Bringing Novel, Bio-based Chemicals to Market: Strategies, Applications & Lessons Learned

Next Generation Bio Based Chemicals
Molecules to Markets
January 29, 2013
Not All Chemicals Are Created Equal™

LOWER CARBON FOOTPRINT

NO GREEN PRICE PREMIUM

NON-FOOD BASED OPTION

HIGHER PERFORMANCE
Myriant’s DNA

The Company

- Formed in 2009; 150 Employees in 2012
- HQ in Quincy, MA
- 18,000 sq.ft. R&D lab in Woburn, MA
- Scale and Pilot Plant in Leuna, Germany
- Commercial Plant in Lake Providence, LA

Bio-Based Chemical Strategy

- Convert Renewable Feedstocks to High Value Chemicals
- Focus on C3-C6 Chemicals
- Leverage Deep Biotech Experience to Further Pipeline
- Build-Own-Operate Model
- Strategic Partnerships to Accelerate Growth
People

- All Core Biotech R&D Conducted in House
- ~50 Professionals; ~50% with PhDs

Facilities / Processes

- State-of-the-Art 18,000 Square Ft. Laboratory
- All Genetic Engineering Tools Available on Site
- **Non-GMO** Platform
- Significant Fermentation Optimization Capabilities
- **Fully Integrated** from Lab to Commercial Scale
Scaled with Partners

R&D  SCALING  PILOT PLANT  COMMERCIAL SCALE

Succinic Acid: Final Scale-Up Step Only 8x

Technology Proven
D(-) Lactic Acid at 20,000L Commercial Scale in 2008

Process Improves With Scale
Commercial Yield Targets Maintained or Improved from 7L to 40L to 50,000L
Lake Providence Plant Online 1Q 2013

- **First** Bio-Succinic Acid Plant in U.S.
- 30 MM lb / Year Commercial Plant in Lake Providence, Louisiana
- Commercial Start-Up Q1 2013
- 140 MM lb/Year Expansion Plans Underway
Succinic Acid – Our Engine for Market Acceleration

Current Succinic Acid Applications

- BDO Drop-in Applications i.e. Maleic Anhydride in BDO
- Replacements for Adipic and Phthalic Anhydride

Proven Chemistry Provides Access to High-Value Markets

- SOLVENTS
- PLASTICIZERS
- BUTANEDIOL
- BIODEGRADABLE PLASTICS
- URETHANES
The Case for Renewable Chemical Feedstocks: How Much Does Your Carbon Cost?

Crude oil is much more price volatile than biomass and is more expensive as a source of carbon for building molecules.

Historical feedstock pricing

Feedstock cost of finished product

WTI Crude

Dextrose

Cost advantage

95 Dextrose

Oil-Based Butane
Competitive Cost Advantage of Bio-based Succinic Acid

More expensive raw material and requires high temperature, pressure, and expensive catalyst and 2 plants

Cheaper raw materials, low temperature and pressure, 1 plant
Continuum of Substitution

Type of Substitution

- Exact Substitute
- Completely New Product

Degree of Difficulty

- Easy
- Hard
Constraints

• Product MUST work

• Price, price, price

• “Green” is insufficient to drive material replacement
The Landscape- “Green” Products Don’t Work

- More expensive
- Poorer quality illumination
- Toxic for the environment

but, you’re green if you use them.............
Constraints

• Product MUST work
  • *WHAT IF*.. It does work?

• Price, price, price
  • *WHAT IF*.. There is no price premium?

• “Green” is insufficient to drive material replacement
  • *WHAT IF*.. It is “Greener” (renewable, smaller footprint)?
Example- Performance Chemicals

• Coalescing Solvents for Waterborne Paints
How Coalescing Solvents Work

Coalescing solvents assist in the formation of a coherent film on a substrate from a dispersed water-borne coating formulation.

As-applied wet film:
- The particles approach and contact and begin to flow together with the help of the coalescing solvent.

As water evaporates from the larger surface area of the applied film:
- The particles continue to flow together.

To make a dry film:
- Hard, tough polymer layer holding pigments in place.
**Myrifilm® Performance Equal to Industry Standard with Zero-VOCs**

<table>
<thead>
<tr>
<th>Property</th>
<th>Semi-Gloss Acrylic with Myrifilm™</th>
<th>Semi-Gloss Acrylic with Texanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>KU Viscosity (immed./24 h)</td>
<td>87.9/14.2</td>
<td>90.7/107.8</td>
</tr>
<tr>
<td>Sag</td>
<td>10.7</td>
<td>10</td>
</tr>
<tr>
<td>Leveling</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Contrast ratio (Air-dry, 24h)</td>
<td>96.24</td>
<td>96.25</td>
</tr>
<tr>
<td>Gloss 20°/60°/85°</td>
<td>44.4/74.4/97.9</td>
<td>39.8/75.3/97.8</td>
</tr>
<tr>
<td>Block Resistance (120 °F, 24 h)</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Scrub Resistance (2400 cycles)</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Low Temperature Coalescing (40 °F, 10 mil)</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Tint Strength (Red) %T_{SUC}</td>
<td>103.3</td>
<td>99.8</td>
</tr>
<tr>
<td>Tint Strength (Yellow) %T_{SUC}</td>
<td>83.5</td>
<td>99.4</td>
</tr>
<tr>
<td>Tint Strength (Blue) %T_{SUC}</td>
<td>101.4</td>
<td>100</td>
</tr>
<tr>
<td>VOC (ASTM D-6866)</td>
<td>0.5</td>
<td>18</td>
</tr>
</tbody>
</table>

10.49 lb/gal density, 33.97% solids in formulation.
Dow Rhoplex SG-30 Binder resin (47.7 % w/w); 2.5 wt% coalescent relative to binder resin; TiO₂ Pigment with final PVC 21.95.
Based on Dow recommended formulation for this resin.
Myrifilm® Retains Performance at Lower Concentration

10.54 lb/gal density, 36.84 vol% solids in formulation. Orgal P885RR binder resin (38.9 % w/w); 2.5 wt% coalescent relative to binder resin; TiO₂ Pigment with final PVC 34.09.

Myrifilm® performs as well as Texanol at half the concentration.
Example- Polyurethanes

- Replacement for Adipic Acid in Polyester Polyols
Succinic Acid in Urethanes

- Succinic acid can be used in place of adipic acid to make polyurethanes with very good physical properties.
- Replacement is straightforward - requires less modification to formulation than other “green” alternatives.
- Same chemical functionality so fits into same processes and applications.
- Provides a renewable alternative that works.

Succinic acid based polyester polyol

\[
\text{CH}_2\text{CH(OH)COOH} + \text{HO}-\text{C}-(\text{CH}_2\text{CH(OH)})_{n}\text{OH} \rightarrow \text{HO}-\text{C}-(\text{CH}_2\text{CH(OH)})_{n}\text{COO}-(\text{CH}_2\text{CH(OH)})_{n}\text{OH}
\]

Adipic acid based polyester polyol

\[
\text{CH}_2\text{CH(OH)COOH} + \text{HO}-\text{C}-(\text{CH}_2\text{CH(OH)})_{n}\text{OH} \rightarrow \text{HO}-\text{C}-(\text{CH}_2\text{CH(OH)})_{n}\text{COO}-(\text{CH}_2\text{CH(OH)})_{n}\text{OH}
\]
## Higher Renewable Content That Works

<table>
<thead>
<tr>
<th>Diacid</th>
<th>Diol</th>
<th>Bio-based Carbon Content (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAC</td>
<td>DEG (90)/PEG (10)/TMP</td>
<td>47</td>
</tr>
<tr>
<td>SAC</td>
<td>DEG (90)/PEG (10)/TMP</td>
<td>47</td>
</tr>
<tr>
<td>SAC</td>
<td>EG</td>
<td>66</td>
</tr>
<tr>
<td>SAC</td>
<td>BDO (80)/MPD (20)</td>
<td>45</td>
</tr>
<tr>
<td>SAC</td>
<td>DEG</td>
<td>50</td>
</tr>
<tr>
<td>SAC</td>
<td>HDO</td>
<td>40</td>
</tr>
<tr>
<td><strong>SAC</strong></td>
<td><strong>PDO</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

**Up to 100% Renewable Content Available**
Polyurethane Physical Properties

Shore A Hardness

Comparative shore a hardness across all compositions

Crystalline materials - increased hardness
Polyurethane Physical Properties

Crystalline materials - increased stiffness

Comparable Modulus across all compositions
Example- Materials

- Plasticizer for Flexible PVC
Succinate Esters as Phthalate-Free Plasticizer Alternatives

**Succinic acid**

\[
\text{HO-CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}-(\text{CO}_2\text{H})_2
\]

- **Isononanol** → **DINSX** (Di-isononyl succinate)
- **Isodecanol** → **DIDDSX** (Di-isodecyl succinate)
- **2-EH** → **DOSX** (Dioctyl succinate)

**Adipic acid**

\[
\text{HO-CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}-(\text{CO}_2\text{H})_2
\]

**2-EH** → **DOA** (Dioctyl adipate)

**Phthalic anhydride**

\[
\text{Phthalic anhydride}
\]

**2-EH** → **DOP** (Dioctyl phthalate)
Plasticizer Efficiency at 50 phr

<table>
<thead>
<tr>
<th>Plasticizer</th>
<th>Shore A</th>
<th>Shore D</th>
<th>$T_b$ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOSX</td>
<td>84</td>
<td>35</td>
<td>-58</td>
</tr>
<tr>
<td>DINSX</td>
<td>91</td>
<td>34</td>
<td>-58</td>
</tr>
<tr>
<td>DIDSX</td>
<td>91</td>
<td>42</td>
<td>-50</td>
</tr>
<tr>
<td>DOA</td>
<td>84</td>
<td>35</td>
<td>-59</td>
</tr>
<tr>
<td>DOP</td>
<td>88</td>
<td>43</td>
<td>-30</td>
</tr>
</tbody>
</table>

Succinate ester plasticizers show efficiency and low temperature flexibility comparable to standard aliphatic plasticizers.

Tested according to ASTM D-2240 and D-746-07
Higher molecular weight succinate esters are less volatile and can retain physical properties better than dioctyl adipate under severe aging conditions.
Succinic Acid in Renewable Performance Materials

Succinic acid

Ester plasticizers for vinyl compounds

Unsaturated Polyesters

PET copolymers for non-wovens and fibers

Polyesters for hot melt adhesives

Polymer polyols for polyurethanes and TPU's

Polyester resins for coatings

Poly(butylene terephthalate) for engineering resins

Poly(butylene succinate) for flexible films and packaging

PTMEG for elastic fibers

1,4-butandiol
Transforming the Chemicals Industry

- Technical barriers to practical commercial supply and adoption of bio-based chemicals are falling quickly.

- Commercial barriers to widespread adoption of bio-based chemicals including capital and supply chains for non-food feedstocks remain.

- Market barriers get lower when a product performs well, has no green premium, and gives a smaller environmental footprint.

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