Thermoforming Enhancement
With Cyclic Olefin Copolymers

Paul D. Tatarka

SPE International Polyolefins Conference
February 22 – 25, 2009
What Are Cyclic Olefin Copolymers (COC)?

The cyclic olefin copolymer (COC) molecule is a linear chain of small CH$_2$-CH$_2$ links randomly interspersed with large bridged ring elements. It cannot fold up to make a regular structure, i.e., a crystallite.

COC has no crystalline melting point, but only a glass transition temperature, $T_g$, at which the polymer goes from “glassy” to “rubbery” behavior.
TOPAS® COC – Value Proposition

- Amorphous Olefin
  - Broad thermoforming window
- Dimensional Stability
  - Little shrinkage & snapback; less overall variation in gauge distribution
- High Transparency
  - Clear product; facilitate inspection
- Water & Alcohol Barrier
  - Satisfies new, unmet needs
- Compatibility
  - Enhances polyolefin formability, enabling downgauging & use of low cost materials
- Heat Resistance
  - Impart temperature resistance to polyolefins
TOPICS

- Depth of Draw Thermoforming
- Monolayer vs. Discrete Layer Forming Films
Depth of Draw Thermoforming
Outline

- Forming Methodology
- Film Structures
- Thermoforming Properties:
  - Volume Retention
  - Gauge Distribution
  - Bottom Thickness
  - Corner Thickness
  - “Slow” Puncture Resistance
  - “Slow” Puncture Energy
- Benefits & Conclusions
Macron Thermoforming Machine
Variable Depth Forming Tool
Material Stretching Parameters

- **Depth of Draw**
  - Distance Or Height Between The Top And Bottom Of The Forming Tool

- **Areal Draw Ratio**
  - The Ratio Of The Surface Area Of The Formed Part To The Available Surface Area Of The Unformed Film Or Sheet
  - Available Surface Area Is Usually Defined By The Open Perimeter Of The Forming Tool
Film Structures (6-mil)

- “o-LLDPE” (0.920 g/cc; 1.0 dg/min)
- “o-LLDPE + 30% 8007F-04” (Monolayer Blend)
- “E / I / E (25 / 50 / 25)” (EVA / Ionomer / EVA)
- “E / I / E (7.5 / 85 / 7.5)” (EVA / Ionomer / EVA)
- “8007-F400” (COC; tg=80°C; 1.02 g/cc; 1.8 dg/min)
- “9506X5” (COC; tg=68°C; 1.02 dg/cc; 0.9 dg/min)
Depth of Draw Forming Examples

o-LLDPE vs. o-LLDPE+30% COC    E/I/E (25/50/25) vs. o-LLDPE+30% COC
1.0-inch vs. 1.50-inch Depth of Draw
Formed Cavity Testing

- Volume Retention, TOPAS® Method
- Gauge Distribution via Coefficient of Variation, ASTM D374
- Bottom Thickness, ASTM D374
- Corner Thickness, ASTM D374
- Bottom “Slow” Puncture Resistance, ASTM F1306
- Bottom “Slow” Puncture Energy, ASTM F1306
Cavity Support Tool: Volume Retention

Adjustable Support Can Accommodate Multiple Cavity Depths
Fill the Secured Cavity with Water and Measure Its Volume
Formed Cavity: Volume Retention

COC Reduces Snapback Or Shrinkage Of LLDPE Films
Softer Films Distorted Excessively; No Measurement
COC Films Have Little Or No Snapback
Gauge Locations in MD and TD
Formed Cavity: Gauge Variation (CV)

Ionomeric Films Have Low Gauge Variation
COCs In LLDPE Significantly Reduce Gauge Variation
COCs & Ionomeric Films Have Similar Performance
Equivalent to Average Gauge of Formed Cavity
COCs in LLDPE Increase Bottom Thickness At High Draw Ratios
Ionomeric Films Are Thickest Across Most Draw Ratios
Formed Cavity: Corner Thickness

Ionomeric Films Have Excellent Corner Thickness
COCs In LLDPE Increase Corner Thickness At Most Ratios
COC Is Superior To Ionomer At High Draw Ratios
Cavity Puncture Tool: Bottom & Corner

Flexible Tool Configuration Enables Accurate Measurement of Puncture Resistance of Formed Cavities
COCs Offer Superior Puncture Resistance vs. Ionomer
COCs Enhance Puncture Resistance of LLDPE Across Range of Areal Draw Ratios
COCs Offer Superior Toughness vs. Ionomer
COC Enhances Toughness of Thermoformed LLDPE
COC Enhances Draw Depth Capacity of Forming Films
COC Benefits For Forming Films

- Improve Thermoformability & Enhance Package Integrity with Less Gauge Variation & Good Dimensional Stability
- Enable Downdragging to Reduce Material Cost
- Improve Most Physical Properties, Including Stiffness, Strength, Impact Resistance & Optics
- Apparently, COC Benefits From Orientation During Forming More Than Other Polyolefins

Any questions?

www.topas.com
Oriented COC Films

**Mechanical Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Unoriented</th>
<th>Oriented</th>
<th>» Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus of elast. (N/mm²)</td>
<td>2100-2200</td>
<td>2800-3800</td>
<td>×1.5</td>
</tr>
<tr>
<td>Tensile strength (N/mm²)</td>
<td>50-60</td>
<td>100-180</td>
<td>×2.5</td>
</tr>
<tr>
<td>Elongation at break (%)</td>
<td>3-5</td>
<td>50-100</td>
<td>×20</td>
</tr>
</tbody>
</table>

pellets → extrusion → brittle film → orientation → flexible film
Monolayer vs. Discrete Layer Forming Films
## Comparative Forming Film Structures

<table>
<thead>
<tr>
<th>COC</th>
<th>Monolayer</th>
<th>Multilayer</th>
</tr>
</thead>
</table>
| 10  | 90% o-LLDPE (0.920 g/cc, 1.0 dg/min) 10% TOPAS 8007 | A: 44.5% (2.7 mil) o-LLDPE  
B:11% (0.6 mil) 100% TOPAS 8007  
A: 44.5% (2.7 mil) o-LLDPE |
| 15  | 85% o-LLDPE (0.920 g/cc, 1.0 dg/min) 15% TOPAS 8007 | A: 42.5% (2.55 mil) o-LLDPE  
B:15% (0.9 mil) 100% TOPAS 8007  
A: 42.5% (2.55 mil) o-LLDPE |
| 20  | 80% o-LLDPE (0.920 g/cc, 1.0 dg/min) 20% TOPAS 8007 | A: 40% (2.40 mil) o-LLDPE  
B:20% (1.2 mil) 100% TOPAS 8007  
A: 40% (2.40 mil) o-LLDPE |
6-mil Monolayer Blend vs. Multilayer Discrete

10% COC Discrete Layer Construction Offers Improvement to Most Properties
Best Enhancement: Formed Tray Corner Puncture

www.topas.com
6-mil Monolayer Blend vs. Multilayer Discrete

15% COC Discrete Layer Construction Offers Improvement to Most Properties
Best Enhancements: Modulus & Formed Tray Corner Puncture

www.topas.com
15% COC Monolayer vs. 10% COC Multilayer

10% COC Discrete Layer Construction Offers Improvement to Many Properties vs. 15% Monolayer Blend

Best Enhancements: Modulus & Formed Tray Corner Puncture

www.topas.com
6-mil Monolayer Blend vs. Multilayer Discrete

20% COC Discrete Layer Construction Offers Improvement to Most Properties
Best Enhancements: Modulus & Formed Tray Corner Puncture
20% COC Monolayer vs. 15% COC Multilayer

15% COC Discrete Layer Construction Offers Improvement to Many Properties vs. 20% Monolayer Blend
Best Enhancements: Modulus & Formed Tray Corner Puncture
Benefits For Films With Discrete COC Layers

- Flat Film Enhancements Include Stiffness, Strength and Optical Properties
- Formed Tray Enhancements Include Puncture Resistance, Corner Thickness & Reduced Gauge Variation, But Not Retained Volume
- Films With Discrete Layers of COC Can Reduce Material Cost Without Sacrificing Performance
- Films With Discrete Layers of COC Are Expected To Have Better Barrier Properties
Acknowledgments

Thermoforming Team:
- Adam Barton
- Tim Kneale

U. of Cincinnati Co-Op Students:
- Elizabeth MacLean
- Angela Martin

TOPAS® Cyclic Olefin Copolymer (COC)
Your Clear Advantage in Thermoforming.

www.topas.com
NOTICE TO USERS: To the best of our knowledge, the information contained in this publication is accurate, however we do not assume any liability whatsoever for the accuracy and completeness of such information. The information contained in this publication should not be construed as a promise or guarantee of specific properties of our products. All technical information and services of TOPAS Advanced Polymers, Inc. are intended for use by persons having skill and experience in the use of such information or service, at their own risk.

Further, the analysis techniques included in this publication are often simplifications and, therefore, approximate in nature. More vigorous analysis techniques and prototype testing are strongly recommended to verify satisfactory part performance. Anyone intending to rely on any recommendation or to use any equipment, processing technique or material mentioned in this publication should satisfy themselves that they can meet all applicable safety and health standards.

It is the sole responsibility of the users to investigate whether any existing patents are infringed by the use of the materials mentioned in this publication.

Properties of molded parts, sheets and films can be influenced by a wide variety of factors including, but not limited to, material selection, additives, part design, processing conditions and environmental exposure. Any determination of the suitability of a particular material and part design for any use contemplated by the user is the sole responsibility of the user. The user must verify that the material, as subsequently processed, meets the requirements of the particular product or use. The user is encouraged to test prototypes or samples of the product under the harshest conditions to be encountered to determine the suitability of the materials.

Material data and values included in this publication are either based on testing of laboratory test specimens and represent data that fall within the normal range of properties for natural material or were extracted from various published sources. All are believed to be representative. These values alone do not represent a sufficient basis for any part design and are not intended for use in establishing maximum, minimum, or ranges of values for specification purposes. Colorants or other additives may cause significant variations in data values.

We strongly recommend that users seek and adhere to the manufacturer’s current instructions for handling each material they use, and to entrust the handling of such material to adequately trained personnel only. Please call TOPAS Advanced Polymers, Inc. - hotline (859) 746-6447 x4400 for additional technical information. Call Customer Services at (859) 746-6447 x4402 for the appropriate Material Safety Data Sheets (MSDS) before attempting to process our products. Moreover, there is a need to reduce human exposure to many materials to the lowest practical limits in view of possible adverse effects. To the extent that any hazards may have been mentioned in this publication, we neither suggest nor guarantee that such hazards are the only ones that exist.

The products mentioned herein are not intended for use in medical or dental implants.