SUPPLY CHAIN DYNAMICS AND FUTURE TECHNOLOGIES IN AUTO INTERIOR TPOs AND TPEs

PRESENTED BY:
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PRESENTED AT:
SPE AUTO ENGINEERED POLYOLEFIN CONFERENCES 2016
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• Where are we on the interiors maturity curve?

• Current status/future vision

• Drivers and enablers for interiors technology

• Interiors evolution: examples of materials/process innovation

• Inter-materials and inter-process technology competition

• Interiors supply chain shifts/reverse globalization

• Provide examples for:
  - New generation smart additives
  - foams
  - skins
  - filled and reinforced compounds
  - the human machine interface (HMI)
<table>
<thead>
<tr>
<th>FEATURE</th>
<th>COMPOUND TYPE</th>
<th>STATUS</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft touch</td>
<td>SBC, TPO</td>
<td>Current(a)</td>
<td></td>
</tr>
<tr>
<td>Silky feel</td>
<td>SBC, s-TPV(b)</td>
<td>- Silicone-based</td>
<td>- Steering wheel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- s-TPV was first</td>
<td>- Other locations</td>
</tr>
<tr>
<td>Better seals</td>
<td>SBC, TPV</td>
<td>Constant improvement</td>
<td>Driven by acoustics</td>
</tr>
<tr>
<td>Improved c’set</td>
<td>SBC, o-TPV</td>
<td>Still targeting</td>
<td>- Seals, gaskets; Multiple markets</td>
</tr>
<tr>
<td>Lower hardness w/o</td>
<td>TPU, TPO, SBC</td>
<td>- TPO starting</td>
<td>Coated fabrics</td>
</tr>
<tr>
<td>compromise</td>
<td></td>
<td>- TPU difficult</td>
<td></td>
</tr>
<tr>
<td>Smart surfaces</td>
<td>TPO, SBC, conductives</td>
<td>Starting</td>
<td>Sensing and controls</td>
</tr>
<tr>
<td>Scratch resistance</td>
<td>TPO, PP compounds</td>
<td>- Steady gains</td>
<td>Has been a long term target</td>
</tr>
<tr>
<td>Controlled cell size in</td>
<td>SBC, TPU(c), o-TPV</td>
<td>o-TPV and SBC</td>
<td>Vibration damping</td>
</tr>
<tr>
<td>foams</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leather look/feel</td>
<td>SBC, TPU, TPO</td>
<td>Getting there slowly</td>
<td>IP, door trim, coated fabrics</td>
</tr>
</tbody>
</table>

(a) Via coatings, some materials innovations
(b) Via silicone-based s-TPV. Note combination of soft touch and silky feel
(c) TPU’s recent entry via bead foam

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
MATURITY CURVE FOR INTERIOR TPEs AND TPOs

TPO BUMPER FASCIA (EXAMPLE)

MIN-FILLED PP

CELLULOSIC FIBER REINFORCEMENT

AUTONOMOUS TECHNOLOGY RESPONSE

GF-PP

TPVs IN BODY/GLAZING SEALS

LGF AND CF-PP

P-TPVs IN IP SKINS

SBC-TPEs IN BODY/GLAZING SEALS (CHALLENGE TPVs)

SMART SURFACES

FOAMED INJECTION MOLDING WITH GOOD SURFACE

NANOCELLS REINFORCEMENT

SEBS IN IP SKINS VIA SLUSH MOLDING

BIO-TPEs?

SMART SURFACES

DEMAND VOLUME

MARKET INTRODUCTION

GROWTH

MATURITY

SATURATION (ORGANIC GROWTH)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016

r/mydox/Visio/Life Cycle Interiors 052316
The HMI Evolution/Smart Surfaces:
- Buttons → touch screens → smart materials, thin film technologies, incorporate into skins
- Wi-Fi interiors: technology drivers for voice activation, need for better acoustics

Convenience and Comfort:
- Trim materials: soft touch, luxury feel, even lower gloss
- Continued VOC reduction
- improved ergonomics

Stronger, Lighter, and Parts Consolidation:
- Stronger/lighter materials: weight reduction
- Parts integration (especially electronics), “smart” materials/surfaces where feasible

Environmental, Recycling:
- Today: Lower oil/gas price challenge recycle efforts /fuel economy
- Continued drive for sustainability
- Government directives as driver
- Increase space

SOURCE: INTEVA; ROBERT ELLER ASSOCIATES LLC, 2016
Model: Renault Ondelios Concept

Note:
- Integration of electronic functions
- Skin as display/switch surface
- Elimination of buttons
- Clean HMI interface
QUALITY SPECTRUM OF COCKPIT AND DOOR TRIM PANEL SKIN TECHNOLOGIES

SOURCE: KRATON

- TPE slush (aliphatic and aromatic+IMC)
- PU RIM (aliphatic and aromatic+IMC)
- PU spray (aliphatic)
- TPO-2 Foil
- TPO Foil
- PVC Foil
- TPE/PP 2k
- PP, PC, ABS, etc. injection molding

cost
125%
100%
75%
50%
25%
0%

low medium high

interior value added
Construction: DecoJect® thin foil
Fabrication process: Back injection; in-mold graining
Benefits:
   Attraction feature
   Durable soft-touch surface
   Customizable
   Processing advantages vs painting
Note: Example of trend toward translucent/transparent “windows”
Incorporate sensing/signal function?
AUTOMOTIVE TPE/TPO TARGETS

AUTO SYSTEMS TARGETS

BODY/GLAZING SEALS*

BODY SEALS*

GLAZING SEALS*

HVAC

FLAPPER DOOR GASKETS*

AIR DUCTS

OTHER

EXTERIOR

FASCIA

PANELS

INTERIOR(a)

BOOT/BELLOWS

HOSE/TUBE/DUCT(b)

ELECTRICAL

AIRBAG DOORS*

SKINS

COATED FABRIC*

SEVERAL PROCESSES

FLOOR SYSTEMS*

ACOUSTIC*

MATS*(c)

CARPET BACKING*

NOTES:
* = RUBBER/TPE INTERFACE
(a) DOES NOT INCLUDE RIGID-FILLED TPOs USED IN INTERIORS
(b) E.G., FUEL, COOLANT, OILS, OTHER HOSE
(c) HIGH GROWTH APPLICATION (in SEBS)/SBS

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
Note:
- Indicates recent share gain, “smart” coatings could enter several material types
- Polyurethane dispersion (PUD) coated fabrics gaining share, improved TPO grades and SEBS may challenge
- Growth process

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
TPE FAMILIES . . . CHANGING COMPOSITION, POEs AS MODIFIERS, BROADENED PROPERTY FOOTPRINTS

(a) Recyclate-based TPV
(b) e.g. Dow Infuse®
(c) Specialty grades of TPE produced by independent compounders or in-house via reactive compounding®
(d) e.g. Hipex from Kraiburg
(e) e.g. COPE, COPA, TPU; PVC-based TPEs not shown
(f) Can be made during extrusion compounding of TPO

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
INTERIOR DESIGN STEPS: PATHS FOR TECHNOLOGY INNOVATIONS

CONSUMER NEEDS/WANTS

TECHNICALLY FEASIBLE?

MATERIALS AVAILABILITY
MEET SAFETY/ CAFE STANDARDS
FABRICATION PROCESSES

HARMONY BETWEEN INTERIOR COMPONENTS
LAUNCH TIMING
COMMERCIAL VIABILITY

GOOD DESIGN

GOV’T DIRECTIVES/STANDARDS

HAS PROFITABILITY BEEN DRIVEN OUT OF THE SUPPLY CHAIN ELEMENT?
HAS LED TO SUPPLY CHAIN CONSOLIDATION AND ACQUISITIONS

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
INTERIOR EVOLUTION VIA NEW MATERIALS AND PROCESSES

- DIRECT p-TPVs
- IN-MOLD PROCESSES
- NEW FOAMING METHODS
  - SKINS
  - MULTI-LAYER STRUCTURES
- ACOUSTIC MAT’LS.
- IMPROVED BODY SEALS
- SKINS
- SOFT TOUCH
- SILKY TOUCH
- TPVs IN MOLD PROCESSES
- NEW FOAMING METHODS
- MULTI-LAYER STRUCTURES
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- IMPROVED BODY SEALS
- ACOUSTIC MAT’LS.
- CURRENT INTERIORS
  - QUIET
  - LIGHTING
  - LOW VOC
  - SMART
  - RENEWABLE SOLUTIONS
  - STRUCTURE WITH WEIGHT SAVING
  - DOOR TRIM
  - OVERHEADS
  - NATURAL FIBERS
  - NANOCELLULOSICS
  - CARBON FIBER/GLASS REINFORCEMENT
- GRAPHENE
- CNTs
- SENSORS
- TOUCH SWITCHES
- BIO-PLASTICS
- NATURAL FIBER REINFORCEMENTS
- LUMINESCENT SURFACE
- IMAGE PROJECTION
- PLASTICIZER SHIFT
- ELIMINATE PLASTICIZERS/OILS

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
SPEPPO 2016/interior solutions 062116
LIGHTING
- LUMINESCENT SURFACE
- IMAGE PROJECTION
- PLASTICIZER SHIFT
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- IMAGE PROJECTION
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SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
SPEPPO 2016/interior solutions 062116
Stalling Out

The average fuel-economy of light vehicles sold in the U.S. increased by about 5 mpg over the past eight-plus years but has been flat recently.

26 miles per gallon

April 2016
25.2 mpg

October 2007
20.1 mpg

Source: Michael Sivak and Brandon Schoettle, University of Michigan Transportation Research Institute
THE WALL STREET JOURNAL.

COMMENTS: ROBERT ELLER ASSOCIATES LLC, 2016

NEW LIGHTWEIGHT SOLUTIONS NEEDED: PLASTICS, COMPOSITES, TPEs/TPOs COMPETE WITH ALTERNATIVES

GETTING TO 54.5 BY 2025 DIFFICULT WITH SALES MIX SHIFT TO PUTs AND SUVs
# TPO/TPE/PP COMPOUND ENHANCEMENT EXAMPLES

<table>
<thead>
<tr>
<th>BASE COMP’D</th>
<th>ENHANCER</th>
<th>TO OBTAIN</th>
<th>APPLICATIONS</th>
</tr>
</thead>
</table>
| TPO, PP, Composites | - Carbon nanotubes (CNTs)  
- Graphene          | Conductivity       | - Smart surfaces, switches  
- Touch sensors (replace membrane switches) |
| TPO, PP            | Blowing agent                   | Foam structure     | - Light weight  
- Decorative effects  
- Soft touch         |
| SBCs              | Crosslinker                      | - Increase c’set  
- Challenge o-TPV   | - Body seals  
- Plugs              |
| PP                | - Nanocellulose  
- Carbon fiber      | Mechanical properties | Semi-structural |
| PP                | Natural fibers                   | - Adequate mechanicals  
- Light weight       | - Door trim  
- Overhead structures |
COMPETITION WITHIN A TPE TRIAD (EXAMPLES)

o-TPV

COPE (heat resistance advantage)

Many apps:
- Body/glazing seals
- Soft touch
- Medical

P-TPV

SEBS

Slush (IP skins)
Injection molded

TPO

Improved soft touch

Bottom line:
- o-TPV under attack, on the defensive
- TPOs steadily improving via catalysts technology, compounding

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
## GLOBALIZATION REVERSE FLOW: CHANGING THE AUTOPLASTICS SUPPLY CHAIN

<table>
<thead>
<tr>
<th>NAFTA/EUROPE</th>
<th>FLOW</th>
<th>ASIA</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 OEMs</td>
<td>TO BENEFIT FROM HIGH GROWTH POTENTIAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 RESIN SUPPLIERS/ COMPOUNDERS/MOLDERS</td>
<td>TO FOLLOW OEM CUSTOMERS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 TECHNOLOGY FLOW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 DOMESTICS ESTABLISH SUPPLY CHAIN TO WESTERN TRANSPLANTS</td>
<td>TECHNOLOGY BARRIERS ARE POROUS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 VIA ACQUISITION/ GREENFIELD</td>
<td>ASIAN OEMs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 TO SERVE DOMESTICS AND WESTERN OEMs WITH WHOM BUSINESS WON IN ASIA</td>
<td>ASIAN RESIN SUPPLIERS AND COMPOUNDERS</td>
<td>COST ADVANTAGE TRANSFERABLE?</td>
<td></td>
</tr>
</tbody>
</table>

**SOURCE:** ROBERT ELLER ASSOCIATES LLC, 2016
• Paths to market:
  - Greenfield
  - Tolling
  - Distribution of imported compounds
  - Follow the customer

• Forces driving supplier transplants to NAFTA:
  - Access Western markets
  - Learn Western business/marketing skills
  - Access Western distribution channels (in some cases via tolling)
  - Employ large cash holdings from years of profitable operations in China
  - In some cases, serve existing customers in West that were developed in China
  - Access to rich, stable Western markets
  - Need for “global” presence

• Some Chinese compounders have moved up the quality/performance scale:
  LOCAL → GLOCAL → GLOBAL

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
## SECOND WAVE OF TRANSPLANT COMPOUNDERS (EXAMPLES)

<table>
<thead>
<tr>
<th>SUPPLIER</th>
<th>HOME</th>
<th>PATH TO NAFTA</th>
<th>ROLE</th>
<th>COMP’D TYPE</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>King Fa</td>
<td>China</td>
<td>Greenfield</td>
<td>Compdr</td>
<td>TPO</td>
<td>Also in Germany</td>
</tr>
<tr>
<td>LCY</td>
<td>Taiwan</td>
<td>Acquisition</td>
<td>Resin</td>
<td>SBCs</td>
<td></td>
</tr>
<tr>
<td>Mitsubishi/CTS</td>
<td>Japan</td>
<td>Acquisition (France)/ existing U.S. plant</td>
<td>Compdr</td>
<td>SEBS</td>
<td>Acquired CTS (France) to get presence in Europe</td>
</tr>
<tr>
<td>Polymax</td>
<td>China</td>
<td>Greenfield</td>
<td>Compdr</td>
<td>SEBS, TPV</td>
<td></td>
</tr>
<tr>
<td>Pret</td>
<td>China</td>
<td>Acquisition</td>
<td>Compdr</td>
<td>TPO</td>
<td>Acquired Wellman</td>
</tr>
<tr>
<td>So.F.teR</td>
<td>Italy</td>
<td>Greenfield</td>
<td>Compdr</td>
<td>SBCs, TPV</td>
<td>In Mexico, U.S., LATAM</td>
</tr>
<tr>
<td>TSRC</td>
<td>Taiwan</td>
<td>Acquisition</td>
<td>Resin supplier</td>
<td>SBCs</td>
<td>Expand compounding?</td>
</tr>
</tbody>
</table>

Note: Does not include some major Chinese compounders

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart skins</td>
<td>Luminescent skins, lighting function, transparent windows(b), sensing</td>
</tr>
<tr>
<td>Indentation recovery</td>
<td>Important for contact surfaces(a)</td>
</tr>
<tr>
<td>Laser score read-through</td>
<td></td>
</tr>
<tr>
<td>Tailoring haptics(c)</td>
<td>Via controlling polyolefin foams/ surface coating</td>
</tr>
<tr>
<td>Performance requirements</td>
<td>- Abrasion resistance; Chemical resistance&lt;br&gt;- Stain cleaning; Denim (blue dye cleanability)(e)</td>
</tr>
<tr>
<td>China interior emissions</td>
<td>Becoming more severe(d)</td>
</tr>
<tr>
<td>requirements</td>
<td></td>
</tr>
<tr>
<td>Moving into hand wrap applications</td>
<td>Requires different stiffness/compression requirements</td>
</tr>
<tr>
<td>More leather-like look</td>
<td>Coated fabrics becoming competitive with leather</td>
</tr>
<tr>
<td>Structural improvements</td>
<td>Reinforcements (nanocellulose, carbon fiber)</td>
</tr>
</tbody>
</table>

Note:
(a) Door trim panel, armrest, console cover  
(b) Display, lighting, switching/sensing functions  
(c) Via both surface touch coatings and foam modification  
(d) Interior emission requirements in China are currently more severe than U.S. or Europe  
(e) Requirements increased at GM/Ford 1-2 years ago (requires compromise between blue dye and coffee stain cleanability)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
MATERIALS:
- Natural fiber reinforcement
- Cellulosic nano reinforcements
- Role for graphenes
- Role for carbon fibers
- Smart textiles/skins and thin film sensors

PROCESSES:
- 3D printing
- Smart/Luminescent coatings
- Slush molding of SBCs
- Skins injection processes

BROADER FUNCTIONS:
- Lighting/display
- Sensing/switching
- Voice activation
- Shielding

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
CARBON: MANY FORMS ➔ INNOVATIVE APPLICATIONS

MOS = Metal-organic framework

SOURCE: GRAPHENICS
GRAPHENE APPLICATIONS IN AUTO INTERIORS (EXAMPLES)

SMART TOUCH
- Hands on sensing
- Seat comfort
- Auto adjust
- Heating

SMART DISPLAYS

SOURCE: GRAPHENICS; UNIVERSITY OF ALABAMA OFFICE OF VICE PRESIDENT FOR RESEARCH AND DEVELOPMENT; ALABAMA INNOVATION AND MENTORING OF ENTREPRENEURS
POTENTIAL GRAPHENE APPLICATIONS IN AUTO INTERIORS (Cont’d.)

CONDUCTIVE FABRICS/THREAD

NEW COATINGS

SOURCES: GRAPHENICS; UNIVERSITY OF ALABAMA OFFICE OF VICE PRESIDENT FOR RESEARCH AND DEVELOPMENT; ALABAMA INNOVATION AND MENTORING OF ENTREPRENEURS
GROWTH MARKET FOR SBC-TYPE TPEs: FLOOR MATS

- Early-mid growth stage
- OEMs entering to capture market
- Ability to add styling cues
- Post consumer, post industrial recycle
- High value – add
- An aftermarket product
- Key enabler: laser mapping
- Based on SEBS/SBS formulations

• Typical hardness 50-75 Shore A
• Non slip, scratch /abrasion resistant
• Can be used in multiple positions
• Easily colored
• High capital investment for molding equipment

PHOTO: THERMOFLEX CORP; HEXPOL TPE; COMMENTS: ROBERT ELLER ASSOCIATES LLC, 2016
• Who will be the customer: Auto OEMs or “technology” sources (GM or Google)?

• New functions required → new materials opportunities

• Who will be captain of the supply chain driving innovation and “shaping” markets?

• Will impact grades be required?

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
CONNECTED/AUTONOMOUS CAR: NEW FUNCTIONS → INTERIORS OPPORTUNITIES

- Acoustics
- Shielding
- “Windows”/transparent sections in the surface
- Lighting
- Image projection
- Sensing
- Damping
- Conduction
- Signaling/data transmission

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2016
THE FRONTIER FOR INTERIOR SKINS: SOME EXAMPLES

Today

- Soft touch
- Solid interior
- Standard “islands” in s-TPVs
- SBCs dominated by standard grades, some specialty grades

Future

- Soft touch - still
- Foamed or solid interior
- New s-TPV grades (new islands/ some new seas)
- Greater share of specialty grades in SBC. Lower MW allows plasticizer reduction or elimination
- TPEs used in “smart” applications, possibly via use of graphenences
- “Silky” feel via compound properties + soft touch
- Haptics via coating
- Elasticity and vibration damping control
- More versatile “TPOs”
SUMMARY

• Autonomous/semi-autonomous cars/EVs will create opportunities for new generations of TPOs and TPEs capable of:
  - integrating electronics
  - providing display, sensor and switching functions
  - operating as “smart surfaces”
  - improving acoustics
  - acting as display surfaces

• The major drivers/opportunity frontiers are:
  - weight save (new control/sensing modes (voice, light, motion, touch))
  - luxury look and feel (haptics)
  - process improvement: replace outdated component fabrication technology
  - role for 3D composite manufacturing: new materials/process combinations
  - electrical/electronic architecture
  - new generation fillers/reinforcements (nanocellulosics, carbon fibers, graphenes, carbon nanotubes)
  - improved conductive materials
• Continued competition in skins:
  - inter-materials; inter-process competition
  - waiting for SBC slush

• TPO skins gaining share on basis of:
  - cost
  - in-house compounding(to produce p-TPVs) and radiation crosslinking
  - controlling rheology
  - new fabrication technologies

• Skin/foam technologies: evolving to meet higher standards/improved performance

• Body/glazing seals: continued growth and broadening of the applications footprint for TPEs
THANKS FOR YOUR ATTENTION

Thanks for inputs from:
Ron Price
Sam He