Samsung’s Bioplastics
For Automobile

Biobased • Sustainable • Renewable Source
Why We Promote the BIO-based Plastics?

• Good in many environmental aspects
  ▶ Oil saving
  ▶ CO₂ Gas Reduce

• Paradigm shift from Oil to biomass
  ▶ Practical alternative to a Petroleum-based plastics

• Customers’ interest
  ▶ Customers can look and touch by using as casing

• GHG emission restrictions
  ▶ Kyoto Protocol, the EU ETS
Zephyr Energy Green Tags from the Bonneville Environmental Foundation (BEF) are a renewable energy certificate product.

NatureWorks' PLA resin

Green Tags

Product Content Label for BEF Zephyr EnergyTM – 2006

Zephyr Energy Green Tags from the Bonneville Environmental Foundation (BEF) are a renewable energy certificate product.

The Green Purchasing Network (GPN)
Life Cycle of Poly Lactic Acid (PLA)

- Lactic Acid
  - Enzyme & Fermentation
  - Photosynthesis
  - Vegetables

- Chemical Synthesis
- Polylactic Acid (PLA)
- Molding with additives
- Injection Molding
- Material Recycling
- Chemical Recycling
- Incineration / Composting
- CO₂
- H₂O
- mineral
EP/Bio-alloy Materials

- Realization of Environmental Friendly Material by EP(Engineering Plastics)/Bio-alloy

- PLA (Poly Lactic Acid) correspond with the move towards green, but PLA is mechanically and thermally weak to use a housing material.

- By combination with Bio material and EP, high performance of mechanical properties and nature-friendly characteristics can be achieved.

- Biomass target is at least 50%.
Samsung’s Technology

- Development of Continuous Polymerization Process
  - PS, HIPS, SAN, ABS, PMMA, PC

- Development of Polymerization Process for Optical Transparent Materials
  - Copolymerization technology
  - New base resin can be produced
  - Impact modifier for PLA
  - Compatibilizer for PC/PLA, ABS/PLA

- PLA Synthesis (Lab Scale)
  - Research & Development for Stereocomplex PLA
Samsung’s Technology

Engineering Plastics

Samsung Cheil industries produces over than 100 thousands ton/year engineering Plastics.

→ Great store of knowledge about formulation, surface modification, producing technology, technical service.

Products: PC, PC/ABS, PC/GF, PPS, LCP, MPPE, High Temperature Nylon

Achievement

• High Value-Added Engineering Plastics
  - Mobile Phone Housing : World M/S 18% (2nd)
  - LCD Back Light Unit Frame : World M/S 20% (2nd)
Our Technical Goal

Heat Resistance

<Crystalline>  <Amorphous>

Modified PLA

Commodity
High Performance
Engineering Thermoplastics

Chemical R&D Center
Cheil Industries INC.
Key Technologies to our goal

- Toughening
  - Impact Modifier
  - Compatibilizer

- Reinforcement
  - SNF * → LNF → MC-LNF

- Crystallization
  - Nucleating Agent
  - Stereocoplex

- U社 Kenaf/PLA
- K社 Jute/PLA

HDT (°C)

Izod Impact Strength (ft-lbf/in)

* SNF - Short Natural Fiber
LNF - Long Natural Fiber
MC-LNF; Multi-Component Long Natural Fiber
Mobile Phone Application

◇ Vegetable base Mobile Phone
- Sony have plans to use bioplastics to replace conventional plastics in some parts of Mobile phone.

◇ Kenaf/PLA Composite
  Developing an highly heat-resistant PLA composite by the combination with kenaf fiber (Maintaining high biomass ratio: 90%)
Automotive Eco-Design Examples

Mazda

A new bio-fabric from Mazda will trade in synthetic fibres for an all-natural upholstery product containing 100% PLA. (2007. 9. 13 日刊自動車新聞)

Toyota

Toyota unveiled the Raum SUV in 2003, which had floor mats and a spare-tire cover made from Toyota’s Eco-Plastic PLA reinforced with kenaf plant fiber (2007. 9. 6 日刊自動車新聞)
Life Cycle Assessment
System Boundaries of LCA for Bioplastics

LCA (Life Cycle Assessment): A scientific approach to measure quantitatively the environmental performance of a product or system
Environmental Impact

Greenhouse Gas Emission
(g-CO₂/g-Resin)

Production Energy Consumption
(MJ/kg)

Clear advantage for bioplastics: GHG emissions ↓, Energy ↓
(compared to conventional polymers & bioenergy)

Ref. Dr. Martin Patel, Utrecht University
Eco-Efficiency

LCA calculation focused on CO₂ Gas reduction

- Incineration
- Transportation
- Resin Production

Eco-Efficient Features:
- Lower Density
- Lighter Part
- Lower CO₂ Emission
- High Performance of Biomass
Stereocomplex of PLA
Sterocomplex PLA

\[
\left\{ \begin{array}{c}
\text{CH}_3 \\
\text{O} - \text{C}^* - \text{C} \\
\text{H} \\
\text{O}
\end{array} \right\}_n
\]

\( C^*: \) asymmetric carbon

\[ \rightarrow \text{L-lactide, D-lactide} \]

PLA: PLLA, PDLA, PLDLA

L-lactide

D-lactide
# Properties of Stereocomplex PLA

<table>
<thead>
<tr>
<th></th>
<th>Pure PLLA</th>
<th>Sc-PLA (PLLA/PDLA 50/50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_g$ ($^\circ$C)</td>
<td>50 ~ 60</td>
<td>65 ~ 72</td>
</tr>
<tr>
<td>$T_m$ ($^\circ$C)</td>
<td>170-180 (depending on D-content)</td>
<td>220-230</td>
</tr>
<tr>
<td>$\Delta H_m$ (J/g)</td>
<td>93</td>
<td>100 ~ 140</td>
</tr>
</tbody>
</table>

**Definitions:**
- **PLLA** = pure L(+)-lactic acid (poly(L-lactide)
- **PDLA** = pure D(-)-lactic acid (poly(D-lactide)
- **sc-PLA** = 1/1 PDLA and PLLA (50/50 w/w)
Practical Benefits of Stereocomplex PLA

- Injection molding PLA: cycle time reduction
- Better heat stability
- Better mechanical properties
- Better durability, slower degradation
- Engineering Applications for PLA

PDLA widens the application window of PLA
Long Fiber Technology
Advantages of Long Fiber Technology (LFT)

Representative Enhanced Properties

- High Strength
- Enhanced Modulus
- Superior Creep Resistance
- Excellent Fatigue Resistance
- Improved Dimensional Stability
- Better Heat Resistance

Total Penetration energy

- PP/SGF 30%: 2.32 J/mm
- PP/LGF 30%: 7.31 J/m
Improving Crystallization of PLA/LGF Composites

Special Nucleating Agent for PLA
Test conditions: 200 °C → 140 °C cooling with 10°C/min rate

<table>
<thead>
<tr>
<th></th>
<th>Neat PLA</th>
<th>PLA + G/F</th>
<th>PLA + G/F + Nucleating Agent</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDT (°C)</td>
<td>55</td>
<td>60</td>
<td>150</td>
</tr>
<tr>
<td>IZOD (ft-lbf/in)</td>
<td>0.6</td>
<td>3</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Optical Microscope

[Images of Optical Microscope for Neat PLA, PLA + G/F, and PLA + G/F + Nucleating Agent]
PLA/Long Glass Fiber (LGF) Composites

Graph showing the relationship between HDT at 264 psi load (°C) and Izod Impact Strength (kgf-cm/cm) vs. Long G/F Content (wt%).
General Properties
### Properties of PC/PLA Alloy

<table>
<thead>
<tr>
<th>General Properties</th>
<th>Unit</th>
<th>Grade</th>
<th>GL-1355S</th>
<th>GL-1455S</th>
<th>PC/ABS (HP-1001N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass cont.</td>
<td></td>
<td></td>
<td>35 %</td>
<td>45%</td>
<td>0 %</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>Psi</td>
<td></td>
<td>7,100</td>
<td>7,700</td>
<td>7,800</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>Psi</td>
<td></td>
<td>10,700</td>
<td>11,400</td>
<td>11,100</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>Psi</td>
<td></td>
<td>291,000</td>
<td>335,000</td>
<td>298,000</td>
</tr>
<tr>
<td>Impact Strength</td>
<td>Ft-lbf/in (1/8”)</td>
<td></td>
<td>12.8</td>
<td>12.8</td>
<td>8.3</td>
</tr>
<tr>
<td>HDT</td>
<td>deg.F (264 psi)</td>
<td></td>
<td>230</td>
<td>167</td>
<td>232</td>
</tr>
<tr>
<td>Melt Flow Index</td>
<td>g/10min (250°C, 10kg)</td>
<td></td>
<td>45</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>Density</td>
<td>g/cm³</td>
<td></td>
<td>1.18</td>
<td>1.18</td>
<td>1.15</td>
</tr>
<tr>
<td>Mold Shrinkage</td>
<td>%</td>
<td></td>
<td>0.8 ~ 1.0</td>
<td>0.8 ~ 1.0</td>
<td>0.5 ~ 0.7</td>
</tr>
<tr>
<td>Hydrolysis Stability</td>
<td>FS retention(%) after 150hr at 80°C &amp; 95%RH</td>
<td></td>
<td>95%</td>
<td>95%</td>
<td>100%</td>
</tr>
</tbody>
</table>
# Long Glass Fiber (LGF) Reinforced PLA Composites

<table>
<thead>
<tr>
<th>General Properties</th>
<th>Unit</th>
<th>Grade</th>
<th>GL-0505G</th>
<th>GL-0755G</th>
<th>PC/GF (HF-3200)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass cont.</td>
<td></td>
<td>50%</td>
<td></td>
<td>75%</td>
<td>0%</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>Psi</td>
<td>14,100</td>
<td>16,600</td>
<td>4,200</td>
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</tr>
<tr>
<td>Flexural Strength</td>
<td>Psi</td>
<td>20,900</td>
<td>20,700</td>
<td>24,100</td>
<td></td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>Psi</td>
<td>1,623,000</td>
<td>880,000</td>
<td>795,000</td>
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</tr>
<tr>
<td>Impact Strength</td>
<td>Ft-lbf/in (1/8”)</td>
<td>2.6</td>
<td>3.1</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>g/cm³</td>
<td>1.6</td>
<td>1.37</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>HDT</td>
<td>deg.F (264psi)</td>
<td>302</td>
<td>302</td>
<td>289</td>
<td></td>
</tr>
<tr>
<td>Hydrolysis Stability</td>
<td>FM retention(%) after 150hr at 80°C &amp; 90%RH</td>
<td>95%</td>
<td>95%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Remark</td>
<td></td>
<td>G/F 40% Reinforced</td>
<td>G/F 20% Reinforced</td>
<td>G/F 20% Reinforced</td>
<td></td>
</tr>
</tbody>
</table>
# Properties of ABS/PLA Alloy

<table>
<thead>
<tr>
<th>General Properties</th>
<th>Unit</th>
<th>Grade</th>
<th>GL-3405H</th>
<th>GL-3405S</th>
<th>ABS (SR-0325)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass cont.</td>
<td></td>
<td></td>
<td>40%</td>
<td>40%</td>
<td>0%</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>Psi</td>
<td></td>
<td>6,400</td>
<td>6,500</td>
<td>7,000</td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>Psi</td>
<td></td>
<td>9,500</td>
<td>9,500</td>
<td>9,900</td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>Psi</td>
<td></td>
<td>285,000</td>
<td>317,000</td>
<td>312,000</td>
</tr>
<tr>
<td>Impact Strength</td>
<td>Ft-lbf/in (1/8”)</td>
<td></td>
<td>5.5</td>
<td>1.1</td>
<td>2.8</td>
</tr>
<tr>
<td>Density</td>
<td>g/cm³</td>
<td></td>
<td>1.11</td>
<td>1.12</td>
<td>1.06</td>
</tr>
<tr>
<td>MI (230 °C, 2.16kg)</td>
<td>g/10min</td>
<td></td>
<td>8</td>
<td>20</td>
<td>8</td>
</tr>
<tr>
<td>VST</td>
<td>deg.F (5kg)</td>
<td></td>
<td>226</td>
<td>234</td>
<td>230</td>
</tr>
<tr>
<td>HDT</td>
<td>deg.F (66 psi)</td>
<td></td>
<td>216</td>
<td>230</td>
<td>266</td>
</tr>
<tr>
<td>Hydrolysis Stability (Retention of FS)</td>
<td></td>
<td>After 8 days at 60°C and 90%RH</td>
<td>~ 92%</td>
<td>~ 93%</td>
<td>100%</td>
</tr>
<tr>
<td>Remark</td>
<td></td>
<td>High Impact ABS/PLA</td>
<td>Standard ABS/PLA</td>
<td>High Temp. ABS</td>
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</table>
## Properties of Reinforced ABS/PLA

<table>
<thead>
<tr>
<th>General Properties</th>
<th>Unit</th>
<th>Grade</th>
<th>GL-3503N</th>
<th>GL-3203G</th>
<th>ABS (SR-0325)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass</td>
<td>%</td>
<td>50%</td>
<td>50%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>Psi</td>
<td>6,800</td>
<td>10,800</td>
<td>7,000</td>
<td></td>
</tr>
<tr>
<td>Flexural Strength</td>
<td>Psi</td>
<td>9,800</td>
<td>15,900</td>
<td>9,900</td>
<td></td>
</tr>
<tr>
<td>Flexural Modulus</td>
<td>Psi</td>
<td>398,000</td>
<td>440,000</td>
<td>312,000</td>
<td></td>
</tr>
<tr>
<td>Impact Strength</td>
<td>Ft-lbf/in (1/8”)</td>
<td>0.9</td>
<td>1.7</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>g/cm³</td>
<td>1.16</td>
<td>1.25</td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td>MI (230 °C, 2.16kg)</td>
<td>g/10min</td>
<td>15</td>
<td>4</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>VST</td>
<td>deg.F (5kg)</td>
<td>212</td>
<td>194</td>
<td>230</td>
<td></td>
</tr>
<tr>
<td>HDT</td>
<td>deg.F (264 psi)</td>
<td>194</td>
<td>221</td>
<td>212</td>
<td></td>
</tr>
<tr>
<td>Hydrolysis Stability (Retention of FS)</td>
<td>After 8 days at 60°C and 90%RH</td>
<td>~ 80%</td>
<td>~ 96%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Remark</td>
<td>Natural Fiber Reinforce</td>
<td>G/F 10% Reinforce</td>
<td>Standard High Temp. ABS</td>
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<td></td>
</tr>
</tbody>
</table>
Yeosu Plant (Synthetic Resin)

Uiwang R&D Center