THERMOPLASTIC ELASTOMERS IN THE AUTOMOTIVE MARKET:
TRENDS AND DEVELOPMENTS

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Automotive: Key Market for Thermoplastic Elastomers

THE AUTO MARKET
- 40-50% of current TPE demand
- Key incumbents: EPDM, PVC, TPO
- Global footprint

- Role for lightweighting, systems cost-save
- Key target properties: low V.O.C., thin wall, low odor, oil/fuel resistance, heat resistance, sustainable
- Role for process technology, co-processing innovations

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2012
### Importance of Automotive varies between TPEs

<table>
<thead>
<tr>
<th>TPE TYPE</th>
<th>AUTO SHARE OF GLOBAL DEMAND</th>
<th>RECENT INCUMBENT</th>
<th>NOTE/ AUTO TARGETS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPO</td>
<td>75%</td>
<td>None –TPO dominates</td>
<td>Bumper fascia, interior trim, skins Growth in non-auto markets</td>
</tr>
<tr>
<td>o-TPV</td>
<td>50%</td>
<td>NBR/PVC, ECO, CPE, EPDM</td>
<td>Boots/bellows, hose, short air ducts, Body/glazing seals</td>
</tr>
<tr>
<td>SEBS</td>
<td>15%</td>
<td>EPDM, o-TPV</td>
<td>Auto share growing via soft touch, skins, body/glazing seals, airbag doors</td>
</tr>
<tr>
<td>TPU</td>
<td>11%</td>
<td>EPDM, o-TPV</td>
<td>Grommets, sleeves, door sills, overmolded films, shift knobs, lamp seals, slush molding, wire/cable</td>
</tr>
<tr>
<td>COPE</td>
<td>10%</td>
<td>EPDM, o-TPV, fluorosilicones</td>
<td>Under-hood ducting(higher temp capability), wire/cable, soft touch trim panels</td>
</tr>
</tbody>
</table>

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Interiors
Competition In Interior Soft Trim/Soft Touch

SOFT TRIM PROCESS MATERIALS OPTIONS

INJECTION
- CONV. INJECTION
  - SOFT TOUCH PAINT
- 2-SHOT
  - SEBS
  - TPV
  - TPU
- OVERMOLD
- BACK INJECTION
  - COATED FABRIC FOILS
  - UNCOATED FABRICS

SKIN PROCESSES
- SLUSH MOLD
  - TPU
  - TPU BLEND
  - PVC
  - TPO
- VAC FORM FOILS
  - THERMO-FORM
  - BACK INJECTION OR LOW PRESSURE MOLDING
  - TPO
  - PVC
  - TPU ALLOY SHEET

COATED FABRICS
- HAND WRAP OR VAC FORM
- BACK INJECTION

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2011
Multi-material Molding

- Cost save vs. incumbent skins methods
- TPVs and SBC-TPEs (TPE-S) competing
- Foaming will accelerate penetration
- Capital investment vs. labor costs (an issue in Asia)
- TPEs with high flow (large area/thin cross-section) required
- Craftsmanship improvement
- Recyclability
- Multi-color capabilities (2 color lower IP and door medallions are often desired by designers

Source: Robert Eller Associates LLC 2011
Door Trim

Example Multi-material (2-shot) Door Trim Panel
- Application: Door trim (dark areas)
- TPE Supplier: A. Schulman
- TPE Type: o-TPV
- OEM: Chrysler
- Vehicles: Caliber, Commander, Grand Caravan

TPE Benefits:
- Haptics → soft (luxury) touch
- Enhanced craftsmanship/multi-color capability
- Single step process/labor cost savings
- Cost save vs. multi-step approach
- Multi-material molding cycle time approaching single shot

TPE Skin Candidates: SEBS (TPE-S), o-TPV, TPU modified TPE (for use over PC/ABS)

Key TPE Challenge:
- Adequate flow (large area/thin cross-section (1-2 mm)
- Capital investment required
- Ability to incorporate foam
- Competition with textile inserts

Incumbents: Thermoformed/backfoam PVC or TPO sheet, PU spray (declining)

Photo Source: A. Schulman
Candidate Material/Process Combinations For IP Skins

NOTES:
(a) TPE/TPU alloys (TPU/SEBS, TPU/TPO, TPU/TPV)
(b) e.g., from Recticel, in use on some high end vehicles (e.g., at BMW)
(c) PUD = polyurethane dispersion
(d) Widely used globally
(e) Limited use on very high end vehicles (e.g., some Mercedes models use leather wrap/adhesive/PVC sheet/adhesive)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2011
IP Skin PVC Substitution Objectives

Environment
• Halogen free?
• Improve recyclability
• Reduce VOC/fog

Performance
• Satisfactory hidden passenger airbag deployment at -30ºC
• Grain reproduction
• Haptics
• Craftsmanship/fit & finish (shrinkage on heat aging effects)
• Mass reduction
• Long-term UV resistance (low ∆ E)
• Heat aging resistance

Cost
• Reduce IP system costs
• Reduce skin costs
• Maintain current labor requirements??

Weight
• Reduce part/car weight

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Instrument Panel: Critical Features

Grain reproduction: key parameter

Logos

Craftsmanship

Hidden airbag doors

Photo Source: Robert Eller Associates LLC

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
# Comparison Of Slush IP Skin Capabilities

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>SLUSH TYPE</th>
<th>SPRAY PU</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material cost ($/lb.)</td>
<td>PVC: Lowest</td>
<td>TPE: Moderate</td>
<td>TPU: Highest</td>
</tr>
<tr>
<td>Typical skin weight (lbs.)</td>
<td>3 – 3.5</td>
<td>1.6</td>
<td>2 – 2.5</td>
</tr>
<tr>
<td>Low temp. airbag deployment (heat aging effect)</td>
<td>Some degradation after heat aging</td>
<td>No deployment performance</td>
<td>--</td>
</tr>
<tr>
<td>$\Delta E$ after UV exposure (2500 kJ, 89ºC)</td>
<td>PVC: Highest</td>
<td>TPE: Very low (&lt; 1)</td>
<td>TPU: Very low (&lt; 1)</td>
</tr>
<tr>
<td>Shrinkage on heat aging</td>
<td>Moderate curling</td>
<td>Remains flat (no curling)</td>
<td>Minor curling</td>
</tr>
<tr>
<td>VOC</td>
<td>Medium</td>
<td>Lowest</td>
<td>High</td>
</tr>
<tr>
<td>Fog</td>
<td>Acceptable</td>
<td>Acceptable</td>
<td>High</td>
</tr>
<tr>
<td>Process window</td>
<td>Narrow</td>
<td>Wide</td>
<td>--</td>
</tr>
<tr>
<td>Scratch &amp; mar resistance</td>
<td>Good</td>
<td>Unknown</td>
<td>Very good</td>
</tr>
</tbody>
</table>

*SOURCE: ROBERT ELLER ASSOCIATES LLC, 2011*
Car Model: Audi E8
Part: Instrument Panel Skin Slush Molded
Raw Material Resin: Kraton
Compound: Laprene S formulated by So.F.teR
Fabricator: Peguform
Features: Halogen free, pthalate free
30-40% lighter weight than PVC
Better low temperature performance than PVC
Better aging characteristics than PVC
Lower processing costs
Recyclable
Deep soft touch/haptics feel

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Slush molded TPE-S Instrument Panel

Photo: So.F.teR
Patented Slush Molded TPE Technologies

• Inteva
  • Uses PP/SEBS compound
  • Currently commercial in North America
  • Concerns over scratch/mar resistance?

• Kraton/So.F.ter
  • Uses special low molecular weight HSBC compounded with PP and Polybutene
  • Currently under development/commercial applications yet to be announced
  • New Formosa plant comes on stream in 2016 with capabilities to supply low molecular weight resin
PVC Substitution: Coated Fabrics

- PVC: the dominant incumbent strongly entrenched, cost effective
- TPE-S (SBC-TPEs:) Phthalate-free, UV resistance, low temp properties

PHOTO: KRATON

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2015
Auto Acoustics Control Technologies: Role For TPEs

AUTOMOTIVE ACOUSTICS SOLUTIONS

- Body/glazing seals* (a)
- Acoustic barrier and absorber Constructions (b)*
- Sound deadening carpet (d)
- Acoustic glazing laminates
- Foams injected into body hollow sections (c)
- Improved engine mount isolation
- Parts re-design*
- Gasketing to control BSR (f)*
- Noise cancellation Technology (e)

Note: *= current or potential TPE opportunities
(a) High growth application for SBC and o-TPVs
(b) Lightweight dash mats and heavy duty barriers (e.g. from Cascade Engineering).
   includes polyolefin foams
(c) For example Betafoam™ from Dow based on PU foams
(d) For example from IAC/Stankiewicz
(e) Becoming common via feedback microphones (e.g. Honda Accord and Chevrolet Impala)
(f) BSR= Buzz, squeak, rattle: opens opportunity for vibration damping TPE layer on plastic substrates

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2015
Acoustic Targets For Polyolefins/TPEs/Foams

Dash Mat
Supplier: Cascade Engineering

Flat Absorber For Gear Drive
Note: White Areas Are Micro-perforated Polyolefin Foams

Foam Supplier: Sekisui Alveo

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2015
Under the hood
Rack and Pinion Bellows

Suspension Bellows

**Boots, Bellows, Dust Covers**

**Key benefits**
- cost-effective compared to EPDM or CR
- weight reduction approx. 20 to 40% compared to CR
- good chemical resistance
- good flexibility and fatigue resistance
- tight tolerance

**Production process**
- blow molding

**TPE Candidates**
- TPV, TPEE (COPE)

**Material(s) replaced**
- EPDM and CR

**Key benefits**
- excellent flex-fatigue properties
- good oil and grease resistance
- weather and ozone stability
- good tear and puncture resistance
- good impact resistance
- protection against dust and dirt

**Production process**
- blow molding

**TPE candidates**
- TPV, TPE-S

**Material(s) replaced**
- EPDM, TPU
Under Hood Temperature Increases ➔ High Heat Thermoplastic Elastomers

- **Application:** Air duct cuff
- **TPE candidate:** s-TPV (Zeotherm)
- **Key properties:** Heat resistance, Ease of processing, Polyamide adhesion

Note: Example of metal replacement (e.g. polyamide) pulling TPEs into under-hood applications

- **Application:** Hot air duct (primarily turbo engines)
- **TPE candidate:** s-TPV (Zeotherm)
- **Key properties:** Heat resistance, Processing ease
- **Processing:** Blow molding

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Broadening the Thermoplastic Elastomer Application Base

- **Application**: High temp hose
- **Target markets**: Auto under hood, industrial hose
- **TPE types**: Several depending on heat resistance level (COPE, TPEE, s-TPV)
- **Key properties**: Temp resistance, Low stiffness
- **Process**: Water Injection molding technology (WIT)
- **TPE enabling technology**: Temp resist (s-TPVs)
- **Note**: Woven mesh inserted during molding process, Mesh insertion developed at IKV

Source: Akro-Plastic GmbH

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
## Co-processing Drives Thermoplastic Elastomer Growth in Rigid/Flexible Systems

<table>
<thead>
<tr>
<th>TYPE</th>
<th>STRUCTURE</th>
<th>NOTE/EXAMPLE APPLICATION</th>
</tr>
</thead>
</table>
| Overmold, Film coex, 2-shot mold | TPE Substrate (rigid segment) | - Soft touch phones  
- Some 2-tone applications  
- Vibration damping |
| Side by Side | TPE Rigid Segment | - 2-tone  
- Door trim, console, IP  
- Bumper fascia |
| Edging | - Body/glazing seals (profiles)  
- Cowl vent seals  
- Co-extrusion or 2-shot |
| Co-blow Mold | TPE (flexible) Rigid | - Boots/bellows, hose  
- Ducting |
| Co-extrusion Blow Mold or Co-extrusion | o-TPV s-TPV or ETP inner | Under-hood:  
- Hose (e.g. fuel)  
- Duct |

Source: Robert Eller Associates LLC, 2012

r/mydox/Visio/Two Shot OM approaches 2012.vsd
Automotive Hose: Adding Value Via Coextrusion

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2014
Exteriors
Glass encapsulation seals

Key benefits
• durable sealing performance
• functional integration and weight reduction
• cost-effective thermoplastic processing compared to EPDM
• good matte surface (color match to GRC/BLS)
• excellent UV and aging resistance

Production process
• stretch-fit glass encapsulation
• direct glass encapsulation by injection molding
• TPV, TPE-S, TPU, PVC/NBR

material replaced
• EPDM
Inner & outer belt line seals

Key benefits
• durable sealing performance
• cost reduction compared to EPDM (PP combination)
• weight reduction by replacing metal
• excellent UV (outer belt line) and aging resistance

Production process
• co-extrusion (dual hardness)

TPE candidates
• TPV, TPE-S, PVC/NBR

Material(s) replaced
• EPDM plus flock, TPE-S, PVC/NBR
• metal
End cap & corner molding seals

Key benefits
• durable sealing performance
• part cost reduction compared to EPDM (no rework, short cycle time)
• adhesion to EPDM
• good surface appearance
• smooth/rubbery surface – no blooming
• excellent UV and aging resistance

Production process
• insert injection molding

TPE Candidates
• TPV, TPE-S

Material(s) replaced
• EPDM

Photos: ExxonMobil
Cowl vent grille seals

Key benefits
• durable sealing performance
• cost-effective through function integration
• weight reduction
• excellent UV and aging resistance

Production process
• extrusion
• injection molding

TPE Candidates
• TPV, TPE-S

Material(s) replaced
• EPDM

Photo: ExxonMobil
Glass run channel seals

Key benefits
• part cost reduction compared to EPDM
• good surface appearance
• smooth/rubbery surface – no blooming
• excellent UV and aging resistance

Production process
• co-extrusion (dual hardness)

TPE Candidates
• TPV

Material(s) replaced
• EPDM plus flock

Photo: ExxonMobil
Cutline seals

Key benefits
• good sealing performance
• cost-effective through function integration
• easy processing and broad process window
• excellent UV and aging properties

Production process
• extrusion

Material(s) replaced
• EPDM
Gap filler seals

Key benefits
• cost-effective through function integration
• durable sealing performance
• excellent UV and aging resistance
• good adhesion to PP

Production process
• two-component (2K) injection molding

Material(s) replaced
• new design
Evolving developments

• Primary door seals
• Trunk seals

• Dynamic seals requiring best compression set performance
• Seal design critical
Thank You!

Robert Eller Associates LLC
CONSULTANTS TO THE PLASTICS AND RUBBER INDUSTRIES