High performance LSZH thermoplastic polyurethanes (TPU) for wire and cable
Polymers in Cables 2018
Oliver Muehren, Christopher A. Bradlee
Agenda

1. Overview of Plastic Polymer Market
2. Wire and Cable Applications of TPU
3. FR and Physical Performance of Elastollan TPU
Plastic Material Consumption
Worldwide 2016 – 330 million tons

- Polyethylene: 33.5%
- Polypropylene: 22.0%
- Polyurethane: 6.0%
- PS/EPS: 7.0%
- PET: 7.0%
- PVC: 15.5%
- ABS, ASA, SAN: 4.0%
- Others: 5.0%
TPU – World-Market 2017

Source: Bluebook and BASF estimations.
Wheel speed sensor cables
Cabling for rear view camera
Charger cables for electric vehicles

Requirements:

▶ flexibility, even at lowest temperatures
▶ resistant against mechanical stress, microbes, weathering, humidity
▶ wide temperature range; halogen free flame retardant
▶ recyclable, easy to process; able for being spiralized
▶ EN 50620 / EVM-1
Charger cables for electric vehicles
Industrial applications

Cables for robots and automatic devices need to be flexible, abrasion resistant and resistant to long term stress. Sheathed with TPU even with a halogenfree flame retardant grade they achieve a long lifetime.
Industrial applications
Drag chain and robotic cables
Injection molding of TPU or PU-systems

Cable connectors, grommets and plugs made of Elastollan for excellent flexibility, watertightness, tear and impact strength.
TPU for consumer electronics
Elastollan

Key features

- Hardness: 93,3 ± 0,5 Sh A
- Tensile strength 20,3 ± 1,4 MPa
- Elongation at break: 488 % ± 27 %
- Tear strength: 63,9 ± 3,3 N/mm
- Abrasion loss: 74,4 ± 6,5 mm³
- Excellent chemical resistance
- Halogen free flame retardant, UL VW1
- Outstanding reliability
Flame Retardance in TPU is a Balancing Act

- TPU is flammable, so... have to add a mineral filler to stop the burn
- Adding mineral filler degrades the physical properties of the TPU
- The more filler......the more degradation in properties
- The **challenge** in finding a balance between **flame resistance** while maintaining the required **physical properties**

How do you achieve superior FR protection, while still having the physical performance of a TPU
From cone data to Petrella* Plot


![Graph showing PHRR and THR](image)

**t_{ig}**

(ISO 5660-1, 100x100x5mm samples burned with 35kW/m²)

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Progression of FR Elastollan TPU Development

Time line: Gen 1 – 1992, Gen 1.5 – early 2000’s, Gen 2.0 – 2012, Gen 3.0 - 2017
Elastollan 1192 A 10 FHF and 1192 A 11 FHF

Density [g/cm³] 1,25
Tensile strength [MPa] 17
Elongation at break [%] 550
Abrasion [mm³] 80
commercialized
Elastollan 1192 A 10 FR

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density [g/cm$^3$]</td>
<td>1.20</td>
</tr>
<tr>
<td>Tensile strength [MPa]</td>
<td>32</td>
</tr>
<tr>
<td>Elongation at break [%]</td>
<td>500</td>
</tr>
<tr>
<td>Abrasion [mm$^3$]</td>
<td>90</td>
</tr>
</tbody>
</table>
# Mechanical properties

<table>
<thead>
<tr>
<th>Material/Property</th>
<th>Standard/Method</th>
<th>1192A10FR</th>
<th>1185 A 10 FHF</th>
<th>1185A10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>DIN 53504-S2</td>
<td>32-36</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>Elongation@break</td>
<td>DIN 53504-S2</td>
<td>550</td>
<td>600</td>
<td>580</td>
</tr>
<tr>
<td>Density</td>
<td>DIN EN ISO 1183-1-A</td>
<td>1,20</td>
<td>1,23</td>
<td>1,12</td>
</tr>
<tr>
<td>Tear strength</td>
<td>DIN ISO 34-1Bb</td>
<td>65</td>
<td>60</td>
<td>70</td>
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<tr>
<td>Hardness</td>
<td>DIN 53505</td>
<td>92</td>
<td>89</td>
<td>87</td>
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<tr>
<td>Abrasion</td>
<td>DIN ISO 4649-A</td>
<td>90</td>
<td>35</td>
<td>25</td>
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</table>
### Corrosivity - Flammability

- **Acidity of gases during combustion**
  (DIN EN 50267-2-2:1999)

- **Burning behaviour by oxygen index**
  (ISO 4589 Part 2:2006-06)

<table>
<thead>
<tr>
<th></th>
<th>1192 A 10 FR</th>
<th>1185 A 10 FHF</th>
<th>1185A10</th>
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</thead>
<tbody>
<tr>
<td><strong>Elastollan®</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>pH-value</strong></td>
<td>8.8</td>
<td>8.9</td>
<td>7.4</td>
</tr>
<tr>
<td><strong>Conductivity [µS/mm]</strong></td>
<td>23</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td><strong>LOI - Limiting Oxygen Index [%]</strong></td>
<td>29</td>
<td>24</td>
<td>22</td>
</tr>
</tbody>
</table>
Heat release over time
Hydrolysis
at 85 °C / 85 % relative humidity

Elastollan 1192A10FR has an excellent hydrolytic stability.

*measured on 1.6mm films
Elastollan 1185A HFFR

Properties:

**Reduced smoke density and toxicity**

- Density [g/cm$^3$] 1.42
- Tensile strength [MPa] 23
- Elongation at break [%] 580
- Abrasion [mm$^3$] 200

Commercialized
Elastollan SP 3092A 10HFFR

Properties:
- Further reduced smoke density and toxicity
- Density [g/cm³] 1.62
- Tensile strength [MPa] 15
- Elongation at break [%] 400
- Abrasion [mm³] >200

Commercialized
# Mechanical properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Standard/Method</th>
<th>Elastollan® SP 3092A10 HFFR</th>
<th>1185A10 FHF</th>
<th>1185A10</th>
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</thead>
<tbody>
<tr>
<td>Tensile strength</td>
<td>DIN 53504-S2</td>
<td>15</td>
<td>35</td>
<td>50</td>
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<tr>
<td>Elongation@break</td>
<td>DIN 53504-S2</td>
<td>400</td>
<td>600</td>
<td>580</td>
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<tr>
<td>Tear strength</td>
<td>DIN ISO 34-1Bb</td>
<td>42</td>
<td>60</td>
<td>70</td>
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<tr>
<td>Hardness</td>
<td>DIN 53505</td>
<td>95</td>
<td>89</td>
<td>87</td>
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<tr>
<td>Abrasion</td>
<td>DIN ISO 4649-A</td>
<td>&gt;200</td>
<td>35</td>
<td>25</td>
</tr>
</tbody>
</table>
Corrosivity - Flammability

- Acidity of gases during combustion (DIN EN 50267-2-2: 1999)
- Determination of burning behaviour by oxygen index (acc. to ISO 4589 Part2: 2006-06)

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**Elastollan® SP3092A10**

- **HFFR**
  - pH-value: 6.7
  - Conductivity [µS/mm]: 8.3
  - LOI - Limiting Oxygen Index [%]: 41

- **1185A10 FHF**
  - pH-value: 8.9
  - Conductivity [µS/mm]: 23.4
  - LOI - Limiting Oxygen Index [%]: 24

- **1185A10 FHF**
  - pH-value: 7.4
  - Conductivity [µS/mm]: 4
  - LOI - Limiting Oxygen Index [%]: 22
Heat release over time
DIN EN 45545-2 (2013-08) R22/R23
Railway applications - Fire protection on railway vehicles

**Elastollan**

<table>
<thead>
<tr>
<th>EN ISO 5659-2: 25 kW/m²</th>
<th>$D_s$ max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Smoke density)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NF X70-100-1 und -2 (Toxicity), 600°C</th>
<th>$CIT_{NLP}$</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>EN ISO 4589-2: OI</th>
<th>Oxygen Vol%</th>
</tr>
</thead>
</table>

Rating R22/23 (e.g. tubes)

**SP 3092 A10 HFFR**

<table>
<thead>
<tr>
<th>65</th>
<th>0,10</th>
<th>41</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1,6 mm)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**A 10 FHF 1185**

<table>
<thead>
<tr>
<th>563</th>
<th>0,36</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>(mm 1,6)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**HL3**

no rating
**DIN EN 45545-2 (2013-08) R15/R16**

Railway applications - Fire protection on railway vehicles

<table>
<thead>
<tr>
<th>Elastollan</th>
<th>SP 3092 A 10 HFFR</th>
<th>A 10 FHF 1185</th>
</tr>
</thead>
<tbody>
<tr>
<td>(DIN EN 50305 (800°C)</td>
<td>ITC</td>
<td></td>
</tr>
<tr>
<td>Smoke Density – Cube test (IEC 61034)</td>
<td>[%] Transmission</td>
<td></td>
</tr>
<tr>
<td>([on the example power cord cable]</td>
<td>8.4</td>
<td>46</td>
</tr>
<tr>
<td>Rating R15/16 (e.g. cables)</td>
<td>62</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>HL1/HL2</td>
<td>no rating</td>
</tr>
</tbody>
</table>

**Notes:**
- Dynamical properties (e.g. cables) have no rating.
Elastollan 3093A10HFFR

Petrella plot standard materials enlarged

Properties:
Further reduced low smoke density and toxicity, improved mechanical performance

Density [g/cm³] 1.51
Tensile strength [MPa] 23
Elongation at break [%] 390
Abrasion [mm³] 220
Elastollan SP 3093 10 HFFR
Railway applications DIN EN 45545-2 (2013-08), R15/R16 for cable applications

(1) Rating DIN EN 45545

<table>
<thead>
<tr>
<th>Elastollan SP A 10 HFFR 3093</th>
<th>Elastollan 1185 A 10 HFFR</th>
<th>Elastollan 1185 A 10 FHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>(DIN EN 50305 (800°C) ITC</td>
<td>9,2</td>
<td>12,8</td>
</tr>
<tr>
<td>Rating R15/16 (e.g. cables)</td>
<td>HL1/HL2</td>
<td>No rating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No rating</td>
</tr>
</tbody>
</table>
Conclusions

- Flame Retardant cables can be difficult to design and certify.
- It’s a significant challenge to design LSZH TPU polymers for wire and cables.
- TPU is often selected for applications that require high physical performance and in safety critical applications, so reducing performance properties is not valued.
- The challenge is in finding a balance between flame resistance while maintaining the required physical properties.
Elastollan® TPU

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http://www.elastollan.basf.us