CURRENT AND FUTURE PROSPECTS FOR TPOs AND TPEs IN AUTO INTERIORS

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PREPARED FOR:
SPE TPO AUTOMOTIVE ENGINEERED POLYOLEFINS 2015
DETROIT, MI (USA)
October 6, 2015
b/mydox/SPETPO 2015/rea present 2015
TODAY’S OBJECTIVES

• Global (interior) demand factors
• Forecast what is coming in interior TPOs and TPEs
• Inter-materials and inter-process competition in interiors
• Growth/value enablers
• Targets
• Paths to innovation and growth in interiors:
  - foams
  - soft touch technology
  - skins
  - body/glazing seals

NOTE: See abbreviations and TPE family chart in Appendix
EMERGING MARKET GROWTH RATES HAVE SLOWED

- Slowed auto growth
- Renminbi devaluation
- NAFTA investments

- Real devaluation
- Economic slowdown
- Rising
- Attracting investment

PHOTO SOURCE: THE ECONOMIST
DEMAND GROWTH FOR INTERIOR PP, PP COMPOUNDS, TPOs

• NAFTA:
  - LV production continues at ~ 16.5-17MM LV/yr
  - 2015 demand for interior PP, PP compounds, TPO = 1428 MM lbs (649 Kt) @ 85 lbs/LV (39 kg/LV)

• CHINA:
  - Yuan devaluation in China will slow vehicle production and affect PP resin, PP compound and TPO demand
  - Production in 2014 was 24 MM LVs
  - Interior demand in 2014 was 1725 MM lbs. (784 kT) at ~ 75 lbs. (34 kg)/LV
  - LV production slowdown will moderately affect global demand growth
China vehicle production slowdown and potential effect on PP + TPO demand

China vehicle Production in 2014 was 24 MM LVs

PP + TPO 2014 = 1725 MM lbs. (784 kT) at ~ 75 lbs. (34kg)/V

SOURCE: ROBERT ELLER ASSOCIATES LLC AND GLOBAL POLYMER SOLUTIONS, 2015
TPE FAMILIES . . . CHANGING COMPOSITION, POEs AS MODIFIERS BROADENED PROPERTY FOOTPRINTS

TPE FAMILIES

POEs ENTERING

OLEFINIC (o-TPEs)

STYRENIC (SBCs)

SUPER-TPVs

OTHER e-TPEs (e)

POE

OLEFINIC (o-TPEs)

STYRENIC (SBCs)

SUPER-TPVs

OTHER e-TPEs (e)

POEs ENTERING

NEW LOW MW GRADES OPEN NEW APPLICATIONS

Notes:
- Production dominated by resin suppliers
- (a) Recyclate-based TPV
- (b) e.g. Dow Infuse™ olefin block copolymers
- (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

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2015
COMPETITION IN INTERIOR SOFT TRIM/SOFT TOUCH

SOFT TRIM PROCESS MATERIALS OPTIONS

INJECTION

CONV. INJECTION

2-SHOT

OVERMOLD

BACK INJECTION

SOFT TOUCH PAINT

SEBS

TPV

TPU

2-SHOT

OVERMOLD

BACK INJECTION

RISING STAR

SLUSH MOLD

VAC FORM FOILS

COATED FABRICS

FLUSH MOLD

VAC FORM FOILS

COATED FABRICS

SEBS (Starting)

TPU

TPU BLENDS

PVC

TPO

SEBS (Starting)

SEBS

TPV

TPU

SLUSH MOLD

VAC FORM FOILS

COATED FABRICS

RISING STAR

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2015
<table>
<thead>
<tr>
<th>SKIN TYPE</th>
<th>MY ‘16 DEMAND SHARE (%)</th>
<th>MAJOR FABRICATION PROCESS</th>
<th>NOTE/TREND</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>25</td>
<td>Slush mold</td>
<td>Incumbent. Low temp deployment resolved</td>
</tr>
<tr>
<td>TPO</td>
<td>50</td>
<td>- Extrusion - Calendering - Thermoform</td>
<td>- May use in-house p-TPV in formulation - Compact and foam bi-laminate types - Includes injection molded soft skin - Gaining share/lower cost</td>
</tr>
<tr>
<td>TPU</td>
<td>20</td>
<td>Spray; slush</td>
<td>Higher end vehicles, Japanese production</td>
</tr>
<tr>
<td>SBC</td>
<td>-</td>
<td>Slush</td>
<td>Under evaluation.</td>
</tr>
<tr>
<td>Leather/textile</td>
<td>5</td>
<td>Hand wrap</td>
<td>High end vehicles only</td>
</tr>
</tbody>
</table>

Note: Share of soft IPs on light vehicles produced and imported

Key trends:
- Grain reproduction continues to improve for all processes
- Dual hardness/dual color increasing share
- Property improvements: VOC decrease, scratch resistance improvement, soft tactile feel, foam improvement (resilience, heat resistance, softness), weight save, weatherability
- In house compounding of TPO formulations for cost save

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2015
PATENTED SLUSH MOLDED HSBC (TPE-S) TECHNOLOGIES

• Inteva
  - Uses PP/SEBS compound (per patent)
  - Currently commercial in North America (await customers)
  - Issues:
    -- Scratch/mar resistance (mostly resolved)
    -- Foam bonding (requires surface treatment)
    -- Sustainability

• Kraton/So.F.teR
  - Uses special low molecular weight HSBC compounded with PP and polybutene (patented)
  - Currently under development/commercial applications yet to be announced
  - New Formosa plant comes on stream in 2016 with capability to supply low molecular weight HSBC resin.
SLUSH MOLDED TPE-S INSTRUMENT PANEL SKINS

Photo: So.F.teR
Example multi-material (2-shot) Door Trim Panel:
• Application: Door trim (dark areas)
• TPE Type: o-TPV, challenge from SEBS

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: TPO, SEBS (TPE-S), p-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, TPO bil-amineate sheet)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2015
Grain reproduction: key parameter

- Hidden airbag doors (non-laser score) eliminates read-through
- Reduced skin weight/improved haptics/grain

PHOTOS: ROBERT ELLER ASSOCIATES LLC, 2015
Note:
- Indentation recovery important property for TPO foam bi-laminates for:
  -- door trim panels
  -- armrests
  -- console covers
- Requires balance between recovery and haptics

PHOTO: O’SULLIVAN/HORNSCHUCH PORTA LIGHT™
CHEMICAL/STAIN RESISTANCE REQ’TS BROADENING FOR TPO SKINS (a)

Note: Haptics can be tailored via soft touch coatings (a) Also for coated fabrics (e.g. in seating). Especially with trend toward lighter colors

PHOTO: O’SULLIVAN FILMS; COMMENTS: ROBERT ELLER ASSOCIATES LLC, 2015
Cutline (beltline) seals (BLS)

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

Production process: extrusion

TPE Candidates: o-TPV

Material replaced: EPDM

Glass run channel seals (GRC)

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

Production process: co-extrusion (dual hardness)

TPE Candidates: o-TPV

Material(s) replaced: EPDM plus flock
Key benefits
- durable sealing performance
- functional integration and weight reduction
- cost-effective thermoplastic processing vs EPDM
- matte surface (color match to GRC/BLS)
- excellent UV and aging resistance
- reduced breakage

Fabrication processes
- stretch-fit glass encapsulation
- direct glass encapsulation by injection molding
- o-TPV, TPE-S, TPU, PVC/NBR

Major incumbent
- EPDM
• Dominant Incumbent: EPDM

• TPE Challengers: o-TPV, SEBS

• Dynamic vs. static requirements differ:
  - Dynamic seals require low compression set
  - Acoustic/wind noise performance (requirements increasing)
  - Adhesion (to glass, polycarbonate)
  - Parts integration opportunities
  - Surface friction properties (controlling COF)
  - Meeting regional performance differences
  - Overcoming institutional resistance
  - Small cars (lower requirements, profitability challenge)

• Movement into:
  - primary door seals
  - trunk seals
APPLICATIONS FOR r-TPVs: ECO-FLEX™ RTPV

SOURCE: SYNESIS
Brake pedal pad

Material: Eco-Flex r-TPV
Benefits:
- Cost/weight reduction vs TS rubber
- Post consumer recyclate content
- Thermoplastic processability

SOURCES: SYNESIS; A. SCHULMAN
• Inter-TPE competition:
  - SBCs continue to challenge o-TPVs, where over-engineered
  - SBCs, COPE-type TPEs competing in airbag doors
  - COPE replacement of o-TPVs in CVJ boots almost complete
  - COPE vs o-TPV when higher heat required
  - OBCs vs SEBS
  - POEs vs SBCs

• Formulation shifts:
  - SBCs and p-TPVs used in “TPO” formulations
  - OBCs in SBC formulations
  - Direct extrusion compounded p-TPVs challenge purchased p-TPVs

• Upgrading:
  - Radiation crosslinking of TPOs (e.g. for skins)
  - Higher heat SEBS formulations (to challenge o-TPVs)
INTERIOR TPO/PP/TPE FOAM TARGETS AND FOAM TYPES

Foam types (color indicates foam type):
- Bead foam(a)
- Sheet foam
- Extruded TPE

Note: Injection molded foams not shown

Note: (a) TPU bead foams (e.g. Infinergy™) from BASF could penetrate interiors market

PHOTO: So-F-Ter
TARGETS: ROBERT ELLER ASSOCIATES LLC., 2015
## IMPROVEMENT TARGETS IN INTERIOR SKIN/FOAM BI-LAMINATES AND COATED FABRICS

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>NOTE</th>
</tr>
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<tbody>
<tr>
<td>Indentation recovery</td>
<td>Important for contact surfaces (a)</td>
</tr>
<tr>
<td>Laser score read-through</td>
<td>Almost all IP skins have converted to invisible passenger side driver-side airbags</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 (b)</td>
</tr>
<tr>
<td></td>
<td>- Stain cleaning; Denim (blue dye cleanability) (e)</td>
</tr>
<tr>
<td>EU interior emissions req’ts</td>
<td>Becoming more severe (d)</td>
</tr>
<tr>
<td>Moving into hand wrap applications (a)</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>
</tbody>
</table>

Note:
(a) Door trim panel, armrest, console cover
(b) NEP (N-ethyl pyrrolidone) resistance requirement being phased out in Europe (VDA standard)
(c) Via both surface touch coatings and foam modification
(d) Interior emission requirements 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)

SOURCES: BENECKE KALIKO, TORAY, O’SULLIVAN
TPO SKIN/FOAM BILAMINATE LAMINATE FOR AUTO INTERIOR APPLICATIONS

**APPLICATION** | **SKIN** | **FOAM**
--- | --- | ---
Instrument panel | 0.6-0.8 | 2-3
Wrap | 0.5-0.7 | 1

TYPICAL THICKNESSES, mm:
Laser score-ability for airbag deployment dictates minimum thickness requirement

1- Lacquer finish
2- Compact TPO skin
3- Foam layer
4- Primer where necessary

PHOTOMICROGRAPH: BENECKE KALIKO, 2015

PHOTO: ROBERT ELLER ASSOCIATES LLC, 2015
CURRENT TREND: NON-LASER SCORED AIRBAG DESIGNS

• Trend for instrument panels using TPO+ foam bi-laminates and vacuum forming (IMG) is toward non-laser scored airbag designs

• Laser scoring can be susceptible to “read through” especially after high temperature exposure and can exhibit a witness line around the perimeter on the A-surface of the IP

• Laser scoring requires specialized equipment (capital)

• Non-laser scored designs require unique foam and TPO modification to meet performance requirements

• OEM’s and Tier-1’s use proprietary designs for airbag and substrate

• Toray Plastics has developed 2nd generation of ToraSoft™ (SR28) foam to work in non-laser applications

• Bi-laminate suppliers have non-laser score solutions.

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2015
LASERSCORE READ-THROUGH-RESOLVABLE VIA
NON-LASER SCORED TECHNOLOGY

PHOTO: TORAY PLASTICS (AMERICA), INC.
NEW GENERATION FOAM FOR IMPROVED HAPTICS

PHOTO: TORAY PLASTICS (AMERICA), INC.
AIR DUCTS: TARGET FOR POLYOLEFIN 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, 2015
PEARLESCENT FILMS: APPLICATION FOR FOAM TECHNOLOGY

Pearlescent film joins auto interior upgrade race
Application: 2015 Nissan Murano

PHOTO: Wards Automotive
INNOVATION EXAMPLE: COMBINING MATERIALS TECHNOLOGIES ➔ SYNERGY

HIGH STIFFNESS/LIGHTWEIGHT SHEET

Combination yields:
- high stiffness from graphene-like layers
- lightweight and thickness effect of polyolefin foam
- easily molded

Target applications:
- auto
- building/construction
- electronics

PHOTO: SEKISUI CHEMICAL CO., LTD

GRAPHENE

Scanning probe microscopic image of graphene, an allotropic form of carbon in a 2 dimensional, atomic scale hexagonal lattice. One atom at each vertex.
- 100x stronger than steel
- efficient heat, electrical conductor
- nearly transparent
- used in semiconductor, electronics,
- battery, composites industries

PHOTO: WIKIPEDIA
CABLE MANAGEMENT SYSTEMS

• Low voltage cable:
  - Cable wiring/vehicle will grow from 1.5 miles to 2.5 miles
  - Opportunities in low voltage cable for SBC compounds, o-TPVs and COPEs

• Connectors: Number of connectors will grow from 280 to 350/vehicle

• COMPUTERS
  - Average number/vehicle will increase from 26 in 2006 to 40 in 2018
PRINTED CIRCUITS
RF SHIELDING
HOUSINGS
HIGH TEMPERATURE PLASTICS AND TPEs
WIRE/CABLE
SEALS
FLEXIBLE CONNECTORS

PHOTO SOURCE: NEW YORK TIMES

Trunk of a self steering vehicle
# A VIEW OF THE FUTURE PROSPECTS IN INTERIORS

<table>
<thead>
<tr>
<th>TYPE</th>
<th>KEY GROWTH DEVELOPMENTS</th>
</tr>
</thead>
</table>
| TPOs    | - Growth in skins vs several current/future competitors  
- Incorporate p-TPVs into TPO formulations  
- “TPO” coated fabrics  
- Wider use of foams  
- Improved performance  
- Foam combination with graphenes |
| SBCs    | - Competing with o-TPV in body/glazing seals  
- Slush skins  
- Coated fabrics  
- Increased use in mats |
| o-TPVs  | - Growth of p-TPV in hybrid body/glazing seal systems (corner molding)  
- Continued penetration into body/glazing seals  
- Broader use of r-TPVs  
- Silky feel surfaces  
- Non-slip surfaces |
| PP Comp’d’s | - High flow grades for thinner moldings  
- Lightweight fillers  
- Natural fibers substituting for glass fibers  
--Continued growth of long glass reinforced PP(LGF-PP) |

SOURCE: ROBERT ELLER ASSOCIATES LLC 2015
SUMMARY

• China:
  - economic slowdown: moderate effect on global growth of interior TPOs and TPEs
  - competition in auto TPOs: more intense than in NAFTA
  - outward investment: in NAFTA TPO and other autoplastics compounds

• Continued competition in skins:
  - inter-materials; inter-process competitions
  - waiting for SBC slush

• TPO skins gaining share on basis of:
  - cost
  - in house compounding and radiation
  - controlling rheology

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

• Body/glazing seals: Continued growth and broadening of the applications footprint for TPEs

• r-TPVs: Usage increasing

• New TPE opportunities: electrical architecture/autonomous vehicles/connectivity
THANKS FOR YOUR ATTENTION

Management DECISIONS

ANALYSIS

Robert Eller Associates LLC
CONSULTANTS TO THE PLASTICS AND RUBBER INDUSTRIES

Thanks for contributions from:
Ron Price - SPE TPO Committee
Norm Kakarala - SPE TPO Committee
Jesse Baldwin - Toray Plastics (America)
Greg Ratlief - O’Sullivan/Hornschuch
Thomas Malner - Benecke Kaliko

See Appendix for definitions and TPE family chart
APPENDIX A-ABBREVIATIONS USED

• o-TPV - Olefinic TPV

• p-TPV - partial olefinic TPV (o-TPV)

• SBC - Styrene block copolymer (also TPE-S and HSBC for hydrogenated version)

• PVC/NBR- PVC/Nitrile rubber blend

• POE - Polyolefin elastomer

• COPE (TPEE) – Co-polyester type TPE

• TPO - Thermoplastic polyolefin

• TPU - Thermoplastic polyurethane. Used alone and as additive

• s-TPV - Super TPV (several types)

• OBC - Olefin block copolymer (e.g. INFUSE™ from Dow Elastomers)