Soy-Based Low-Temperature Powder Coating

Coatings Trends & Technologies
Bio-Based/Sustainable Technology
September 10, 2019

Jeff Cafmeyer
Sr. Research Scientist
Advanced Materials & Microfabrication
Battelle’s mission and purpose

To translate scientific discovery and technology advances into societal benefits

• Nonprofit, charitable trust formed in 1925
• Profits reinvested in science & technology and in charitable causes, making the world better for generations to come
• Knowledge, talents and resources applied to help our customers achieve their most important goals
Pioneered commercial powder coatings on a heat sensitive substrate – Xerography
United Soybean Board

- Established in 1991
- 73 elected farmer-directors representing over 574,000 soybean producers
- Investments in crop science, promotion and industrial uses to increase the value of soybean crop
- US soybean production: >4 billion bushels (>250 billion pounds)
- Battelle has 25+ year history with USB and individual state programs
  - Portfolio of projects demonstrating feasibility leading to commercialization
    - Leveraging unique characteristics
    - Identifying opportunities and developing products to meet market needs
Soybeans as chemical building blocks

**Soybean Feedstock**

- Protein
- Oil
- Carbohydrates

**Coatings**
- Paints
- Powder Coatings
- Coalescing Solvents
- Reactive Diluent

**Toners**
- Resins

**Adhesives**
- Polyurethane
- PF/UF
- Acrylate PSA's
- Extenders

**Foams**
- Soft
- Rigid

**Additives**
- Polyols
- Plasticizers
- Fillers
- Pigment Dispersants
- Processing Aids

**Lubricants**
- Bar & Chain
- 2-Cycle
- Hydraulic
- Greases
- Transformer
Low-temperature cure powder coatings for MDF are needed

- Focus on low-temperature powder coatings for interior use on medium density fiberboard (MDF) products such as:
  - Kitchen cabinetry
  - Consumer furniture
  - Office furniture
  - Lab furniture
  - Garage cabinets
  - Closet shelving
  - Signage
  - Medical carts
  - Point of purchase displays
  - Partitions

- Interest in sustainability, once performance and cost criteria are met
No current biobased powder coating for MDF applications

Incumbent Technologies

- Thermofoils (low-pressure PVC laminates)
- High pressure laminates (melamine-based; Formica®)
- Solvent borne paints
- Powder coating (DSM Uralac polyester/DVE thermoset system)
- 140°C Ultra-low bake systems emerging

- MDF not fully addressed with a powder coating technology
  - Adapted conventional high-temperature systems
  - Lack finishes and performance of higher temperature systems
- Soy-based resin feedstocks can introduce attributes to meet low-temperature need
Global market for powder coatings is large and growing

• Global powder coating market is ~5.5 billion pounds with an overall growth trend of 5-10% per year
  ▪ Heat sensitive substrates represent a large, attractive opportunity
  ▪ Soy-based low-temperature powder coating can also address existing metal substrate market
• Current MDF powder coating market only ~1 million pounds
• End user initiatives converting from traditional liquid paint finishes to powder coating can dramatically impact the market – coatings is an active and progressive market for sustainability
Development of new soy-based resin systems for powder coatings

• Resin Synthesis Objectives:
  ▪ Maximize soy content (>20%)
  ▪ Compatibility with conventional powder coating operations
  ▪ Low-temperature cure conditions of 125°C or less

• Resin approach:
  ▪ Use of long-chain diacids – derived from soy fatty acids
  ▪ Carboxyl (-COOH) resins for conventional triglycidyl isocyanurate (TGIC) and hydroxyalkylamide (HAA) cure systems
Powder coating resin building blocks

Petroleum-based Polyesters

Biobased Polyester-amide
Melt properties of soy-based resin are suited for powder coating

- Expanded melt process window
- Further compositional tuning of melting point demonstrated
Conversion of soybean oil to long-chain diacids
Conventional resin synthesis and standard powder conversion processes used

Bulk Condensation Synthesis

Mechanical Grinding

Compounding and Extrusion

22L Reactor

5kg Batch

Powder Coating
Successful scale-up of resin and powder formulation

• Produced 66-kg batch of resin and 27-kg batch of formulated powder with toll manufacturers
Best overall coating properties achieved by C18 and C19 diacid resins – 135°C cure

<table>
<thead>
<tr>
<th>Resin Description</th>
<th>60° Gloss</th>
<th>Solvent Resistance 100 DR MEK</th>
<th>Crosshatch Adhesion</th>
<th>Impact Resistance</th>
<th>Appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>C19 diacid</td>
<td>78.5</td>
<td>No Effect</td>
<td>5B</td>
<td>160</td>
<td>160 Smooth</td>
</tr>
<tr>
<td>C18 diacid</td>
<td>64.3</td>
<td>No Effect</td>
<td>5B</td>
<td>160</td>
<td>160 Smooth, high flow</td>
</tr>
<tr>
<td>C16 diacid</td>
<td>54.7</td>
<td>No Effect</td>
<td>5B</td>
<td>140</td>
<td>120 Smooth, high flow</td>
</tr>
<tr>
<td>C14 diacid</td>
<td>62.5</td>
<td>No Effect</td>
<td>5B</td>
<td>100</td>
<td>120 Smooth, high flow</td>
</tr>
<tr>
<td>C12 diacid</td>
<td>81.5</td>
<td>Slight Softening</td>
<td>5B</td>
<td>160</td>
<td>160 Smooth, glossy, high flow</td>
</tr>
<tr>
<td>80% C18 diacid- 20% C9 diacid</td>
<td>77.8</td>
<td>No Effect</td>
<td>5B</td>
<td>20</td>
<td>40 Smooth</td>
</tr>
<tr>
<td>C18 diacid 1-amino-2-propanol</td>
<td>62.9</td>
<td>No Effect</td>
<td>5B</td>
<td>20</td>
<td>&lt;20 Smooth, high flow</td>
</tr>
<tr>
<td>C18 diacid low AV</td>
<td>30.8</td>
<td>No Effect</td>
<td>2B</td>
<td>&lt;20</td>
<td>&lt;20 Smooth, high flow</td>
</tr>
<tr>
<td>C18 diacid high AV</td>
<td>77.9</td>
<td>No Effect</td>
<td>5B</td>
<td>160</td>
<td>160 Smooth, glossy, high flow</td>
</tr>
</tbody>
</table>
Coating performance of polyester-amide resins

C12  C14  C18  C18 High AV  C18 Low AV
QUV-A exposure testing indicates the resin has outdoor durability

- Essentially no difference or change compared to super durable polyester resin control
QUV-B performance exceeds super durable formulation

![Graph showing gloss retention over hours for different formulations.](image-url)
Demonstration of chemical resistance to typical kitchen exposures

<table>
<thead>
<tr>
<th>Reagent</th>
<th>Duration</th>
<th>004-109-9 White</th>
<th>Yellow IKEA MDF Step Stool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vinegar</td>
<td>24 hours</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Lemon</td>
<td>24 hours</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Orange Juice</td>
<td>24 hours</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Grape Juice</td>
<td>24 hours</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Ketchup</td>
<td>24 hours</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Instant Coffee</td>
<td>24 hours</td>
<td>Slight Stain</td>
<td>Pass</td>
</tr>
<tr>
<td>Olive Oil</td>
<td>24 hours</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>100-Proof Alcohol</td>
<td>24 hours</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Detergent Solution</td>
<td>24 hours</td>
<td>Pass</td>
<td>Pass</td>
</tr>
<tr>
<td>Mustard</td>
<td>1 hour</td>
<td>Pass</td>
<td>Pass</td>
</tr>
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</table>

KCMA A161.1 test protocol
Soy-based powder coating combines low-temperature cure, flexibility and UV durability

<table>
<thead>
<tr>
<th>Property</th>
<th>Standard Durable Polyester</th>
<th>Super Durable Polyester</th>
<th>Acrylic</th>
<th>Soy-based Resin w/ TGIC</th>
<th>Fluoro-Polymer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cure Temperature Limit (°C)</td>
<td>150</td>
<td>160</td>
<td>135</td>
<td>135</td>
<td>180</td>
</tr>
<tr>
<td>ASTM D-4587 QUV-B (hrs)</td>
<td>250</td>
<td>1000</td>
<td>&gt;1500</td>
<td>4000</td>
<td>4000+</td>
</tr>
<tr>
<td>Florida Durability (yrs)</td>
<td>1.5</td>
<td>5</td>
<td>10</td>
<td>?</td>
<td>20</td>
</tr>
<tr>
<td>Impact Resistance (in-lbs)</td>
<td>160</td>
<td>60</td>
<td>40</td>
<td>160</td>
<td>80</td>
</tr>
</tbody>
</table>
Successful low temperature coating of MDF at 135°C
...and thermoplastic and composite substrates

Engineering Thermoplastic

Epoxy Fiberglass Composite
Hydroxyalkyl amide (HAA) Cure Systems

20min @ 180°C

10min @ 180°C

20min @ 160°C
Soy-based resin and powder coating formulation has been developed with

- High soy content – 84% for resin
- Low-temperature cure – approaching 125°C on metal, 135°C on MDF
- Coating flexibility – >160 in-lbs impact resistance on steel
- Better than super durable weathering performance – 4000 hours QUV-B
- Chemical resistance
- Smooth coatings with architectural gloss levels
- Unique combination of cure and performance properties
Acknowledgements

• Dan Garbark, Mark Perry and Melissa Roshon – Battelle
• Kevin Biller, Nathan Biller and Nick Page – PCR Group
• Lee Walko – Omni Tech
• United Soybean Board