TPEs AND TPOs MEETING AUTOMOTIVE CHALLENGES AND BEYOND

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Bob/papers/polyolefins 2013
1. Global Automotive Market: Regional Shifts and Global Platforms
2. Asia-Pacific Role in the Global Auto Market
3. The North American Auto Market/Supply Chain
4. Automotive PP Compounds and TPO Types and Trends
5. The TPE Families
6. Automotive TPE Substitution: Key Drivers
7. Automotive TPE Target Applications, 2012
8. Summary
Global automotive sales growth has shown steady increases since 1975 at a rate somewhere between 2.4-3.6%/yr.

China has become the No. 1, fastest growth, global automotive market.
<table>
<thead>
<tr>
<th>REGION</th>
<th>PRODUCTION, MM VEHICLES</th>
<th>CAGR %/YR.</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2015</td>
<td>16%</td>
<td></td>
</tr>
</tbody>
</table>
| China | 2.5  | 22  | - Reduced gov’t. incentives will slow growth in 2012  
- Recent barriers to non-Chinese OEM investment  
- Possible overcapacity by 2020? |
| India | 1.0  | 5   | 11%                                                                                                                                |
| S. America | 2.5  | 5   | 5%  
- Brazil dominates                                                                                                               |
| Europe | 19.0 | 23  | 1%  
- Current overcapacity  
- Stagnant market                                                                                                                 |
| Japan/Korea | 12.5 | 13  | 0%  
- Yen strength → Japan shift to non-domestic production                                                                             |
| NAFTA | 17.0 | 17  | 0%  
- 13.8MM in 2012                                                                                                                 |

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2012
SEGMENT SHIFT IN N. AMERICAN AUTO SALES, 2000/2005/2010

FASTEST GROWTH SEGMENT

SALES SHARE, %

SMALL CAR | CUV | SUV | VAN | PICKUP TRUCKS

Sources: WardsAuto.com; Robert Eller Associates LLC, 2012
## GLOBAL PLATFORM STRATEGY SHIFTS

<table>
<thead>
<tr>
<th>OEM</th>
<th>CURRENT/ FUTURE EXAMPLES</th>
<th>GLOBAL PLATFORM STRATEGY</th>
<th>NOTE</th>
</tr>
</thead>
</table>
| VW   | - Passat                 | - Has been in place for 30-40 years (e.g., Golf platform)  
- Shifting from global platforms?  
- U.S. Passat is departure from global platform strategy | - Borrows components and modules from other models, as appropriate  
- Strong VW entry into European “A” vehicle segment |
| Honda| - Civic  
- Accord  
- Acura | - Shifting from strict adherence to global platforms | - Flexible assembly lines allow multiple models/regional differentiation |
| GM   | - Cruze  
- Malibu | - Reduce number of vehicle platforms (30 in 2010 → 14 in 2018)  
- Increase vehicles per core global platform | - Cruze is first global model  
- Malibu to follow  
- Core platforms → 90% of production in 2018  
- Have been slower to → global platforms |
| Ford | - Fiesta  
- Focus  
- CUVs  
- C/D platform (Fusion/Edge) | - “One Ford” strategy  
- Single Focus model for U.S./Europe | - Move to global platforms  
- Reducing number of global platforms from 11 → 9 by 2013 |

**SOURCE:** ROBERT ELLER ASSOCIATES LLC, 2012
1. GLOBAL AUTOMOTIVE MARKET: REGIONAL SHIFTS and GLOBAL PLATFORMS

• Trend line for global sales volume: steady sales gain ~ 3%/yr.
• BRIC countries: rapid growth vs. stagnation in Western regions
• Globalization: a new world automotive reality → global:
  - Platform strategies: Ford, GM moving forward, VW already there
  - Platform share of global vehicle production will → ~40% by 2015, from 34% in 2010
  - Global vehicles/platforms reshaping the supply chain: need for global supplier footprint
  - Specifications: evolving, e.g., 3-4 global TPE specs
    Asia: benefit of arriving with TPE spec in hand
2. ASIA-PACIFIC ROLE IN THE GLOBAL AUTO MARKET

• China
  - Economic growth: 8.5% in 2011; Inflation: 5% in mid-2011
  - Exports: export boom in 2011
    production capacity $\rightarrow$ 40MM in 2020, drives export threat?
  - GM and VW: major market shares (combined = ~ 27%)
  - Central government limit foreign investment >2012?

• China automotive PP compounding capacity: expanding (e.g., China XD/Sumitomo joint venture)

• Acquisition investment coming out of Asia, seeking Western technology affecting Western TPE supply chain and customers – examples:
  - Chongqing Light Industry acquisition of Saargummi (sealing systems)
  - Ruia Group (India) acquisition of Sealynx (France)
  - TSRC acquisition of Dexco (SBS resins)
  - Toyota Boshoku (Japan) acquisition of Polytec’s interiors business
  - Motherson Sumi (India) acquisition of Peguform (Germany)
### INDUSTRY SECTOR

<table>
<thead>
<tr>
<th>INDUSTRY SECTOR</th>
<th>SHARE, %</th>
<th>EXAMPLES</th>
<th>COVERAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESIN SUPPLIER/ CAPTIVE COMPOUNDER</td>
<td>70</td>
<td>LyondellBasell Mitsui/Prime ExxonMobil Styron, Sabic Mytex, Sumitomo</td>
<td>GLOBAL</td>
</tr>
<tr>
<td>INDEPENDENT COMPOUNDER</td>
<td>30</td>
<td>Rhetec Ferro Wash Penn</td>
<td>REGIONAL</td>
</tr>
</tbody>
</table>

### INDUSTRY STRUCTURE TRENDS

- Resin suppliers integrating toward compounding
- Tier 1s back-integrating to in-house compounding (IAC, Inteva)
- Market globalization/supply chain shift
- Offshore resin companies → N. American market (natural gas driver?)
- Western OEMs, Tier 1s → Asia expansion (major portions of supply chain)
4. AUTOMOTIVE PP COMPOUNDS, TPOs: DRIVERS AND TRENDS


- Shift to eco-friendly PP compounds (e.g., 2012 Ford Escape door trim panel from 50% Kenaf/PP).

- TPO: Reaching maturity, growth tied to auto production. Demand shrinkage with thinner walls and smaller vehicles.

<table>
<thead>
<tr>
<th>DEMAND DECREASERS</th>
<th>DEMAND INCREASERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small car/CUV trend</td>
<td>Scratch resistant PP compounds and TPOs</td>
</tr>
<tr>
<td>Thin walling</td>
<td>Increased demand for semi-structural PP grades</td>
</tr>
<tr>
<td>Recycling</td>
<td>Integral soft surface treatments</td>
</tr>
<tr>
<td></td>
<td>Cost benefits of direct LGF-PP compounds</td>
</tr>
<tr>
<td></td>
<td>Drive for lightweighting. 10% weight reduction → 5-7% fuel save</td>
</tr>
</tbody>
</table>

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2012
**AUTO POLYOLEFIN SHARES: NAFTA**

<table>
<thead>
<tr>
<th>PP FORM</th>
<th>SHARE, %</th>
<th>EST. 2011 DEMAND, MM LBS.</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neat copolymer Filled/reinforced grades</td>
<td>47</td>
<td>565</td>
<td>Includes battery (neat copolymer)</td>
</tr>
<tr>
<td>TPO</td>
<td>53</td>
<td>635</td>
<td>TPOs have grown at the expense of copolymer (driven by safety and performance requirements)</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>1,200</td>
<td></td>
</tr>
</tbody>
</table>

Source: Robert Eller Associates LLC; Global Polymer Solutions LLC

- **PP penetration (% of all plastics and use/vehicle increased steadily from 2000 → 2011):**
  - 2000: 7.6% of all plastics used
  - 2010: 9.6% of all plastics used

- **Usage per vehicle will increase slightly in next 5 years:**
  - Smaller vehicles → usage decline, thin-walling
  - Increased usage for LGF-PP, some new applications
• Bumper fascia (but growth in size/vehicle)
• Interior trim (instrument panel structure?, airbag door, kick panels)
• Exterior trim (grill, body molding, cowl vents)
• Some trunk liner applications
• Fender liners
### Example Growth Applications for Auto PP Compounds

<table>
<thead>
<tr>
<th>Applications</th>
<th>Comp’d.</th>
<th>Demand Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intake manifold/Other under-hood</td>
<td>SGF-PP PP-resin</td>
<td>Competes with SGF-nylon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Started at VW (Borealis development)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WIT process for 3-D hose</td>
</tr>
<tr>
<td>IP substrate</td>
<td>LGF-PP</td>
<td>Soft touch trim adds value</td>
</tr>
<tr>
<td>Underbody shields</td>
<td>LGF-PP</td>
<td>Competes with neat copolymer, SGF-PP</td>
</tr>
<tr>
<td>Door hardware modules</td>
<td>LGF-PP</td>
<td>High growth application</td>
</tr>
<tr>
<td>Exterior panel inners</td>
<td>SGF-PP</td>
<td>Started on Ford Kuga (Europe)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Very early; uncertain application</td>
</tr>
<tr>
<td>Trunk inserts</td>
<td>Talc-PP</td>
<td>Several applications (e.g. door panels), generally modest performance</td>
</tr>
<tr>
<td>Bio-fiber reinforced</td>
<td></td>
<td>Replaces metal. Offers systems cost savings when combined with TPEs</td>
</tr>
<tr>
<td>Body/glazing seal systems</td>
<td>Talc-PP</td>
<td></td>
</tr>
</tbody>
</table>

Note: LGF-PP competes with SGF-PP and with SGF (and LGF) polyamides
EXAMPLE OF PP SYSTEMS COST SAVE VIA INTEGRATION OF FUNCTIONS

Photo: Teklas, A. Schulman, PME Fluidtech

Part: Drain channel (note integrated bellows/clip functions)
Material: Unreinforced PP (Polyfort PPC 03 SP-E from A. Schulman)
Fabricator: Teklas (Turkey)
Equipment supplier: PME Fluidtech GmbH
Process: Water Injection Technology (WIT), also suitable for GF-PP, GF-PA
Note: Hutchinson and Contitech possibly will use WIT for similar parts
Commercial status: To be used on Opel “Delta” platform, 1.4 liter engines (Astra, others)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2012
5. THE TPE FAMILIES

TPE FAMILIES

OLEFINIC (o-TPEs)
- TPO
- o-TPV

STYRENIC (SBCs)
- SBS
- SEBS (TPE-S)
- VULCANIZED SBC TPVs (TPES-V)

SUPER-TPVs
- SILICONE
- ACRYLATES

OTHER E-TPEs

PVC TPEs

Note:
(a) e.g., recently introduced melt processable polyurea-based TPEs

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2012
6. AUTOMOTIVE TPE SUBSTITUTION: KEY DRIVERS

- Cost save vs. direct substitution for rubber
  - Rigid/flexible combinations (important for under-hood)
  - Net shape potential: systems cost savings/reduced assembly cost

- Luxury upgrade (important for small car and CUV interiors)
  - Soft touch (growing area coverage in interior)
  - Foamability: still under-exploited
  - Elimination of buzz, squeak, rattle (BSR) between adjoining surfaces

- Recyclability/Sustainability Emphasis (e.g., PP/Kenaf door trim panels)

- Steep rise in fuel economy standards/fuel costs → weight save emphasis
  - Cost efficiency of TPEs vs. alternative fuel efficiency measures
  - Demand for systems/features that add to vehicle mass → weight save emphasis to offset
SOME EPDM-RELATED ISSUES

• Supply
  - Currently tight, will remain so until 2014
  - Has driven up pricing
  - Expansions are in Asia and Middle East

• EPDM types
  - Most expansions (2011-2014) are metallocene-based
  - Petro-Rabigh in KSA (Sumitomo/Aramco) is exception (ZN –based)
  - Medium-high Moody and medium-high diene content work best for TPVs
  - ZN-based EPDM has some advantages vs metallo-EPDM grades
  - Bio-based EPDMs starting (from Lanxess via Braskem)

• EPDM vs POEs
  - For TPOs the shift from EPDM to POEs for most applications
  - Swing capacity (POE and EPDM) in some plants
## 7. AUTOMOTIVE TPE TARGET APPLICATIONS, 2012

<table>
<thead>
<tr>
<th>TARGET COMPONENTS</th>
<th>TPE TYPE</th>
<th>HIGH STIFFNESS TPOs</th>
<th>LOW STIFFNESS TPOs</th>
<th>SEBS</th>
<th>r-TPOs</th>
<th>o-TPV</th>
<th>COPE</th>
<th>s-TPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior:</td>
<td></td>
<td></td>
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<tr>
<td>Panel</td>
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<td>X</td>
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<td></td>
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<tr>
<td>Rocker Panel</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>Fascia</td>
<td></td>
<td>X</td>
<td>X*</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body/Glazing Seals</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Interior:</td>
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<td></td>
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</tr>
<tr>
<td>Airbag Door</td>
<td></td>
<td>X*</td>
<td>X*</td>
<td>X*</td>
<td>X*</td>
<td>X*</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Trim</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IP Skins</td>
<td></td>
<td></td>
<td>X*</td>
<td>X?*</td>
<td>X*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Door trim skins</td>
<td></td>
<td>X</td>
<td>X*</td>
<td>X*</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Steering Wheel</td>
<td></td>
<td>X</td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>HVAC Louvers</td>
<td></td>
<td></td>
<td>X*</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Under-carpet floor acoustic mat</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*X* = multi-shot injection molding, multi-material blow molding, or co-extrusion candidate

(Cont’d.)
### AUTOMOTIVE TPE TARGET APPLICATIONS, 2012 (Cont’d.)

<table>
<thead>
<tr>
<th>TARGET COMPONENTS</th>
<th>HIGH STIFFNESS TPOs</th>
<th>LOW STIFFNESS TPOs</th>
<th>SEBS</th>
<th>r-TPOs</th>
<th>o-TPV</th>
<th>COPE</th>
<th>s-TPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under-hood:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cowl Vent Seal</td>
<td>X*</td>
<td>X*</td>
<td>X*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ducting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X*</td>
<td>X?</td>
<td></td>
</tr>
<tr>
<td>Boots/Bellows</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Hose</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wiring</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Oil/Gas Resistant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Underbody shields</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

X* = multi-shot injection molding, multi-material blow molding, or co-extrusion candidate
# APPROACHES TO 2-SHOT OR OVERMOLDING OF TPEs FOR AUTOPLASTIC COMPONENTS

<table>
<thead>
<tr>
<th>TYPE</th>
<th>STRUCTURE</th>
<th>NOTE/EXAMPLE APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overmold, Multi-material</td>
<td>TPE Substrate (rigid segment)</td>
<td>- Soft touch interiors</td>
</tr>
<tr>
<td>Mold, 2-shot Mold</td>
<td></td>
<td>- Small, tactile parts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Some 2-tone applications</td>
</tr>
<tr>
<td>Side by Side</td>
<td>TPE Rigid Segment</td>
<td>- 2-tone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Door trim, console, IP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Bumper fascia</td>
</tr>
<tr>
<td>Edging</td>
<td></td>
<td>- Body/glazing seals (profiles)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Cowl vent seals</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Co-extrusion or 2-shot</td>
</tr>
<tr>
<td>Co-blow Mold</td>
<td>TPE (flexible) Rigid</td>
<td>- Boots/bellows</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Under-hood</td>
</tr>
<tr>
<td>Co-extrusion Blow Mold or Co-extrusion</td>
<td>TPE outer ETP inner</td>
<td>Under-hood:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Hose</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Duct</td>
</tr>
</tbody>
</table>

**SOURCE:** ROBERT ELLER ASSOCIATES LLC, 2012
AUTOMOTIVE TPE TARGET ZONES

- Oil seals
- Ducting
- Acoustic barrier role for POEs
- Dust covers (bellows)
- Acoustic mats
- Cowl vent gasket
- Belt line molding
- Under-carpet acoustic mats
- Glazing seals (static, dynamic)
- Body seals
- Lighting seals
- Exterior skins
- Skins: IP, door trim
- Lighting seals
- Acoustic mats
- Under-carpet acoustic mats

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2012
r/mydox/Visio/TPE Battle Zones 2012.vsd // lg/myfiles/Visio/TPE Battle Zones 2012.vsd
Targets:

• Instrument panel, door trim, console, steering wheel

• Multi-materials (2-shot) molding benefits:
  - Cost save vs. incumbent skin methods
  - TPVs and SBC-TPEs competing
  - Foaming will accelerate TPE penetration
  - Capital investment vs. labor costs (an issue in Asia)
  - TPEs with high flow (large area/thin cross-section) required
  - Craftsmanship improvement
  - Recyclability

• Lower IP is entry point for 2-shot molded TPE skin/substrate
  - 2-color
  - Reduces BSR
  - Grain is less critical than upper
INSTRUMENT PANEL SKIN SUBSTITUTION OBJECTIVES

Environment
• Eliminate chlorine?
• Improve recyclability/sustainability
• Reduce VOC/fog

Performance
• Scratch/Mar resistance (improved via radiation crosslinked TPO)
• Satisfactory hidden passenger airbag deployment at -30ºC
• Grain reproduction
• Haptics ("deep" soft touch)
• Craftsmanship/fit & finish (shrinkage on heat aging effects)
• Mass reduction
• Long-term UV resistance (low Δ E)
• Heat aging resistance

Cost
• Reduce IP system costs (2-shot molding; eliminate skin?)
• Skin cost reduction
Car Model: Audi E8
Part: Instrument panel skin (slush molded/cast)
Raw Material Resin: Kraton
Compound: Laprene S formulated by SO.F.TER
Fabricator: Peguform (80% owned Motherson Sumi)
Features:
- Halogen free, phthalate 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

Photo Source: News-On-Tour

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2012
### HARD/SOFT IP BREAKDOWN

<table>
<thead>
<tr>
<th>IP TYPE</th>
<th>%</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard</td>
<td>60</td>
<td>Primarily PP-based</td>
</tr>
<tr>
<td>Soft</td>
<td>40</td>
<td>See process shares below</td>
</tr>
</tbody>
</table>

### SOFT IP MATERIALS SHARES

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>SHARE, %</th>
<th>MATERIAL TYPE</th>
<th>NOTE</th>
</tr>
</thead>
</table>
| Slush (cast) molding   | 72       | - PVC dominates (about 70%)  
- TPU at Japanese OEMs  
- TPO has not made significant penetration                                                                                                             | - SEBS-based slush seeking entry  
- Inteva patent                                                    |
| Thermoform            | 15       | - TPO compact and foam backed dominate  
- Still some PVC/ABS                                                                                                                                         |                                                                                                |
| PU spray              | 10       | - Expensive  
- Primarily on high end models                                                                                                                                                                                |                                                                                                |
| Leather, other        | 3        | - High end models  
- Hand wrap                                                                                                                                                                                                     |                                                                                                |

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2012
INTERIOR SOFT TRIM/SOFT TOUCH MATERIALS/PROCESSES

INJECTION
- CONV. INJECTION
- 2-SHOT
- OVERMOLD
- BACK INJECTION
  - COATED FABRIC
  - FOILS
  - UNCOATED FABRICS

SKIN PROCESSES

- TPU
- BLENDS
- PVC (a)
- TPO
- SEBS (TPE-S)

SLUSH MOLD (CAST)
- TPU
- TPU
- BLENDS
- PVC (a)
- TPO
- SEBS (TPE-S)

VAC FORM FOILS
- THERMOFORM
- BACK INJECTION OR LOW PRESSURE MOLDING
  - TPO
  - PVC
  - TPU ALLOY SHEET

COATED FABRICS (a)
- HAND WRAP (a)
- BACK INJECTION

NOTE: (a) Polyurethane dispersion (PUD) coated fabrics gaining share

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2012


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AUTO INTERIOR: COST/VALUE ADD CURVE for MATERIAL/PROCESS COMBINATIONS

- Leather is dominant incumbent
- PUD/coated fabrics are challenger

Hand Wrapping

- Single-shot Injection:
  - Typically PP copolymers, rigid TPO
  - Filled or (recently) long-glass fiber reinforced PP or nylon

- 2-shot:
  - Injection, (b)
  - In-mold decoration
  - Knobs, gearshift, door handles

- Compression Molding:
  - Typically textiles(a) for trim or acoustic components(c)

- Thermoformed Foils:
  - Typically TPO or PVC compact or PO foam backed

- Slush Molding: TPU or TPE-S
- Slush Molding: PVC

Notes:
(a) For door trim medallions
(b) Door trim medallions or upper elbow rest
(c) TPE growth target

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2012
<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>SLUSH TYPE</th>
<th>SPRAY PU</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PVC</td>
<td>TPE (TPE-S)</td>
<td>TPU</td>
</tr>
<tr>
<td>Raw material cost, $/lb.</td>
<td>Lowest</td>
<td>Moderate</td>
<td>Highest</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical skin weight, lbs.</td>
<td>3 – 3.5</td>
<td>1.6 – 2.0</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 loss</td>
<td>--</td>
</tr>
<tr>
<td>Δ E after UV exposure (2500 kJ, 89°C)</td>
<td>Highest</td>
<td>Very low (&lt; 1)</td>
<td>Very low (&lt; 1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></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></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process window</td>
<td>Narrow</td>
<td>Wide</td>
<td>--</td>
</tr>
</tbody>
</table>

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2012
• Incumbents: PVC, EPDM, (dense[solid] and foamed [sponge]), PU
• TPE challengers: o-TPV, SEBS (“TPE” or TPE-S), SEBS-V (TPES-V)
• Tier 1 portion of supply chain has undergone consolidation
• TPEs offer systems cost savings opportunities
• Hollow cross-sections competing with foams
BODY/GLAZING SEALS – MAJOR TPE TARGETS

- Rear light seal
- Sun roof seal
- Windshield (difficult target, but TPE substitution starting)
- Cowl vent seal (TPE seal reduces BSR between glass/plastic)
- Hood seal
- Wheel arch seal
- Glass run channel
- Door seal
- Belt line seal
- Door sill plate
- Mirror gasket
- Lighting seal
- Engine shield (recyclable?)

Photo Source: Toyoda Gosei
Foaming has proven to be difficult for TPVs. Recent low Shore A hardness grades (25-35) can compete with foam EPDM using solid wall TPV with hollow cross-sections.
• Difficult profitability

• Key role for systems approach (combine rigid/flexible):
  - TPV/TALC-PP compound co-extrusion vs. EPDM/ encapsulated metal

• Static and dynamic seals have different performance requirements:
  easier TPE penetration in static seals

• Key trends:
  - Tier 1 supplier consolidation
  - Penetration of TPES-Vs (starting in Europe)
  - Faster TPE penetration in Europe/Japan

• Drivers:
  - Cost save vs. EPDM seals
  - Getting to net shape via systems approach
Evolution and globalization as well as shrinking the number of platforms (claim increased quality/lower costs) is resulting in Tier 1 consolidation:

• Increases Tier 1 buying power for raw materials, reduces lead time and development costs

• Driven (in part) by OEM increased concern about financial viability of weaker suppliers

• Places increased price pressure on compound suppliers

• Strengthens Tier 1 willingness (and incentives) to compound in-house (for example - TPV compounds for body/glazing seals)

• Examples:
  - Cooper Standard acquisition of Sigit (Europe - sealing systems)
  - Faurecia acquisition of Plastal (Germany, Spain, France), exteriors
  - Plastic Omnium acquisition of Plastal Poland, exteriors
• Emerging as new TPE competitive zone
  - Rubber
  - Plastics (PVC is major incumbent)
  - TPEs (o-TPV, will be COPE and TPU type TPE opportunity targets)
• Will grow for TPEs via increased hybrids, EVs, 42 volt electrical systems
• Temperature requirements increasing:
  - Hotter engine compartments
  - Smaller conductor cross-sections/higher voltage
• Process:
  - Co-extrusion
  - Extrusion coating (flat cables)
• **The auto market**
  - Global auto sales growth likely to continue at 3-3.2%/yr.
  - Growth regions will be China, the BRI countries, (and recently N. America)
  - Global platforms will gain share (~ 40% of global prod’n. in 2015):
    - Global supply capability necessary for auto TPE suppliers
    - Global TPE specs evolving
    - Supply chain consolidation/acquisitions

• **Asia:**
  - Investment (compounding, Tier 1s) starting to look toward West
  - OEM/Tier 1 investment in China (slows?)
  - China vehicle export threat from China by 2020?
  - Importance of domestic markets
  - Supply chain in place and highly efficient/responsive

• **Demand drivers:**
  - Sustainability
  - Vehicle size downshift
  - TPO growth/vehicle may slow
  - Systems cost savings
  - Softening the interior
• **Supply chain:**
  - Resin supplier/ integrated compounders dominate PP, TPO
  - Independent compounders and integrated resin supplier/compounders share the TPE market
  - Back integration to compounding by some tier 1s

• **Materials shifts:**
  - Higher performance TPEs under-hood (COPE vs. o-TPV)
  - SEBS challenging o-TPV in some auto applications
  - SEBS slush skins vs. TPU (and PVC) (starting?)
  - Biopolymers penetration starting in the auto TPE sector
  - PP still a growth polymer (intake manifold); long glass reinforced
  - TPEs and PP compounds shift to higher performance grades