PARTNERING IN THE AUTOMOTIVE SUPPLY CHAIN TO DEVELOP CLOSED-LOOP RECYCLING OF PET FOR AUTOMOTIVE FOAMS
Linear Economy

NATURAL RESOURCES

TAKE

MAKE

USE

WASTE
Need for Circular Economy

• The world population is projected to reach 9B by 2050

• 80% of all U.S. landfills are full.
  o Americans generated about 508 billion pounds solid waste-2013
  o 13% plastics

• Plastic Production in 2015:
  • The U.S. produced 311 MILLION Tons
  • 40% landfilled, 14% incinerated, 32% leakage
  • 14% collected for recycling
    • 4% process losses
    • 8% cascaded recycling
    • 2% closed loop recycling
Case for Circular Economy-Automotive

• Approximately 12-16% of a vehicle weight is plastic (≈400 lb)
• ≈15 lb to 20 lb is PET plastics (not including PET used in assembly process)
Circular Economy

UPCYCLE

RECLAIM

MAKE

USE
Resinate Materials Group

- **Incorporated 2011: Plymouth, MI**
- **Vision:** To be the leading innovator in Performance Driven Green Chemistry
  - Extending the life-cycle of finite resource
  - Advance the circular economy

- **Technical Expertise**
  - 8200 ft² Product and Applications Development Facilities
  - More than 31 patent applications based on recycled content

- **Core Technology:** Molecular up-cycling of spent materials into polyester polyols for polyurethanes
Recycled PET and Polycarbonate

Recycled Glycols

BIORENEWABLE INGREDIENTS

FUNCTIONALITY

Resinate High Performance Polyols for Specialty Applications

Glycolysis Process

Resinate Materials Group
Recycolysis™ Process

PET Bottle Bales

PET Carpet

Auto PET Scrap

Densification
Pelletization
Or Flaking

Resinate Patent-Pending Glycolysis and Purification Process

Polyol A

Flexible and Rigid Foam Applications

Polyol B

Coatings, Adhesives, Sealants, Plasticizers

This Process Provides a Route for Redirecting Unused PET Raw Materials Into High Performance Sustainable Specialty Polyols
Innovate
Collaborate
Rethink the way we take-make-use plastics

Polyester Polyol

Automotive Waste
Recycled PET

Circular Economy

Auto Manufacturing
Flexible Foam

Tier One

Pet Pellets or flakes

PET

Polyester Polyol

Composites
Adhesives
Foams
Coatings
Plasticizers

Resinate

Ford
PLASTICS INDUSTRY ASSOCIATION

The Woodbridge Group
CLOSED-LOOP RECYCLING OF rPET

Scope/Technical Approach:
- Reducing foam costs and extending raw material supplies
- Create closed-loop model for discarded PET feedstock
- Good mechanical and thermal properties

Problem:
- Unfavorable wet heat aging properties
- Vulnerable to gradual hydrolysis

Objective:
- To determine the stability and viability of rPETF polyols in production of PU flexible foams for automotive applications. Physical, mechanical, and thermal properties were measured and compared to control samples purely composed of petroleum-based polyol.
## MATERIALS AND FORMULATION

### Description of recycled polyols, including appearance and recycled content

<table>
<thead>
<tr>
<th>Polyol Name</th>
<th>FFP1000-1.2</th>
<th>FFP1000-2.1</th>
<th>FFP1000-2.2</th>
<th>FFP1000-2.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Sustainable Content</td>
<td>95.5%</td>
<td>79.2%</td>
<td>82.1%</td>
<td>81.0%</td>
</tr>
<tr>
<td>% Recycled Content</td>
<td>12.7%</td>
<td>29.3%</td>
<td>32.2%</td>
<td>24.0%</td>
</tr>
</tbody>
</table>

### Formulas used to create individual foams; each component listed in a relative manner, by part

<table>
<thead>
<tr>
<th>Component</th>
<th>0%</th>
<th>10%</th>
<th>20%</th>
<th>30%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyether Polyol</td>
<td>100.0</td>
<td>90.0</td>
<td>80.0</td>
<td>70.0</td>
<td>50.0</td>
</tr>
<tr>
<td>FFP1000-1.2/FFP1000-2.1/FFP1000-2.2/FFP1000-2.3</td>
<td>0.0</td>
<td>10.0</td>
<td>20.0</td>
<td>30.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Niax A1</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Tegostab B4690</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Niax A300</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Lumulse POE (26) GLYC</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Diethanolamine</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Deionized Water</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Isocyanate</td>
<td>53.8</td>
<td>56.0/53.9/</td>
<td>58.4/54.3/</td>
<td>60.8/54.7/</td>
<td>65.7/54.3/</td>
</tr>
</tbody>
</table>
MECHANICAL AND PHYSICAL PROPERTIES

Stress at 65% Deflection

Density (kg/m^3)

Tensile Stress at Max Load (kPa)

Compression Stress (kPa)

Wet Compression Set (%)

- FFP1000-1.2
- FFP1000-2.1
- FFP1000-2.2
- FFP1000-2.3

03/10/2017
FOGGING AND ODOR

Fogging:
- SAE J1756, 3 h at 100 °C, 21 °C cooling plate, post-test cond. 16h
- Fog Number 70 min
- Formation of clear film, droplets or crystals is cause for rejection

Odor
- Rating 3 max
- FLTM BO 131-03-Variant C

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>FFP1000-1.2</th>
<th>FFP1000-2.1</th>
<th>FFP1000-2.2</th>
<th>FFP1000-2.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fog Number</td>
<td>99</td>
<td>99</td>
<td>99</td>
<td>99</td>
<td>99*</td>
</tr>
<tr>
<td>Odor (23 °C)</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Odor (40 °C)</td>
<td>1.5</td>
<td>2.0</td>
<td>1.5</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Odor (65 °C)</td>
<td>2.0</td>
<td>2.0</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>

*oily spots present
CONCLUSIONS

- ‘Up-cycling’ a waste stream to create a sustainable, value-added polyol

- High rPET content foams are mechanically stronger & stiffer, and more thermally durable

- Positive photometric fogging results

- Odor and flammability test results meet Ford requirements.

- PET required for polyol synthesis and automotive foam production can come directly from automotive PET scrap
ONGOING PROJECTS

- Collaboration with Tier 1 and PDC (Headliner Team, WSS-M15P27-G).

- VOC
  - Micro-chamber and GC-MS

- Hydrolytic Stability
  - 60 °C and 98% Humidity for a duration of 3 weeks
  - Investigation of different glycol systems

- Manuscript submitted to WM journal.

03/10/2017
THE SUSTAINABILITY IMPERATIVE – A Short Presentation
Michigan Sustainability Conference (MISCON)
Dr. Hamdy Khalil - The Woodbridge Group
September 14, 2017
In 1999 Woodbridge pioneered the use of renewable and sustainable resources in the manufacturing of automotive interior parts before it became fashionable. Interior automotive parts include seat cushions, headliners, headrests, armrests, etc.

Seed oil derivatives were among the first material we introduced.

We coined the phrases: “From Seed–To–Seat” and “Bio-Foam”
Woodbridge Reference Points:

Among the first to collaborate on the development and use of recyclable material in Automotive Parts. Despite the genuine efforts, progress was slow and the implementation challenges were difficult to overcome at the time.

Open Innovation is important to us.

Transparent collaboration with Suppliers and Customers is critical to our success.
WOODBRIDGE REFERENCE POINTS:

We consider Natural Resources and Clean recycled materials are the “New Oil Wells”.

Sustainability is a Strategic Imperative at Woodbridge. We are always searching for Opportunities to reduce our Carbon Footprint.
COLLABORATING WITH LIKE-MINDED SUPPLIERS AND CUSTOMERS

- Resinate Inc. Development of new approach to recycling of PET

- Ford Motor Company’s “Relentless” search for, and interest in reducing their footprint, represents an attractive opportunity for Resinate Inc. to supply new recycled material for Woodbridge to manufacture Automotive Interior Parts using the Recycled Material while meeting Ford Motor Company’s Quality Specifications.

- This is a good example of “Circular Economy”.