Development of Sustainable Hybrid Composites Using Recycled Polypropylene and Engineered Polysaccharide

*Sea Ho Jeon Ph.D.*

*Wellman Advanced Materials*
Agenda

- Carpet Recycling
- Advantages of Carpet Recycled products
- Project Development
- Product Development
Carpet Recycling
Carpet’s life in US

- In 2014 11.7 billion ft$^2$ of carpet and rug produced in US
- Average life time of carpet is ~8 years

- 89% Landfill
- 5% Recycle
- 6% Incineration

Wellman Recycles
- 1.4%
- 42 X 10$^6$ lbs/year
- 2.9 X 10$^9$ lbs in total
Why Recycle?

- Ecological impact of synthetic polymers
- Controlled and uncontrolled waste significant impacts on environment
- Large portion of polymers and polymer composites’ density are over 1 g/mL including carpet
Why Recycle?

- Ecological impact of synthetic polymers
- Controlled and uncontrolled waste significant impacts on environment
- Large portion of polymers and polymer composites’ density are over 1 g/mL including carpet

8 million tons of plastic goes to ocean each year

https://www.nationthailand.com/national/30344702
Construction of Carpet

**Carpet as a Raw Material**

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face Fiber/Tuft*</td>
<td>45 - 55</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Calcium Carbonate</td>
<td>25 - 35</td>
</tr>
</tbody>
</table>

*Face fiber composition includes Polyamide 6, Polyamide 6/6, polypropylene, polyester, wool, cotton, and acrylic.*
Customer Confidential

Carpet as a Raw Material

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face Fiber/Tuft*</td>
<td>45 - 55</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>10 - 20</td>
</tr>
<tr>
<td>Calcium Carbonate</td>
<td>25 - 35</td>
</tr>
</tbody>
</table>

* Face fiber composition includes Polyamide 6, Polyamide 6/6, polypropylene, polyester, wool, cotton, and acrylic

Market share of carpet materials

Wellman
Wellman Advanced Materials

Looking for applications

PA6 and PA66 products

Applications
- Automotive parts
- Furniture
Advantages of Carpet Recycled products
Advantages of Carpet Recycling

✔ Abundant resources
  - In 2014 11.7 billion ft$^2$ of carpet and rug produced in US
  - Total of $2.9 \times 10^9$ lbs is available for recycling each year

*How to make a successful case of circular economy
Advantages of Carpet Recycling

- Stable/Consistent feed stream

*Depend on applications there are numerous types of polypropylene products

<table>
<thead>
<tr>
<th>Chemical compositional and structural type</th>
<th>Catalyst, tacticity, crystallinity homo-PP or co-PP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact modifier</td>
<td>Polybutene, polyoctene, copolymers</td>
</tr>
<tr>
<td>Inorganic filler</td>
<td>SGF, LGF, Talc</td>
</tr>
<tr>
<td>Flame retardant</td>
<td>Organo Phosphorus, Halogen based, Metal derivatives</td>
</tr>
</tbody>
</table>

Carpet backing is unfilled homo-PP with small impurities such as nylon fibers
Advantages of Carpet Recycling

- PA fiber improve tensile modulus of polypropylene composites

Figure 2. Variation of tensile modulus with fibre loading

No need to add cost for this
Project Development
Project Initiation; Sustainable material

Ford

- WRS-M4D941-B1
- WSS-M4D854-B5

Specification for hidden structural components in floor console and for air cleaner housing and cover/Headlamp housing

To replace 30% SGF filled polypropylene

Wellman

- Compounding for automotive application; both prime and recycle grades
- Bio-filler compounding

Dupont

- Bio-filler development
  - Nuvolve™ Engineered Polysaccharide
Green Chemistry = Sustainable chemistry and 3R’s

1. Reduce
2. Reuse
3. Recycle
❖ Raw material

- PCR Carpet Recycled Wellman Product
- **Bio-filler, Polysaccharide**

- To reduce use of petroleum-based plastic
  - DuPont Nuvolve was used

- Carpet Recycling

- Sustain the Future.

- Nuvolve™ Engineered Polysaccharide
- Micron size particle
- Semi crystalline linear polymer
Product development
❖ Prime grade with GF

- GF10 is 10% glass fiber filled i-PP
- While adding more SGF, tensile strength was gradually improved

Target: 55 MPa
Prime grade with GF/Polysaccharide

- Tensile strength slightly decreased while adding polysaccharide
- Target: 55 MPa

15-10 is Glass fiber 15% with Polysaccharide 10%
❖ Prime grade with GF

Target: 6 KJ/m²

GF10 is 10% glass fiber filled i-PP

While adding more SGF, tensile strength was gradually improved
Prime grade with GF/Polysaccharide

Notched Impact strength was not much affected by polysaccharide addition

15-10 is Glass fiber 15% with Polysaccharide 10%

Target: 6 KJ/m²
## Prime grade PP with GF20%/Polysaccharide10%

<table>
<thead>
<tr>
<th>Property</th>
<th>Method</th>
<th>Unit</th>
<th>Prime PP</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prime PP</td>
<td>WRS-M4D941-B1</td>
</tr>
<tr>
<td>Density</td>
<td>Q-002 / ISO 1183</td>
<td>g/cm³</td>
<td>1.0950</td>
<td>1.09-1.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.09-1.16</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.08-1.21</td>
<td></td>
</tr>
<tr>
<td>Tensile Strength @ Yield</td>
<td>Q-006 / ISO 527,50mm/min</td>
<td>MPa</td>
<td>76</td>
<td>≥53</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>76</td>
<td>≥53</td>
</tr>
<tr>
<td>Tensile Modulus</td>
<td>Q-006 / ISO 527,1mm/min</td>
<td>MPa</td>
<td>4920</td>
<td>≥4000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4920</td>
<td>≥4000</td>
</tr>
<tr>
<td>Impact Charpy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notched 23 °C</td>
<td>Q-003 / ISO 179</td>
<td>kJ/m²</td>
<td>8.15</td>
<td>≥4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8.15</td>
<td>≥4.5</td>
</tr>
<tr>
<td>Notched -40 °C</td>
<td>Q-003 / ISO 179</td>
<td>kJ/m²</td>
<td>6.76</td>
<td>≥2.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>6.76</td>
<td>≥2.5</td>
</tr>
</tbody>
</table>
## 20-10

<table>
<thead>
<tr>
<th>Property</th>
<th>Method</th>
<th>Unit</th>
<th>Prime PP</th>
<th>Recycled PP</th>
<th>Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Density</strong></td>
<td>Q-002 / ISO 1183</td>
<td>g/cm³</td>
<td>1.0950</td>
<td>1.1370</td>
<td>1.09-1.16</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.08-1.21</td>
</tr>
<tr>
<td><strong>Tensile Strength @ Yield</strong></td>
<td>Q-006 / ISO 527,50mm/min</td>
<td>MPa</td>
<td>76</td>
<td>65</td>
<td>≥53</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥55</td>
</tr>
<tr>
<td><strong>Tensile Modulus</strong></td>
<td>Q-006 / ISO 527,1mm/min</td>
<td>MPa</td>
<td>4920</td>
<td>5300</td>
<td>≥4000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥4000</td>
</tr>
<tr>
<td><strong>Impact Charpy</strong></td>
<td>Notched 23 °C</td>
<td>kJ/m²</td>
<td>8.2</td>
<td>6.2</td>
<td>≥4.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥6.0</td>
</tr>
<tr>
<td></td>
<td>Notched -40 °C</td>
<td>kJ/m²</td>
<td>6.8</td>
<td>4.7</td>
<td>≥2.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>≥3.1</td>
</tr>
</tbody>
</table>
**Conclusion**

- Developed recycle-grade product, which fulfill Ford Specs WRS-M4D941-B1 and WSS-M4D854-B5
- Recycled PP from PCR carpet was successfully used in the formulation
- By using Polysaccharide reduced of petroleum base polymer
Future Works

✓ More carpet collection
  - How to bring in carpet instead of landfill?
  - Importance of economic circulation

✓ Improve adhesion between polysaccharide and polypropylene
  - Hydroxyl group to Maleic anhydride; introducing other functional group