Commercial Applications of Bio-Based Polymers in Automotive

Rick Bell – RS Development Manager
SPE ACCE
208 Years of Innovation and Success

- A Dynamic Science Company
- 60,000 employees in over 90 Countries
- $32 Billion in Global Revenue
- Above numbers do not reflect recent Danisco acquisition.

- A World Leader in Renewable Materials and Biotechnologies
Terminology

- RENEWABLY SOURCED and BIO-BASED define the same thing. It refers to a material that contains carbon originating from a renewable plant source. DuPont™ Renewably Sourced™ materials contain a minimum of 20% renewably sourced ingredients by weight.

- RENEWABLY SOURCED can include BIODEGRADABLE products that can be broken down by living organisms like bacteria. It also includes durable goods that are designed for long life.

- Products discussed in this presentation are for durable good type applications.
Renewable Materials from DuPont

- **Sorona®** for interior textiles
- **Sorona® EP** PTT polyester for molded parts
- **Cerenol™** for polyurethane parts
- **BioFuels**
- **Hytrel® RS** thermoplastic elastomer for injection and extrusion
- **Zytel® RS** polyamides for injection and extrusion
Next Generation Materials and Fuels from Biomass

Automotive OEMs around the world are developing cars to be more environmentally friendly.

Deliver renewably sourced materials made from biomass instead of petroleum with uncompromised product performance.
DuPont Renewably Sourced Materials
Brodest Portfolio for Engineering Polymers

Sorona® EP Thermoplastic Polymer

- DuPont™ Sorona® EP is a PTT polyester with properties similar to PBT polyester.

Hytrel® RS Thermoplastic Elastomer

- DuPont™ Hytrel® RS, is TPC-ET thermoplastic elastomer (TPE). Properties are similar to standard Hytrel®.

Zytel® RS 6,10 and 10,10 Long Chain Polyamides

- Comprises all products based on PA 6,10 and 10,10 including copolymers, alloys, and reinforced grades.

Product data sheets, brochures and processing guides available at:

www.plastics.dupont.com and www.renewable.dupont.com
Bio-PDO Provides Bio Content in Sorona®

HO-CH₂-CH₂-CH₂-OH

Current Production facility is sold out producing over 100 million lbs/year of bio-PDO. Over 30% Capacity Increase Underway

LCA: 10 million gallons of gasoline/yr saved
Sorona® Life Cycle Analysis

Sorona® vs nylon 6 Life Cycle Analysis (Cradle to gate) per ISO standards

- 37% renewable content
- 63% less greenhouse gas emissions
- 30% less energy and 21% less process water.

Major ISO 14000-series documents:

- ISO-14040 Environmental management- Life cycle assessment- Principles and framework
- ISO-14044 Environmental management- Life cycle assessment- Requirements and guidelines
- ISO-14047 Environmental management- Life cycle impact assessment- Examples of application of ISO-14042
- ISO-14048 Environmental management- Life cycle assessment- Data documentation format
- ISO-14049 Environmental management- Life cycle assessment- Examples of application of ISO-14041 to goal and scope definition and inventory analysis

Holistic Approach:

Evaluate the impact of all upstream and downstream products and processes.

Third party certified.
# Sorona® Polymer - Product Properties

<table>
<thead>
<tr>
<th></th>
<th>Sorona®</th>
<th>PET</th>
<th>PBT</th>
<th>Nylon 6</th>
<th>Nylon 6,6</th>
<th>PP</th>
<th>PLA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melt Temperature, Tm (°C)</td>
<td>228</td>
<td>260</td>
<td>225</td>
<td>222</td>
<td>262</td>
<td>160</td>
<td>130-175</td>
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<tr>
<td>Glass Transition, Tg (°C)</td>
<td>50-70</td>
<td>70 - 80</td>
<td>25 - 35</td>
<td>40 - 60</td>
<td>45 - 65</td>
<td>-30</td>
<td>55 - 65</td>
</tr>
<tr>
<td>Density</td>
<td>1.33</td>
<td>1.38</td>
<td>1.32</td>
<td>1.14</td>
<td>1.14</td>
<td>0.91</td>
<td>1.25</td>
</tr>
</tbody>
</table>

1,3-propanediol + DMT / TPA

Catalyst (Sb-free)

Bio-PDO™

- (-C

O

- C-O

C-\(\text{OCH}_2\text{CH}_2\text{CH}_2\text{O}\))\(^n\)

PET  2GT

PTT  3GT

PBT  4GT
Sorona® EP Thermoplastic Polyester

- PTT polyester similar to PBT in performance and price.
- Better surface appearance, UV resistance.
- Stronger and stiffer than PBT.
- Lower shrink vs PBT, less warpage.
- Improved hydrolysis resistance and laser weldability. Slightly better electrical properties.

Applications

- Electronic control module housings
- Headlamp bezels
- Connectors, electrical, electronic parts
- Handles, seat trim components
- Any painted part (eliminate paint)

Commercial at Toyota on interior parts
Sorona® EP – Toyota Vent Louver - Commercial

Cost reduction by eliminating painting process compared with glass reinforced PBT, former material

Design freedom because of higher mechanical property than glass reinforced PBT

Material chosen and Why

Sorona® 2045G, 45% glass filled grade was chosen because of its excellent combination of good appearance and mechanical property.
Comparative Properties – Glass Reinforced

Datasheets at www.plastics.dupont.com
Contact Rick Bell for detailed product comparisons
DuPont™ Sorona® Fibers

- Currently available in apparel, commercial and residential carpet.
- **Commercial today as carpet pad on five different car lines.**
- Provides improved stain resistance vs nylon.
- Significantly improved crush resistance and durability vs. polyester fibers.
- Superior softness compared to nylon and polyester.
- Resistant to mold, mildew and odor without surface treatments.

*If only 20% of the residential carpet sold in the U.S. were made from Sorona®, the energy equivalent of approximately 50 million gallons of gasoline would be saved per year.*
Sorona® Fiber Commercial Examples

Toyota SAI
Sustainable compact luxury car
60 percent of the interior fabrics use DuPont™ Sorona® renewably sourced fiber
- headliner
- sun visor
- other fabric covered surfaces
- floor mats. (Also on Prius).
Zytel® RS Long Chain Polyamides

- Based on biofeedstock derived from castor plant. Includes various grades of PA10,10 (100% biobased) and PA6,10 (60% biobased).
- Commercial in monofilaments, consumer products, sporting goods, hand held devices, automotive.
- High performance polyamides that provide high flexibility, toughness and thermal properties with superior chemical and hydrolysis resistance.
- Provides competitive cost options vs nylon 11 and 12.
Renewable Sourcing for Long Chain Polyamides

100% Renewable Carbon

16 Sept 15, 2011

PA10,10

PA6,10

Castor Oil

Sebacic acid

Diaminodecane

Petrochemicals

Hexamethylene diamine
Comparative properties of base polymers

<table>
<thead>
<tr>
<th>Mechanical Properties (dry as moulded)</th>
<th>PA610</th>
<th>PA612</th>
<th>PA1010</th>
<th>PA11</th>
<th>PA12</th>
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<tbody>
<tr>
<td>Yield Stress (Mpa)</td>
<td>62</td>
<td>61</td>
<td>50</td>
<td>43</td>
<td>45</td>
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<tr>
<td>Yield Strain (%)</td>
<td>4.3</td>
<td>4.6</td>
<td>5</td>
<td>5.2</td>
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<tr>
<td>Strain at Break (%)</td>
<td>&gt;50</td>
<td>&gt;50</td>
<td>&gt;50</td>
<td>&gt;50</td>
<td>&gt;50</td>
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<tr>
<td>Tensile Modulus (MPa)</td>
<td>2250</td>
<td>2100</td>
<td>1550</td>
<td>1350</td>
<td>1400</td>
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<tr>
<td>Unnotched Charpy Impact Strength -50C (kJ/m2)</td>
<td>NB</td>
<td>NB</td>
<td>NB</td>
<td>NB</td>
<td>NB</td>
</tr>
<tr>
<td>Notched Charpy Impact Strength -50C (kJ/m2)</td>
<td>2.4</td>
<td>3.5</td>
<td>6.3</td>
<td></td>
<td>5.2</td>
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</tbody>
</table>
Positioning of Various Polyamides

Hydrocarbons resistance
Barrier Properties (fuel, CO2)

Chain length

Polar Fluids resistance
Flexibility
Moisture resistance
Hydrolysis resistance
Stress Cracking resistance
Radiator End-Tanks - Denso
Commercial example of better performance at lower cost while reducing carbon footprint

- Zytel® RS (PA 610) commercial in radiator end tanks
- First use of this renewably sourced plastic in a mechanical component exposed to the hot, chemically aggressive underhood environment
- DuPont won Denso's "Innovative Technology of the Year" award and SPE 2009 automotive award “Most Innovative Use of Plastics for the Environment”

Lower cost vs PA11, PA12 or PA6,12
Hytrel® RS Thermoplastic Elastomer

Properties similar to standard Hytrel®

- Excellent elasticity & low temperature flexibility
- Excellent flex fatigue and cut growth life
- Good chemical & oil resistance
- High tear strength, toughness, resilience, impact resistance
- Commercial in sporting goods, furniture and consumer products.

In Hytrel® RS, petroleum sourced polyether glycols in the soft segments are replaced by Renewably Sourced polyether glycols made from non-food biomass.

The renewably sourced content of Hytrel® RS varies with the hardness of the grade.

Air bag door covers

Sept 15, 2011
Hytrel® RS – Potential Applications

Properties similar as regular Hytrel® TPE

- ABD Covers (Driver)
- Overmolded parts (Door latches)
- CVJ, shifter boot, seat shift dust covers
- Air duct
- Hose & tubing (vacuum hoses)
- Air brake hose

Any thermoplastic elastomer, soft touch application
Our goal is to provide performance and functionality equivalent to or better than today’s fully petroleum based materials while reducing the environmental footprint.