application</th>
<th>Trends</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Trend</td>
<td>(+) Growth in most applications</td>
<td>- 1 KMM LBS → 1.25 KMMLBS (2016→2020)</td>
</tr>
<tr>
<td></td>
<td>(+) Growth of vehicle size</td>
<td>- CAGR = 5.7 %/YR</td>
</tr>
<tr>
<td></td>
<td>(+) Vehicle electrification</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(+) Autonomous semi-autonomous vehicles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-) Production shift to Asia (a)</td>
<td></td>
</tr>
<tr>
<td>Instrument Panel</td>
<td>(-) Downgauging</td>
<td>- Component for “SMART” innovations</td>
</tr>
<tr>
<td></td>
<td>(+) Add glass fibers</td>
<td>- New fabrication technologies</td>
</tr>
<tr>
<td></td>
<td>(+) Carbon fiber grades</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(+) Growth of TPO skins</td>
<td></td>
</tr>
<tr>
<td>Interior TPO</td>
<td>(-) Downgauging Cont’d</td>
<td>(+) Cont’d. TPO substitution</td>
</tr>
<tr>
<td></td>
<td>(-) Foam substitution</td>
<td></td>
</tr>
</tbody>
</table>

Note: (a) Ford Focus for example

Source: ROBERT ELLER ASSOCIATES LLC, 2017
AUTO TPO GROWTH CURVES (NAFTA)s

TREND LINE

INNOVATION GROWTH CONTINUING

BODY PANEL OPPORTUNITIES

NEW INTERIOR STRUCTURAL APPLICATIONS

NEW INST PANEL NANO + LT WT: CARBON & CELIOULOSE

SOURCE: GLOBAL POLYMER SOLUTIONS, 2017
INTRA-TPE COMPETITION: CASCADE EFFECT TO LOWER COST TPEs WHERE FEASIBLE

**Note:**
(a) Reactor TPO and SBS attacking SEBS
(b) e.g PP/UHMW EPDM (xlinked) blends

**Source:** ROBERT ELLER ASSOCIATES LLC, 2017
### TPEs/TPO/PPC COMPETITIONS

<table>
<thead>
<tr>
<th>Direct competition</th>
<th>Complementary</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP copolymer compound vs TPO</td>
<td>SEBS-type TPE used in conjunction with molded PP and LGF-PP (piggyback effect)</td>
</tr>
<tr>
<td>r-TPO competes with conventional TPO and SEBS compounds</td>
<td>e.g. r-TPO vs SEBS in floor mats(a)</td>
</tr>
<tr>
<td>SEBS competes with TPOs</td>
<td>PPs and POEs used as ingredients in SEBS and o-TPV compounds</td>
</tr>
</tbody>
</table>
| UHMW-EPDM competing with conventional EPDM in o-TPV formulations | Improved:  
- heat/chemical resistance  
- compression set? |
| p-TPV (crosslinked) competes with TPO in skins         | p-TPV → better thermoforming and grain retention                              |

Note: (a) For example Catalloy from LyondellBasell in floor mats  
Source: ROBERT ELLER ASSOCIATES LLC, 2017
• Benefit: Facilitates processes such as:
  - Foaming
  - Blow molding
  - Thermoforming large parts (especially deep draw designs)
  - Twin sheet forming

• Current/potential HMS applications (interior):
  - Foam ductwork (see example slide)
  - Headliner substrate (current application)

• Non-interior applications
  - Truck bed liners
  - Underbody shields

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
AIR DUCTS: TARGET FOR HMS PP FOAMS

OVER 10 AIR DUCTS PER CAR

EXAMPLE AIR DUCT
- MATERIAL: PP FOAM
- PROCESS: TWIN SHEET FORMING
- SUPPLIER: SEKISUI ALVEO

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
FUTURE VIEW: INTERIOR FUNCTIONALITY CHANGES
NEW OPPORTUNITIES FOR TPOs, TPEs AND PP COMPOUNDS

• Sensing
• Display
• Role in lighting shifts
• EMI shielding
• Increased soft touch
• “Smart” functions
• Touch functions
• Continued pressure for lightweight solutions
• Increased pressure for acoustics solutions
• Increased pressure for leather-like look
• Pressure for processing cost save
• Selective transparency
• Role for 3D/nanoscale-design fillers

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
EV/AUTONOMOUS CAR: NEW FUNCTIONS ➔ INTERIORS OPPORTUNITIES/CHALLENGES

• Tie with electric vehicles
• Shift of some instrument panel/cockpit functions ➔ computers vs gauges
• “Windows”/transparent sections in the surface
• Improved acoustics
• Improved EMI Shielding
• Image projection
• Sensing
• Conduction
• Signaling/data transmission

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
ELECTRIC VEHICLES (EVs): EFFECT ON TPOs, TPEs AND PP COMPOUNDS

• Transformative technology affecting:
  - interior design,
  - component types
  - material selection criteria
  - battery-associated components
  - fewer switches and buttons/consolidated
  - skins.. still required(display surface?)

• Simple tablet computer or video screen instead of full instrument panel (See Tesla model 3)?

• Trend toward autonomous vehicle so fewer instruments needed

• Head impact criteria?

• Still tiny market (< 1% of global production)/Numerous uncertainties, positive growth likely

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
SELECTIVE 3D MOLDING (ADDITIVE MFG): ROLE IN AUTO?

- Weight save potential
- Putting resin where structural requirements dictate
- Tailoring fillers
- Deposition via sintering (suited for some TPEs (e.g. SEBS, PP powders?)) or from filaments

SOURCE: PLASTICS TECHNOLOGY MAGAZINE 042017; COMMENTS: ROBERT ELLER ASSOCIATES LLC, 2017
FILLER STRUCTURES: TAILORED AT NANO SCALE VIA 3D MOLDING

Ceramic cube:
- 50 micrometers per side, ultralight - mostly air
- strong, not brittle

Precise control of structure at nanoscale:
- increased energy density of batteries with weight save
- space at nanoscale to precisely control flow of heat and light

SOURCE: MIT Technology Review, vol. 118 no. 2, Caltech
ADDITIVE MFG. (AM): OPP’Y FOR INTERIOR TPOs, TPEs AND PP COMPOUNDS

• Allows tailored (at nanoscale)/partially hollow (lightweight structures):
  - competes with foam? (advantage: tailoring to structural requirements)
  - conductives (circuitry, carbon nanotubes)

• Currently process-oriented:
  - sintering
  - fusion of filaments
  - direct polymerization
  - production speed has increased

• Materials potential just starting (not fully exploited):
  - SEBS, TPOs starting
  - TPUs, polyamides
  - silicones
  - fiber-reinforced?
  - suitable for lightweight fillers

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
STRUCTURAL AUTOMOTIVE CANDIDATES: CARBON FIBER/PP IN THE RUNNING

Materials Comparison

![Graph showing materials comparison](image)

**SOURCE:** ZUMHAGEN COMPANY LLC, 2017
EXAMPLES OF IMSE AUTOMOTIVE APPLICATION AREAS

- Illumination & control solutions in curved decorative panels
- Force and capacitive sensing integration for enhanced applications, preventing unintentional activations
- Illumination adjustment

SOURCE: TACTO TEK, 2017
<table>
<thead>
<tr>
<th>DRIVER</th>
<th>EFFECT</th>
<th>FEATURES/MAT’LS</th>
<th>COMPONENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less driver attention req’d</td>
<td>Increase luxury</td>
<td>- Soft touch</td>
<td>- Skins</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Leather look</td>
<td>- Touch surfaces</td>
</tr>
<tr>
<td>Less/no? collision risk</td>
<td>Lower HIC(d) req’ts</td>
<td>- Broader mat’tls choice</td>
<td>- Pillar trim, IP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Lower impact req’d.</td>
<td>- Headrests</td>
</tr>
<tr>
<td>- Display</td>
<td>Interior as display/lighting surface</td>
<td>- Conductive(a)/luminescent mat’tls</td>
<td>- Skins</td>
</tr>
<tr>
<td>- Lighting</td>
<td></td>
<td>- Selective /variable transparency</td>
<td>- Headliner</td>
</tr>
<tr>
<td>- Signaling</td>
<td>- Reduce buttons</td>
<td>- EMI shielding</td>
<td>- Touch surfaces</td>
</tr>
<tr>
<td>- Voice activation</td>
<td>- Console design</td>
<td>- Conductives</td>
<td>- Console</td>
</tr>
<tr>
<td></td>
<td>- Smart surfaces</td>
<td>- Acoustics/damping</td>
<td>- IP</td>
</tr>
</tbody>
</table>

Note: (a) Graphenes, carbon nanotubes for example

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
CONDUCTIVE POLYMERS FOR AUTO INTERIORS

Coatings – Electrostatic Spray Painting

Sensors – Pressure, Touch

Comfort – Heating, Lighting

HEART RATE – SENSING SEAT

Steering Wheel Contact

(polypyrrole)

SOURCE: GRAPHENICS/UNIVERSITY OF ALABAMA (OFFICE OF VP FOR R/D)
EXAMPLE PATH TO AUTO INTERIOR LIGHTING VIA PHOTOLUMINESCENCE

Note:
- Example of role of carbon-based ingredients (CNTs, Graphene, fibers) in auto interiors
- Photoluminescence color can be varied
- Role for TPEs/TPOs in (skins?, other components?)
- Potential role for image projection, sensing, signaling, smart surfaces, etc.

SKETCH SOURCE: NAGOYA UNIVERSITY; COMMENTS: ROBERT ELLER ASSOCIATES LLC, 2017
### Potential Interior Surfaces for Image Projection and Lighting Surfaces

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>IMAGE</th>
<th>LIGHTING</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headliner</td>
<td>X</td>
<td>X</td>
<td>Nissan previously had image projection on headliner surface</td>
</tr>
<tr>
<td>Door trim</td>
<td></td>
<td>X</td>
<td>On lower; Seats swivel for viewing</td>
</tr>
<tr>
<td>Inner firewall (upper)</td>
<td>X</td>
<td>X</td>
<td>Assumes reduction/elimination? of full instrument panel</td>
</tr>
<tr>
<td>Front seat back</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Package tray</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Highlight remaining knobs, controls</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Door edge</td>
<td></td>
<td>X</td>
<td>Shows to oncoming vehicles</td>
</tr>
<tr>
<td>Glove compartment</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Consoles</td>
<td></td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

Note:
1-Surfaces can be “smart” for command, transmission/signaling functions
2-Many other potential applications (cup holders, interior mirrors, foot wells)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
INTERIOR TPOs/TPEs/PP COMPOUNDS AT A TURNING POINT

BEFORE
- SUBSTITUTION FOR OTHER PLASTICS/RUBBERS/METALS
- SEMI-MODERNIZED LEGACY FABRICATION PROCESSES
- SLIGHTLY EVOLVED INTERIORS
- GETTING STARTED ON LIGHTWEIGHTING
- VEHICLE DEMAND GROWTH > ’09
- CONSOLIDATED SUPPLY CHAIN

2017

- GEOGRAPHIC VEHICLE PROD’N SHIFTS
  - GLOBAL SPECS
  - SUPPLY CHAIN SHIFTS

LOOKING FORWARD
- NEW INTERIORS FUNCTIONS (SEMI-AUTONOMOUS VEHICLES, LIGHTING, ETC)
- GLOBAL REQ’TS/SPECS GROWTH
- SHIFT: GAS VS ELECTRIC?
- FURTHER SUPPLY CHAIN SHIFTS
- SLOWED VEHICLE PRODUCTION
- INDUSTRY DISRUPTION

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
THE NAFTA INTERIORS SUPPLY CHAIN IS SHIFTING

• Reverse globalization of compounders/resin suppliers from Asia/Europe
• Asian/European Tier 1s continue shift to NAFTA
• Interior functions shift: Silicon Valley suppliers → interiors supply chain
• 3D (AM) fabrication could shift supplier base
• Increased “at press” processes affect compounder supply base
• New additive classes/functions → new suppliers

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
INTERIOR EVOLUTION: NEW DRIVING FORCES AND MATERIALS

- DIRECT p-TPVs
- IN-MOLD PROCESSES
- NEW FOAMING METHODS
  - SKINS
  - MULTI-LAYER STRUCTURES
- ACOUSTIC/DAMPING MAT’LS.
- IMPROVED BODY SEALS
- SKINS
- SOFT TOUCH
- SILKY TOUCH

LUXURY

PROCESS COST SAVE

SMART FUNCTIONS

SHIELDING

- ROLE FOR CONDUCTIVES
  - CARBON NANOTUBES

LIGHT WEIGHTING

- LUMINESCENT SURFACES
- IMAGE PROJECTION

LIGHTING

- ADDITIVE MANUFACTURING
  - FOAMS (ROLE FOR HMS PP)
  - NANO-TAILORED FILLERS (VIA ADDITIVE TECHNOLOGY)

- MANY PARTS

STRUCTURE WITH WEIGHT SAVING

- QUIET

CURRENT INTERIOR

- SENSORS
- TOUCH SWITCHES
- GRAPHEENE
  - CNTs
  - IMSE
- NATURAL FIBERS
- NANOCELLULOSICS
- CARBON FIBER/GLASS REINFORCEMENT

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
STRATEGIES FOR AUTO INTERIOR TPO, PP AND TPE INNOVATION

• Previous strategies:
  - metal substitution (bumper fascia, instrument panel)
  - implement polymer developments (e.g. POEs, catalyst developments, fiber/filler)
  - comply with directives (e.g. weight save/CAFE)

• Current/future oriented strategies:
  - seek role in vehicle electrification/autonomous vehicles/”smart” applications
  - continued advances in polymer science (POEs, improved EPDM, LMW SEBS)
  - piggy-back on parallel developments (e.g. LGF and LCF reinforced plastics)

• New fabrication technologies (e.g. additive manufacturing)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2017
SUMMARY

• **Previous:** Strong growth since the 80’s via:
  - System re-design (e.g. bumper fascia)
  - Direct substitution for incumbents (e.g. ETPs, metals)

• **Vehicle interior:** changing with vehicle electrification/autonomy; creates new opportunities for:
  - higher performance TPOs, TPEs and PP compounds
  - fillers and reinforcements

• **Future Interiors growth will be driven by:**
  - New functional values (“smart”, conductive, shielding, touch, sensing, display improved acoustics)
  - New fabrication technologies (additive mfg., foaming)
  - Simplified fabrication unit operations (multi-layer/single step mfg., co-processing)

• **Inter-materials competition:** TPOs, TPEs ,TPVs, PP compounds compete in the interiors market space
• Additive manufacturing:
  - Emerging from prototype stage
  - High growth potential/higher speeds, broader materials footprint
  - TPOs, TPEs, PP compounds will have a role

• 3-D processes: will affect molding, parts consolidation, fillers tailoring at nano-scale

• Growth: Interior TPO/TPE/PP compound demand growth:
  - From domestic NAFTA sources, stimulated by the shift to larger vehicles
  - Diminished by shift of NAFTA vehicles to production in Asia

• Reverse globalization: will continue to affect the NAFTA TPO/TPE/PP compound supply chain
SUMMARY (Cont’d.)

• **Organic growth:** Interior TPO/TPE/PP compound demand growth:
  - from domestic NAFTA sources, stimulated by the shift to larger vehicles
  - diminished by shift of NAFTA vehicles to production in Asia

• **NAFTA TPO/TPE/PP compound supply chain shift from:**
  - globalization/reverse globalization
  - acquisitions
  - entry of EVs/autonomous vehicles
THANKS FOR YOUR ATTENTION

Management DECISIONS

ANALYSIS

Robert Eller Associates LLC
CONSULTANTS TO THE PLASTICS AND RUBBER INDUSTRIES

Thanks to Ron Price for inputs