New Soy-based Materials for Automotive Applications

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Presentation Outline

- CARA Plastics and ACRES
  - Goals and Activities
- New Soy-based Resins
- Adhesives
- Foams
- All-natural Composite Materials
- Potential Automotive Applications
• Cara Plastics, Inc. ("Cara") has exclusive worldwide rights to the technology for converting natural oils to high value resins for a variety of commercial applications.

• One patent has been issued, and two others filed.

• Cara has an exclusive license from the University of Delaware to commercialize this technology and utilize the resources of the Composite Center.
ACRES Group Activities

ACRES group was awarded DoE funding for the following applications:

- Automotive and Trucking
  - SMC, Natural Fibers, Foam, Resins
- Adhesives and Resins
  - PSA, Coatings,
- Structures
  - Hurricane Resistant Housing
Synthesis and Polymerization of Soybean Oil Pentaerythritol Glyceride Maleates (SO/PER/MA)

Soybean oil triglyceride

Pentaerythritol

\[ \text{Soybean oil triglyceride} + \text{Pentaerythritol} \xrightarrow{230-240^\circ C} \]

\[ \%1 \text{ Ca(OH)}_2, \text{N}_2 \]
1% Triphenyl antimony
0.1% Hydroquinone

T = 100°C

Pentaerythritol glyceride tris-maleate half ester + Monoglyceride bis-maleate halfester

Free radical copolymerization

Rigid Thermosetting Polymer
Adhesives

Oleic Methyl Ester

Formic Acid
Hydrogen Peroxide

Epoxidized Oleic Methyl Ester

Acrylic Acid

Acrylated Oleic Methyl Ester

Oleic Methyl Ester

Epoxidized Oleic Methyl Ester

Acrylic Acid
Modified Adhesive Properties

Peel Energy (J/m²)

- MiniEP AOME/MMA
- MiniEP AOME/MMA/Mac
- Scotch Tape
ACRES Group

All-Natural Composite Materials

- Resins
- Fibers
- Processing
- Current Applications
  - Housing
  - Furniture
  - Infrastructure
Chemistry of Soybean Oil: Triglyceride

Fatty acid weight composition of soybean oil.

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>Formula</th>
<th>Weight %</th>
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</thead>
<tbody>
<tr>
<td>16:0</td>
<td>C16H32O2</td>
<td>11</td>
</tr>
<tr>
<td>18:0</td>
<td>C18H36O2</td>
<td>4</td>
</tr>
<tr>
<td>18:1</td>
<td>C18H34O2</td>
<td>25</td>
</tr>
<tr>
<td>18:2</td>
<td>C18H32O2</td>
<td>51</td>
</tr>
<tr>
<td>18:3</td>
<td>C20H40O2</td>
<td>9</td>
</tr>
</tbody>
</table>
AESO Resin Chemistry

Fatty Acid Chain

0-6 Double Bonds

12-22 Carbons Long

Glycerol

1. Formic Acid
   \( \text{H}_2\text{O}_2 \)
2. Acrylic Acid
   Catalyst (AMC2)

Acrylate

Acrylated Epoxidized Soybean Oil

Epoxy
Natural Fibers – Flax and Cellulose
Processing: Vacuum Assisted Resin Transfer Molding (VARTM)
Current Applications

- **Housing**
  - Hurricane Resistant Structures
- **Furniture**
  - All-natural Composite Chair
- **Transportation Infrastructure**
  - Stay-in-place Form for Bridge Decking
Roof: Design and a Unit Beam Schematic

railer foam core

waffle foam core

SECTION

SIDE VIEW
HRS Unit Beam: Manufacturing
Structural Unit Beam
HRS Unit Beam: Testing
All-Natural Composite Chair: Manufacturing
All-Natural Composites Chair
Stay-in Place Form for Bridge Decking: Manufacturing
Highway Bridge: Stay-in-Place Form for Bridge Decking
Stay-in-Place Form for Bridge Decking: Testing
Stay-in-Place (Bridge Deck) Form: Testing with Concrete
Potential Automotive Applications

- Structural: exterior, interior
  - Deflectors
  - Trunk liners
- Adhesives
- Foams
Summary and Next Steps

- Resins and composites are available for testing and tailoring for specific end-uses.
- Adhesives are available for testing and formulation.
- Foams are in early stage development for work with partners.
- Contact Cara for licensing and joint development opportunities.
Acknowledgement

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  – Erde Can
  – Shana Bunker

• Center for Composite Materials