Innovative Materials and Their Improved Design and Processing

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Eastman Chemical Company
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Outline

- Introduction
- Where do we play?
- What’s Eastman Tritan™ copolyester?
- Material Properties
- Card Properties
  - NCITS 322 Tests
  - ISO 7810
  - Laser Engraving
  - Printing
- Conclusions
Eastman Chemical Company

- A global manufacturer of chemicals, plastics and fibers headquartered in Kingsport, Tennessee.
- A company dedicated to environmental stewardship, social responsibility and economic growth.
- Winner of the 2009 U.S. Presidential Green Chemistry Challenge.
- One of *Newsweek*’s Top 100 Greenest Companies in America in 2009.
- The first company to commercialize a gasification facility in the U.S., in 1983, which is operating at industry-leading performance.
Eastman Chemical Company

- Specialty Plastics
- Coatings, Adhesives, Specialty Polymers and Inks
- Fibers
- Performance Chemicals and Intermediates

- 2010 Sales Revenue $5.8B
Eastman Plastic Innovation

Chemical Composition influences the properties of a polymer

- Chemical structure of the monomers
  - From the simple… to the complex.

- Arrangement of the units within the chain
  - Homopolymer
    - Ex. PMMA, PVC, PC, PET
  - Copolymer
    - Ex. ABS, PETG, Tritan™

From the simple… to the complex.
# Polymer Composition

<table>
<thead>
<tr>
<th>Polymer</th>
<th>PVC</th>
<th>ABS</th>
<th>PC</th>
<th>PET</th>
<th>PETG (Eastar™ 6763)</th>
<th>Tritan™ (FX 100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PMMA</td>
<td><img src="image" alt="PMMA" /></td>
<td><img src="image" alt="ABS" /></td>
<td><img src="image" alt="PC" /></td>
<td>1,4-Cyclohexanediol monomer</td>
<td>Proprietary high temperature monomer</td>
<td></td>
</tr>
</tbody>
</table>

- **PVC**: Polyvinyl Chloride
- **ABS**: Acrylonitrile Butadiene Styrene
- **PC**: Polycarbonate
- **PET**: Polyester
- **PETG**: Polyethylene Terephthalate Glycol
- **Tritan™**: High Performance Resin
China ID Card Structure (PETG)

- Clear BOPET (100 micron, 4 mil)
- Clear PETG (65 Micron, 2.6 mil)
- White PETG (95 micron printing layer)
- White PETG (95 micron, 3.7 mil)
- White PETG (330 micron, 13 mil)

(Film and thickness are same as the above)
PETG Cards (with IC Chip)
Performance Attributes of PETG

Advantages:

- Environmental Friendly Material
- Compatible with multiple printing ink systems
- Low temperature lamination & Short Cycle Time
- No De-Lamination
- Ease of Cutting
- Compatible with IC chips and adhesives

Improvements Needed:

- Longer Life
- Insufficient Emboss retention
- Chemical Resistance
- Laser Engraving

Tritan™ has all the advantages of PETG and addresses the improvements needed.
Eastman Tritan™ Copolyester

A new generation copolyester which has a unique balance of properties – great toughness with easy processing, clarity, chemical resistance, improved heat resistance, as well as BPA-free.
Tritan™ Commercial Applications
Eastman Tritan™ copolyester

- Toughness
- Heat Resistance
- Chemical Resistance
- Clarity
- Processability
Polymer Mechanical Behavior

- **Brittle plastic**
  - Absorbs very little energy, shatters like glass

- **Tough plastic**
  - High energy absorption, can be significantly deformed without failing

- **Elastomer**
  - Rubbery materials, think soft-touch grips on pens etc.
Notched Izod Impact Test (ASTM D256)

Notch Sensitivity is a measure of the reduction in strength of a material caused by the presence of a notch.
Instrumented Impact Test (ASTM D3763)

The determination of puncture properties of rigid plastics over a range of test velocities.
Impact Strength

- Tritan: Notched Izod Impact = 101 J/dm, Instrumented Impact = 67 J
- PC: Notched Izod Impact = 96 J/dm, Instrumented Impact = 80 J
- PMMA: Notched Izod Impact = 3 J, Instrumented Impact = 6 J
- PETG: Notched Izod Impact = 9 J, Instrumented Impact = 33 J
Eastman Tritan™ copolyester

- Toughness
- Clarity
- Heat Resistance
- Chemical Resistance
- Processability
Heat Deflection Temperature Test

Load = \( \frac{2Sbd^2}{3L} \)

\( S = 1.82 \) or \( 0.455 \) MPa

Specimen

LVDT

Weight

Thermocouple

Oil

100 mm

ASTM D648  Deflection is 0.01 in (0.25 mm)
Heat Deflection Temperature

1.82 MPa (264 psi)

<table>
<thead>
<tr>
<th>Material</th>
<th>HDT, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tritan</td>
<td>90</td>
</tr>
<tr>
<td>PC</td>
<td>135</td>
</tr>
<tr>
<td>PMMA</td>
<td>90</td>
</tr>
<tr>
<td>PETG</td>
<td>70</td>
</tr>
</tbody>
</table>
Eastman Tritan™ copolyester

Toughness - Heat Resistance - Chemical Resistance - Clarity - Processability
Critical Strain Testing

- Sample is placed on an elliptical jig \((a = 10\”, b = 5\”)\)
- Chemical is applied at RT for 24 hr
- Critical strain \((\varepsilon_c)\) is defined as the strain at which crazes appear

\[
\varepsilon = \frac{tb}{2a^2} \left[ 1 - \left( \frac{1}{a^2} - \frac{b^2}{a^4} \right) X^2 \right]^{-1.5}
\]

![Graph showing critical strain as a function of craze distance](image)
Plasticizer Resistance

Critical Strain

- Diethyl phthalate
- Dimethyl phthalate
- Dibutyl phthalate
- Dioctyl adipate (DOA)
- Dibutoxyethyl adipate

Tritan
PC
Eastman Tritan™ copolyester

- Toughness
- Heat Resistance
- Chemical Resistance
- Clarity
- Processability
Lamination requires temperatures above glass transition.
Tritan has a wider process window.
Eastman Tritan™ copolyester

- Toughness
- Heat Resistance
- Chemical Resistance
- Clarity
- Processability
High clarity is good for overlay material.
## Other Properties

<table>
<thead>
<tr>
<th>Properties</th>
<th>PET</th>
<th>PETG</th>
<th>PC</th>
<th>Tritan™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>1.33</td>
<td>1.27</td>
<td>1.20</td>
<td>1.18</td>
</tr>
<tr>
<td>Glass Transition Temp (° C)</td>
<td>78</td>
<td>82</td>
<td>148</td>
<td>110</td>
</tr>
<tr>
<td>Flexural Modulus (kpsi)</td>
<td>360</td>
<td>300</td>
<td>340</td>
<td>225</td>
</tr>
<tr>
<td>Tensile Elongation @ Break (%)</td>
<td>120</td>
<td>130</td>
<td>110</td>
<td>210</td>
</tr>
</tbody>
</table>
Tritan Card Lamination

4 mil clear Tritan™
12 mil white Tritan™
12 mil white Tritan™
4 mil clear Tritan™
NCITS 322 Tests @ Eclipse Labs

- Peel Strength - 180°
- Peel Strength - 90°
- Card Flexure
- Static Stress
- Card Stress and Plasticizer Exposure

- Impact Resistance
- Card Structure Integrity
- Ultraviolet Light Exposure Stability
- Laundry Test
# Card Flexure

<table>
<thead>
<tr>
<th>Card Type</th>
<th>Flex cycles until fracture</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A-axis</td>
<td>B-axis</td>
</tr>
<tr>
<td>PETG</td>
<td>60,500 - 68,500</td>
<td>40,600 - 66,400</td>
</tr>
<tr>
<td>Tritan</td>
<td>100,000*</td>
<td>100,000*</td>
</tr>
<tr>
<td>PVC/Tritan/PVC</td>
<td>100,000*</td>
<td>13,200 - 49,300</td>
</tr>
<tr>
<td>Tritan/PVC/Tritan</td>
<td>93,400 - 100,000*</td>
<td>30,500 - 58,200</td>
</tr>
<tr>
<td>PC</td>
<td>64,700 - 93,400</td>
<td>58,000 - 76,000</td>
</tr>
<tr>
<td>PVC</td>
<td>30,400 - 36,400</td>
<td>36,200 - 67,800</td>
</tr>
</tbody>
</table>

* The test was stopped after 100,000 cycles without fracture.
**Impact Resistance**

- 4 lb 5/8\(^{th}\) inch diameter dart is dropped from increasing heights until penetration
  - Mean Failure Energy (MFE) is determined at minimum height

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Height of Weight, in</th>
<th>MFE (in-lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PETG</td>
<td>19-20</td>
<td>76 - 80</td>
</tr>
<tr>
<td>Tritan</td>
<td>24-26</td>
<td>96-104</td>
</tr>
<tr>
<td>PVC/Tritan/PVC</td>
<td>20-21</td>
<td>80 - 84</td>
</tr>
<tr>
<td>Tritan/PVC/Tritan</td>
<td>23-25</td>
<td>92-100</td>
</tr>
<tr>
<td>PC</td>
<td>24-25</td>
<td>96-100</td>
</tr>
<tr>
<td>PVC</td>
<td>16-17</td>
<td>64 - 68</td>
</tr>
</tbody>
</table>
Card Structure Integrity Test

- 16 cards were first exposed to a 50°C/95% RH for 7 days.
- 8 cards were subject to the card corner impact.
- 8 cards were sealed and shook in a paint can for 3 hours.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>90° Peel Strength</th>
<th>Corner Impact</th>
<th>Paint Shaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>PETG</td>
<td>Unable to Separate</td>
<td>No Separation</td>
<td>No Separation</td>
</tr>
<tr>
<td>Tritan</td>
<td>US</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PVC/Tritan/PVC</td>
<td>US</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Tritan/PVC/Tritan</td>
<td>US</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PC</td>
<td>US</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>PVC</td>
<td>US</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>
ISO/IEC 7810
8.12 Resistance to Heat

- Requirement: deflection <10 mm @ 50°C for 4 hours

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Deflection, mm</th>
<th>Pass?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tritan</td>
<td>0 - 0.3</td>
<td>yes</td>
</tr>
<tr>
<td>PVC/Tritan/PVC</td>
<td>0.3 - 0.5</td>
<td>yes</td>
</tr>
<tr>
<td>Tritan/PVC/Tritan</td>
<td>0.4 - 0.7</td>
<td>yes</td>
</tr>
<tr>
<td>PC</td>
<td>0 - 0.2</td>
<td>yes</td>
</tr>
<tr>
<td>PVC</td>
<td>0.5 - 0.7</td>
<td>yes</td>
</tr>
</tbody>
</table>
Laser Engraving Contrast Measurement

- Its contrast versus the background
  - No contrast - 0%
  - Totally black – 100%
- Average of contrast measurements – shows breadth of laser engravability
- The higher the average the more breadth
Laser Marking Contrast

Ave. Contrast, %

<table>
<thead>
<tr>
<th>Material</th>
<th>Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tritan</td>
<td>87</td>
</tr>
<tr>
<td>PC</td>
<td>89</td>
</tr>
</tbody>
</table>
## Ink Adhesion
(Cross-Hatch Test, ASTM D3359-02)

<table>
<thead>
<tr>
<th>Toyo PowerCure UV Offset Ink</th>
<th>Magenta</th>
<th>Cyan</th>
<th>Black</th>
<th>Yellow</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>5B</td>
<td>5B</td>
<td>5B</td>
<td>5B</td>
</tr>
<tr>
<td>Tritan</td>
<td>5B</td>
<td>5B</td>
<td>5B</td>
<td>5B</td>
</tr>
<tr>
<td>PETG</td>
<td>4.5B</td>
<td>4.5B</td>
<td>5B</td>
<td>5B</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nazdar PowerPrint 1600 UV Screen Ink</th>
<th>PowerPrint 1600 UV Screen Ink</th>
<th>S2 Thermal Vinyl Screen Ink</th>
<th>rating</th>
<th>effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>5B</td>
<td>5B</td>
<td>5B</td>
<td>no change</td>
</tr>
<tr>
<td>Tritan</td>
<td>5B</td>
<td>5B</td>
<td>5B</td>
<td>&lt;5% ink removed</td>
</tr>
<tr>
<td>PETG</td>
<td>4B</td>
<td>5B</td>
<td>4B</td>
<td>5-15% ink removed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3B</td>
<td>15-30% ink removed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2B</td>
<td>30-65% ink removed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0B</td>
<td>&gt;65% ink removed</td>
</tr>
</tbody>
</table>

EASTMAN
Conclusions

- Excellent clarity and high gloss
- Very tough with long flex cycles
- High heat resistance
- Good chemical resistance
- Lower temperature & shorter lamination cycle
- Heat sealable without delamination
- Compatible with conventional printing inks
- Ease of die cutting
- Laser marking capability