TERRYL™ BIO-BASED NYLON: DEVELOPMENT, PRODUCTION AND GROWTH POTENTIAL

PAUL J. CASWELL
PRESIDENT
JUNE, 2013
AGENDA

- Bio-plastics—driving the evolution of plastics
- A broad range of renewablenylons & monomers
- Cathay Industrial Biotech Introduction
Bio-plastics Classification & History

- **Renewable raw materials**
  - I: Cellulose acetate (CA), Rubber
  - II: Polyethylene (PE), Polypropylene (PP), Polyvinyl chloride (PVC), Polyamide (PA)
  - III: Polycaprolactone (PCL), Polyvinyl alcohol (PVAL)
  - IV: Starch blends, polyhydroxyalkanoate (PHA), Polylactic acid (PLA), Regenerated cellulose (CH)
  - V: Bio-PE, Bio-PA

- **Non-renewable raw materials**
  - Non-biodegradable
  - Biodegradable
Bio-plastics Production Capacity 2016 (by type)

Bioplastics production capacity 2016 (by type)

- Others: 1.0%
- Bio-PA: 1.2%
- Bio-PE: 4.3%
- Bio-PET 30: 80.1%
- PLA: 5.1%
- Biodegradable Polysters: 2.7%
- Biodegradable Starch Blends: 2.5%
- PHA: 2.5%
- Others: 0.6%

In %
Total: 5,778,500 metric tonnes

Biobased/non-biodegradable: 86.6%
Biodegradable: 13.4%

Source: European Bioplastics | Institute for Bioplastics and Biocomposites (October 2012)

1 only hydrated cellulose foils
Bio-plastics—drive the evolution of plastics

A broad range of renewable nylons & monomers

Cathay Industrial Biotech Introduction
Cathay green nylon project

- Bioprocess long chain diacids (LCDAs)
- Green Diamine (DN5)
- DN5-based Green nylon (PA5X)

H₂N-(CH₂)₅-NH₂
Green/Petro Diamine

HOOC-(CH₂)n-COOH
Green/Petro Diacid
Diacid Bioprocess Alternative to Chemical Synthesis

Bio-Based Process

Petro/Plant Paraffin

CH3-(CH2)n-CH3

Or

Fatty Acids

CH3-(CH2)n-COOH
(Renewable Source)

Micro-organism

LCDAs

Or

Green LCDAs

Standard Chemical Based Process

Butadiene

Ti/Al

CDT

H2

CDD

Air

OH

CDDA

CDDK

HNO3

LCDAs

Multiple Chemical Steps

(1) Ube uses a similar chemical-based benzene process

Competitive Landscape

• INVISTA
• Ube\(^{(1)}\)
• Evonik Industries AG

Ube uses a similar chemical-based benzene process
Cathay Diacid Factory

Increased α-oxidation

Engineer peroxisomes

Decrease β-oxidation

P450s

Plasmid

Nucleus

Sequenced Genome

Increased ω-oxidation

TCA

Mitochondria

Acetyl-CoA

Peroxisome

HOOC

Plasmid
Broad Innovative Product Range

1,11-Undecanedioic Acid

1,12-Dodecanedioic Acid

1,13-Brassylic Acid

1,14-Tetradecanedioic Acid

1,15-Pentadecanedioic Acid

1,16-Hexadecanedioic Acid

1,18-Octadecanedioic Acid

1,5 Pentane Diamine

HOOC(CH$_2$)$_9$COOH

HOOC(CH$_2$)$_{10}$COOH

HOOC(CH$_2$)$_{11}$COOH

HOOC(CH$_2$)$_{12}$COOH

HOOC(CH$_2$)$_{13}$COOH

HOOC(CH$_2$)$_{14}$COOH

HOOC(CH$_2$)$_{16}$COOH

H$_2$N(CH$_2$)$_5$NH$_2$
Cathay Major Markets

**Engineering Plastics**
- Polyamide 5-6, 5-X, 6-12 & 6-14

**Adhesives & Performance Coatings**
- Co-polyamide adhesives
- Polyester adhesives and paints

**Coatings GMA Powder Coat Cross-linker**

**Wheels**

**Anti Corrosion**
- Metal working fluids/Industrial cooling systems

**Synthetic Lubricants (Dibasic Esters)**
- High Performance/Automobiles

**Personal Care-Synthetic Musk & Ketone Fragrances**
- Household cleaners

**Pharmaceutical Intermediates**
Diamine Bioprocess Alternative to Chemical Synthesis

Process Comparison

Bio Process

Biomass
Or
Sugar

Micro-organism

1,5-pentane diamine
C-BIO N5 (DN5)

Competitive Landscape

- Invista
- Ascend

Standard Chemical Process

Naphtha

FCC Separato
Butadiene

Adiponitrile

1,6-hexamethylenediamine
HMDA (DN6)

Naphtha Natural Gas

Olefin Cracker
Propylene

Acrylonitrile
Cathay Diamine Factory

Genomic DNA Modifications

Random Mutagenesis

Genomic DNA Modifications

Sensor
Plasmid

Screen High
Production and
Tolerance Mutants

Metabolic engineering

Protein engineering

TCA

Random Mutagenesis

NH₂

Metabolic engineering

H₂N

Protein engineering

NH₂

H₂N
# Cathay C-Bio N5 Technical Data

<table>
<thead>
<tr>
<th></th>
<th>C-BIO N5</th>
<th>HMDA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS No.</td>
<td>462-94-2</td>
<td>124-09-4</td>
</tr>
<tr>
<td>% Renewable (ASTM D6866)</td>
<td>100%</td>
<td>0%</td>
</tr>
<tr>
<td>Molecular weight</td>
<td>102</td>
<td>116</td>
</tr>
<tr>
<td>Formula</td>
<td>H₂N-(CH₂)₅-NH₂</td>
<td>H₂N-(CH₂)₆-NH₂</td>
</tr>
<tr>
<td>% NH₂</td>
<td>31%</td>
<td>28%</td>
</tr>
<tr>
<td>Appearance</td>
<td>clear liquid</td>
<td>clear solid</td>
</tr>
<tr>
<td>Melting point (°C)</td>
<td>9</td>
<td>41</td>
</tr>
<tr>
<td>pKa1</td>
<td>10.05</td>
<td>10.24</td>
</tr>
<tr>
<td>pKa2</td>
<td>10.93</td>
<td>11.02</td>
</tr>
<tr>
<td>pH 5% solution</td>
<td>12.6</td>
<td>12.4</td>
</tr>
</tbody>
</table>

8% less diamine needed with C-Bio N5
Cathay Terryl™ PA5X

TERRYL™ product line: current offering includes PA56, PA510, PA512, PA514 and copolymers

Renewable Polyamides

Strength Barrier Properties

- PA12 • PA1212
- PA11 • PA1012
- PA1010
- PA612
- PA514

Chain Length

- PA6 • PA66
- PA510
- PA610
- PA512
- PA56
- PA46

Moisture Resistance
Stress Cracking Resistance

CATHAY INDUSTRIAL BIOTECH
<table>
<thead>
<tr>
<th><strong>Terryl™</strong></th>
<th><strong>Renewable %</strong></th>
<th><strong>Diamine</strong></th>
<th><strong>Diacid</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>PA56</td>
<td>47%</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>PA510</td>
<td>100%</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>PA511</td>
<td>36%</td>
<td>5</td>
<td>11</td>
</tr>
<tr>
<td>PA512</td>
<td>34-100%</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>PA513</td>
<td>32-100%</td>
<td>5</td>
<td>13</td>
</tr>
<tr>
<td>PA612</td>
<td>up to 63%</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>PA514</td>
<td>31-100%</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>PA1012</td>
<td>46-100%</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>PA1212</td>
<td>up to 100%</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>
## Cathay Terryl™ PA56 Properties

<table>
<thead>
<tr>
<th>Test Method</th>
<th>Unit</th>
<th>PA66</th>
<th>PA6</th>
<th>Terryl™ PA56</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decomposition temperature</td>
<td>TGA °C</td>
<td>424.7</td>
<td>426.3</td>
<td>424.3</td>
</tr>
<tr>
<td>Melting point</td>
<td>TGA °C</td>
<td>261.1</td>
<td>217.9</td>
<td>254.0</td>
</tr>
<tr>
<td>Crystallization temperature</td>
<td>DSC °C</td>
<td>222.3</td>
<td>193.7</td>
<td>213.5</td>
</tr>
<tr>
<td>Notched Izod Impact</td>
<td>ASTM D256 J/m</td>
<td>42.4</td>
<td>41.8</td>
<td>35.3</td>
</tr>
<tr>
<td>Tensile Modulus</td>
<td>ASTM D638 Mpa</td>
<td>3087.2</td>
<td>3010.2</td>
<td>2940.1</td>
</tr>
<tr>
<td>Tensile Strength at Break</td>
<td>ASTM D638 Mpa</td>
<td>75.4</td>
<td>72.4</td>
<td>69.8</td>
</tr>
<tr>
<td>Elongation at Break</td>
<td>ASTM D638 %</td>
<td>17.4</td>
<td>8.0</td>
<td>15.7</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>ASTM D790 Mpa</td>
<td>2851.8</td>
<td>2600.0</td>
<td>2870.1</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>ASTM D790 Mpa</td>
<td>124.3</td>
<td>118.0</td>
<td>125.6</td>
</tr>
<tr>
<td>Density</td>
<td>ASTM D792 g/cm³</td>
<td>1.14</td>
<td>1.13</td>
<td>1.13</td>
</tr>
<tr>
<td>% Renewable</td>
<td>ASTM D6866 %</td>
<td>0</td>
<td>0</td>
<td>47%</td>
</tr>
</tbody>
</table>

**PA56 seems more similar to PA66 than PA6**
Samples

PA56 Chip

PA510 Chip

PA512 Chip

PA56 Compounded

PA56 Cable ties

PA56 filament
Green Nylon in Test Products

Heated Bug Repellent
Pure PA56

Electric part
PA56 + 30% glass fiber
- Bio-plastics——drive the evolution of plastics
- World’s broadest range of renewable nylons
- Cathay Industrial Biotech Introduction
Company History

1997
- Company founded

2001
- Built first plant

2003
- Series A & B Financing

2005
- Series C Financing

2007
- Achieved revenue of >US$150 mn

2009
- 2011

2013
- 2015

Corporate

**Long Chain Diacid**
- Began R&D
- Began commercial production
- Expansions
- Major DC12 supplier globally
- Developed next generation process

**Bio-butanol**
- Board approves bio-butanol project
- 100,000 MT plant built
- Cellulosic biomass tech breakthroughs

**Green Diamine**
- Began R&D
- Technology breakthroughs
- Pilot production
- Annual production 20,000 MT

**Green Nylon**
- Began R&D
- Pilot production
- Annual production 40,000 MT
Our World Footprint

- Sales Office
- Warehouse
Cathay Shandong Province Production Facility (bio-butanol, bio-acetone)
Summary

- Biopolymers are the fastest growing segment of the polymer industry.
- Cathay’s fermentation of long chain diacids has already replaced the chemical process as market leader by providing a “drop in” chemicals.
- New competitive biobased C5 diamine, CBIO N5 is available for new polyamides and adhesives.
- Terryl™ PA5,6 has comparable performance properties to PA6,6.
- Terryl™ PA5XX provides unique new performance properties for high performance polyamides.

Contact Cathay for a sample of www.cathaybiotech.com
Thank You

Also Available Biobutanol and Bioacetone