Thermoforming Enhancement With Cyclic Olefin Copolymers

Paul D. Tatarka

SPE International Polyolefins Conference
February 22 – 25, 2009

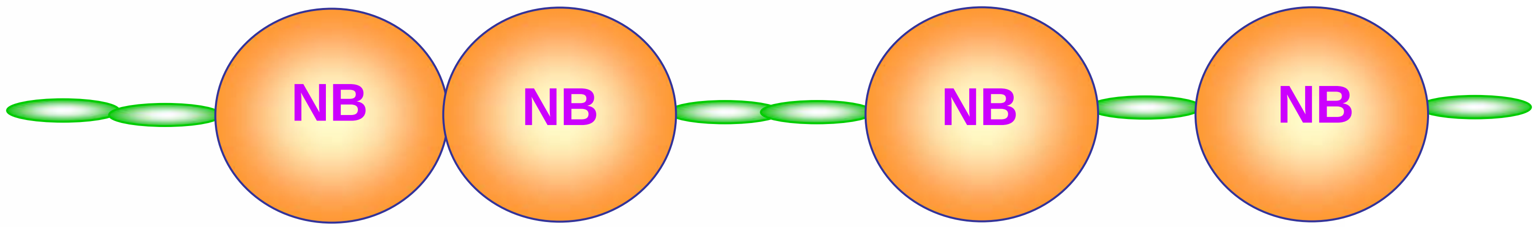
www.topas.com

TOPAS Advanced Polymers
A member of Daicel/Polyplastics Group

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

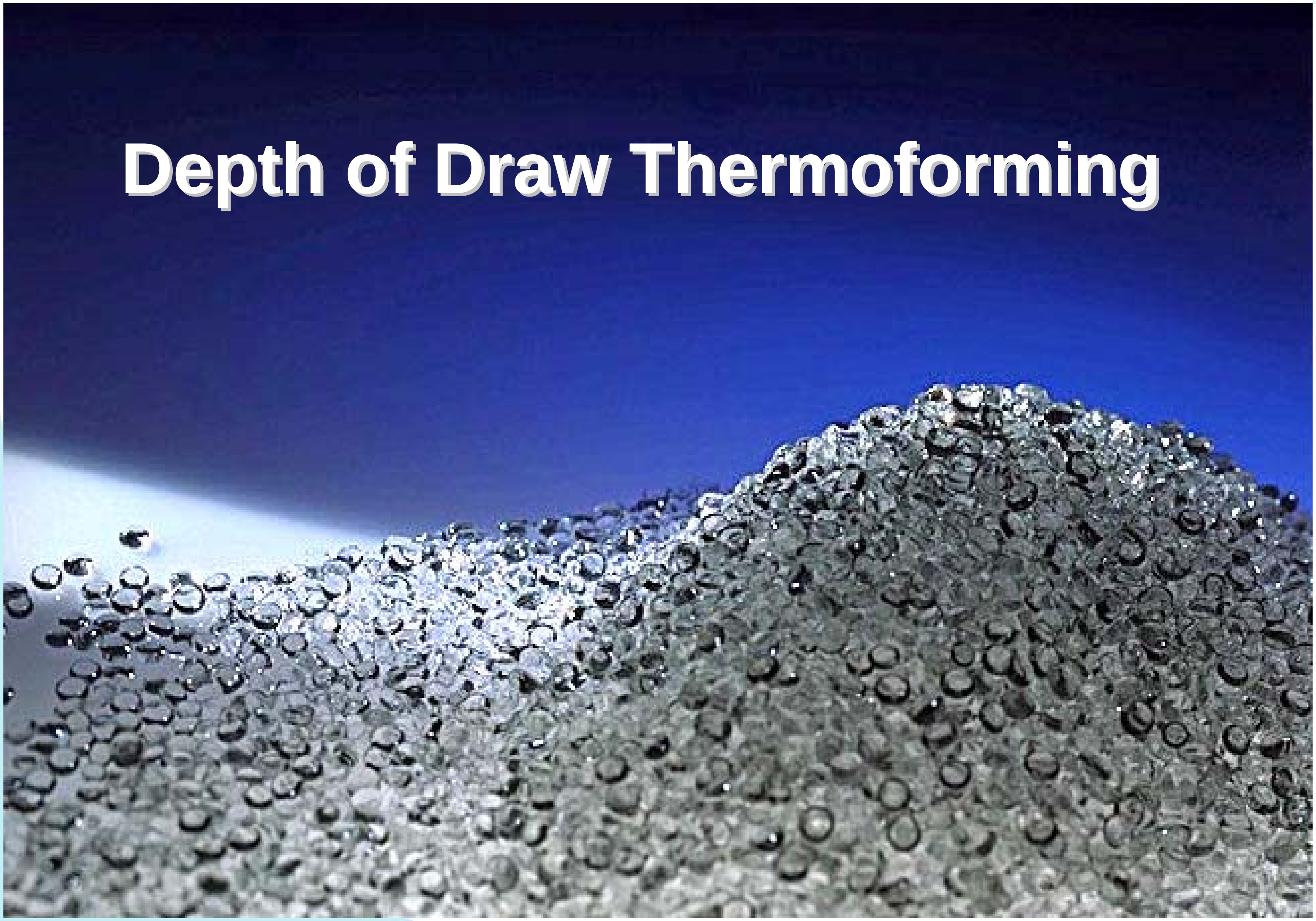
TOPAS® COC – Value Proposition

- **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



SPE Olefins 2009 Std

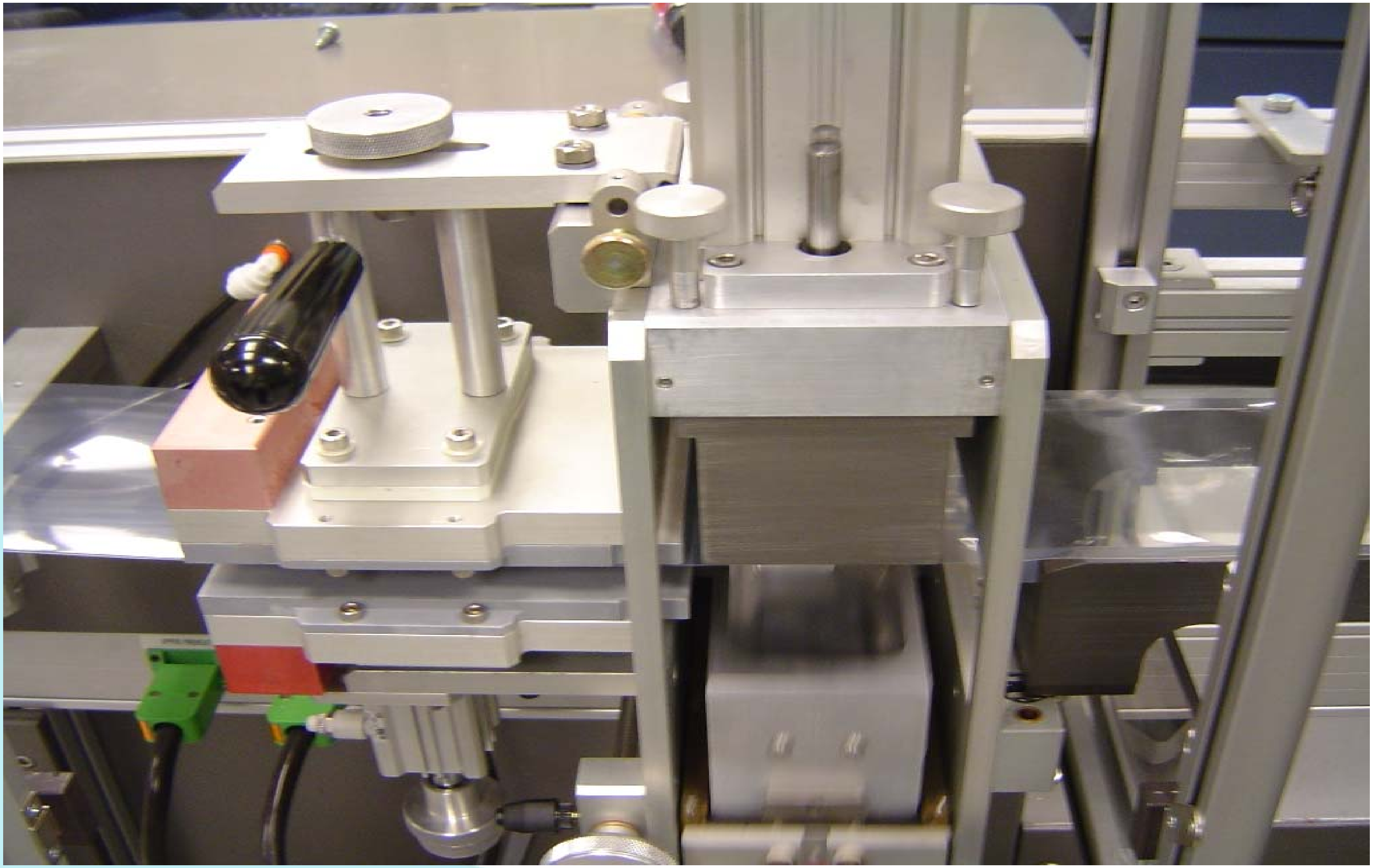
www.topas.com

TOPAS Advanced Polymers
A member of Daicel/Polyplastics Group

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

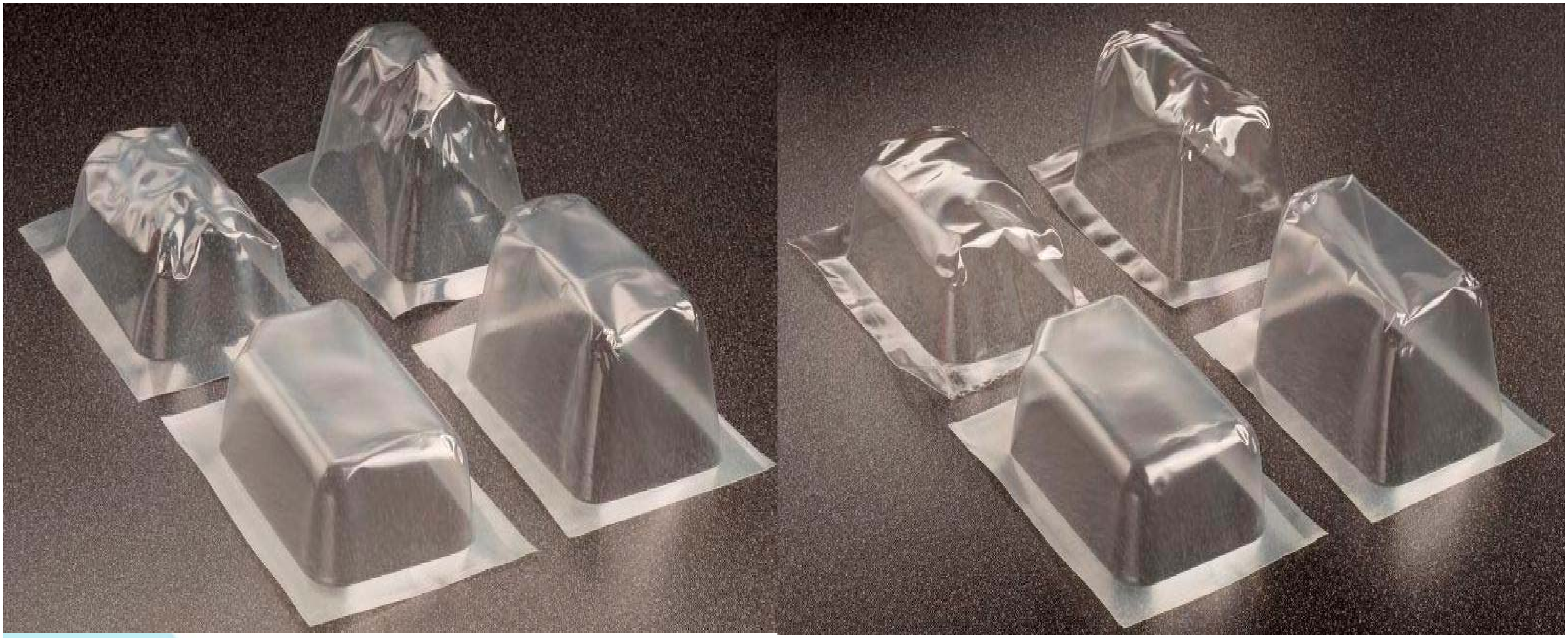
TOPAS Advanced Polymers

- **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=80ºC; 1.02 g/cc; 1.8 dg/min)
- "9506X5" (COC; tg=68ºC; 1.02 dg/cc; 0.9 dg/min)

Depth of Draw Forming Examples



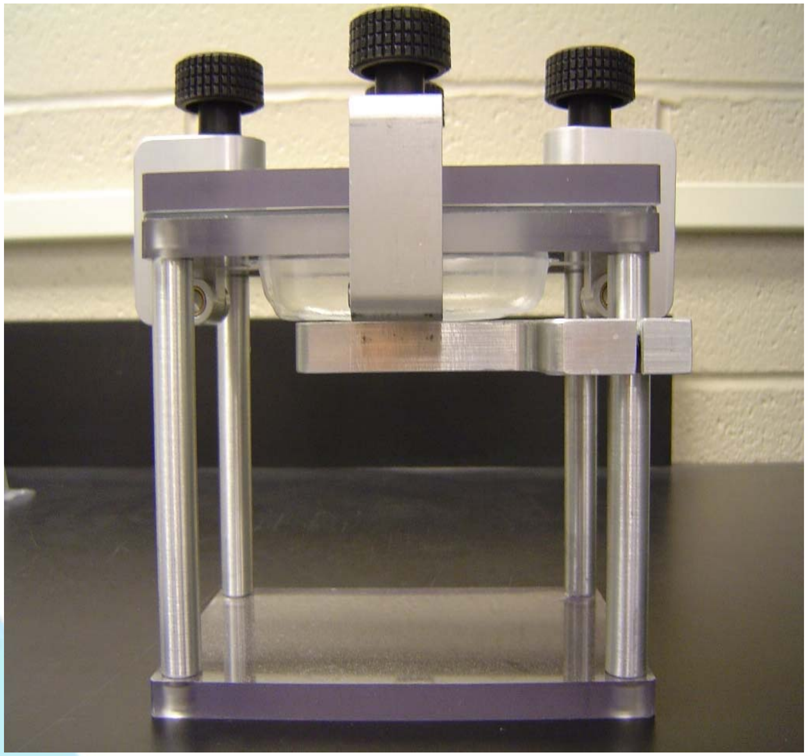
o-LLDPE vs. o-LLDPE+30% COC E/I/E (25/50/25) vs. o-LLDPE+30% COC

1.0-inch vs. 1.50-inch Depth of Draw

Formed Cavity Testing

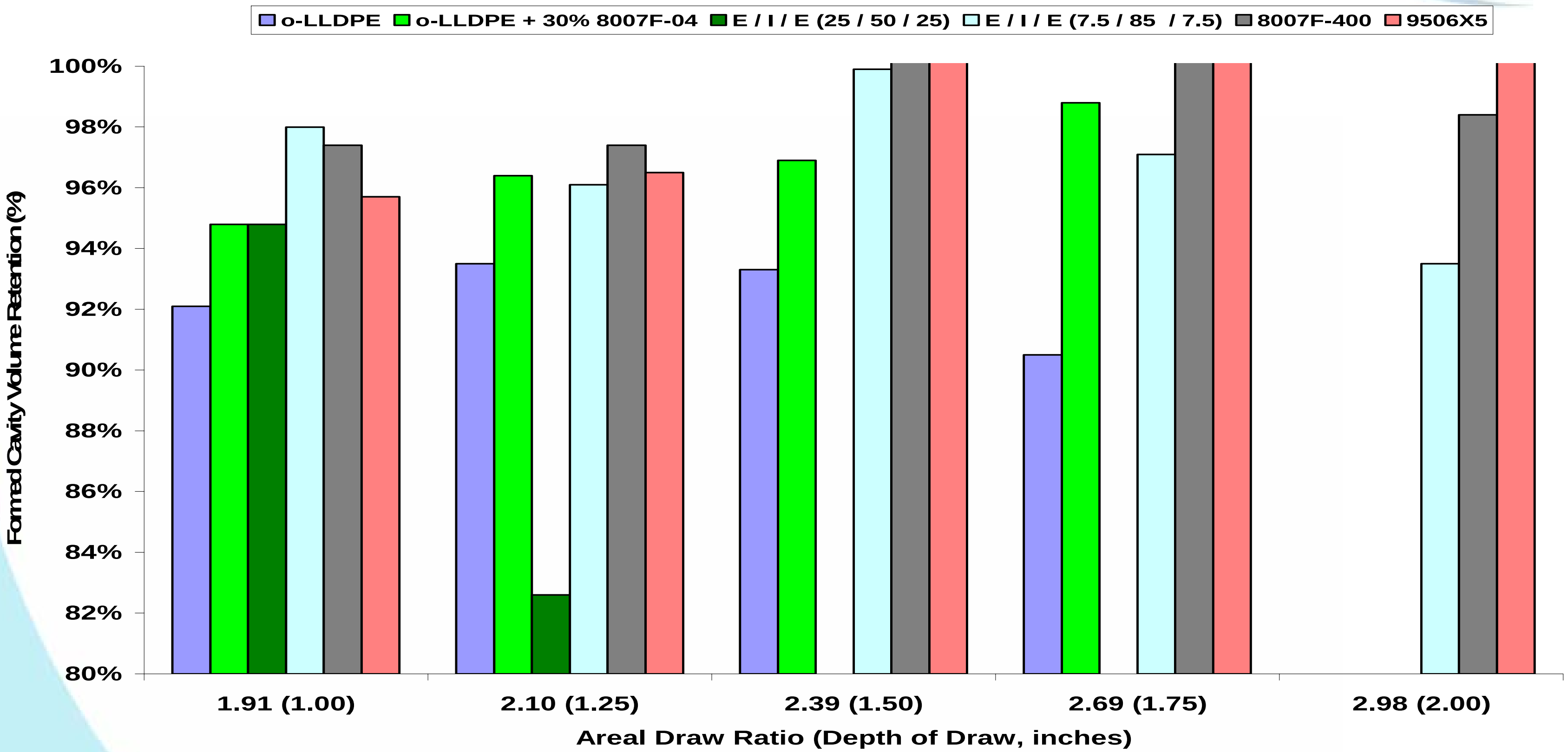
- Volume Retention, TOPAS® Method
- Gauge Distribution via Coefficient of Variation, ASTM D374
- Bottom Thickness, ASTM D374
- Corner Thickness, ASTM D374
- Bottom “Slow” Puncture Resistance, ASTM F1306
- Bottom “Slow” Puncture Energy, ASTM F1306

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

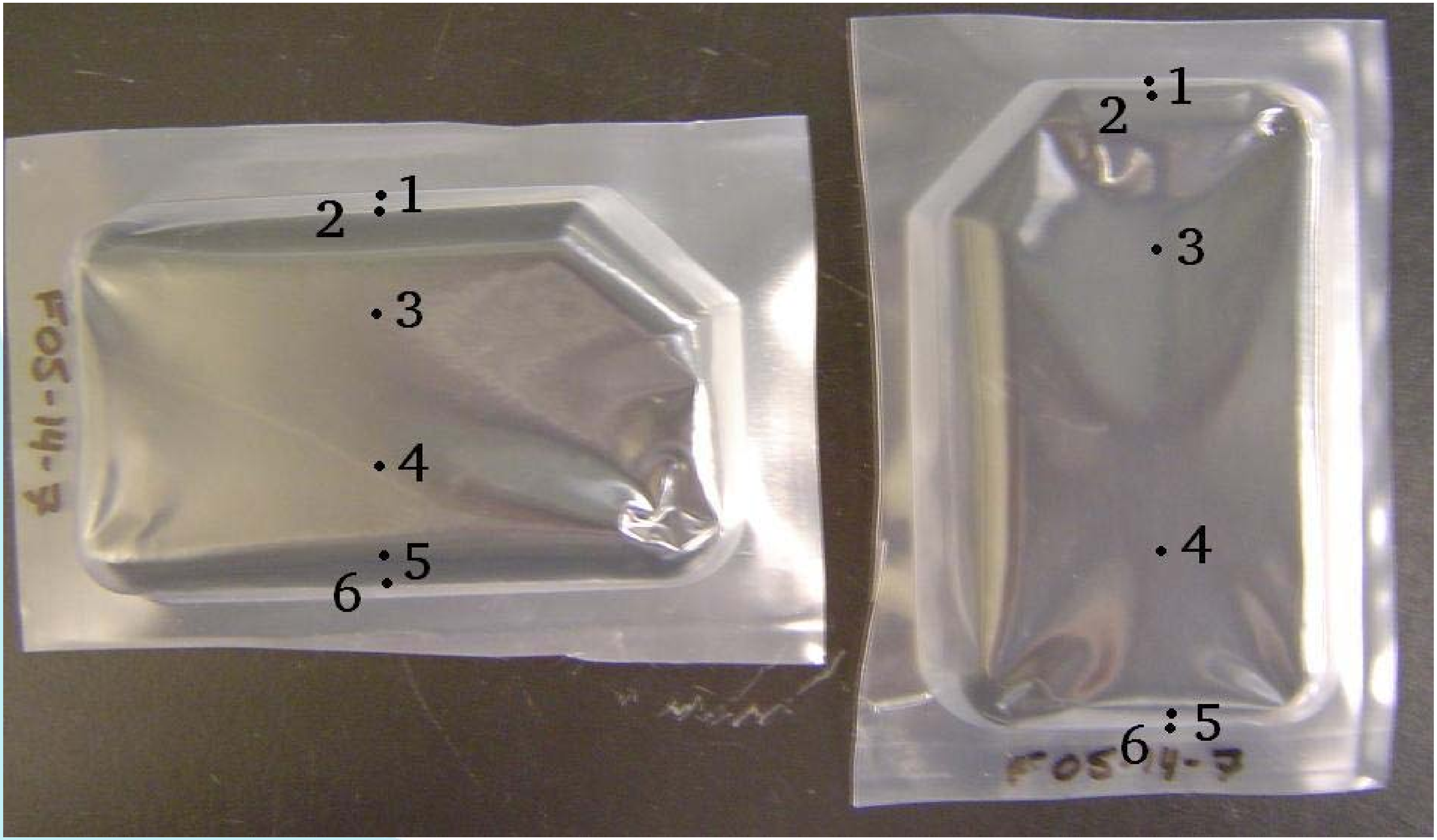


COC Reduces Snapback Or Shrinkage Of LLDPE Films

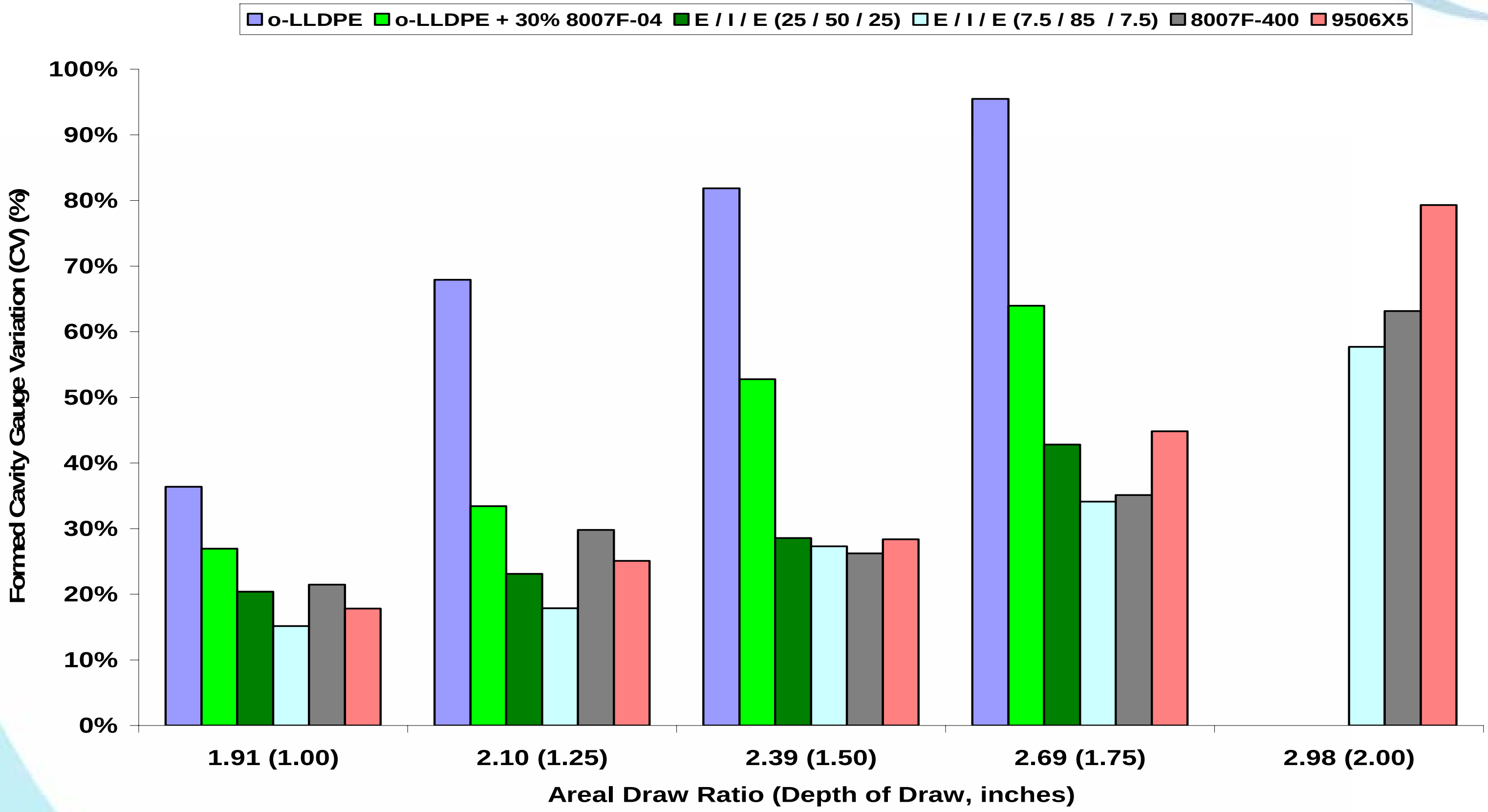
Softer Films Distorted Excessively; No Measurement

COC Films Have Little Or No Snapback

Gauge Locations in MD and TD



Formed Cavity: Gauge Variation (CV)

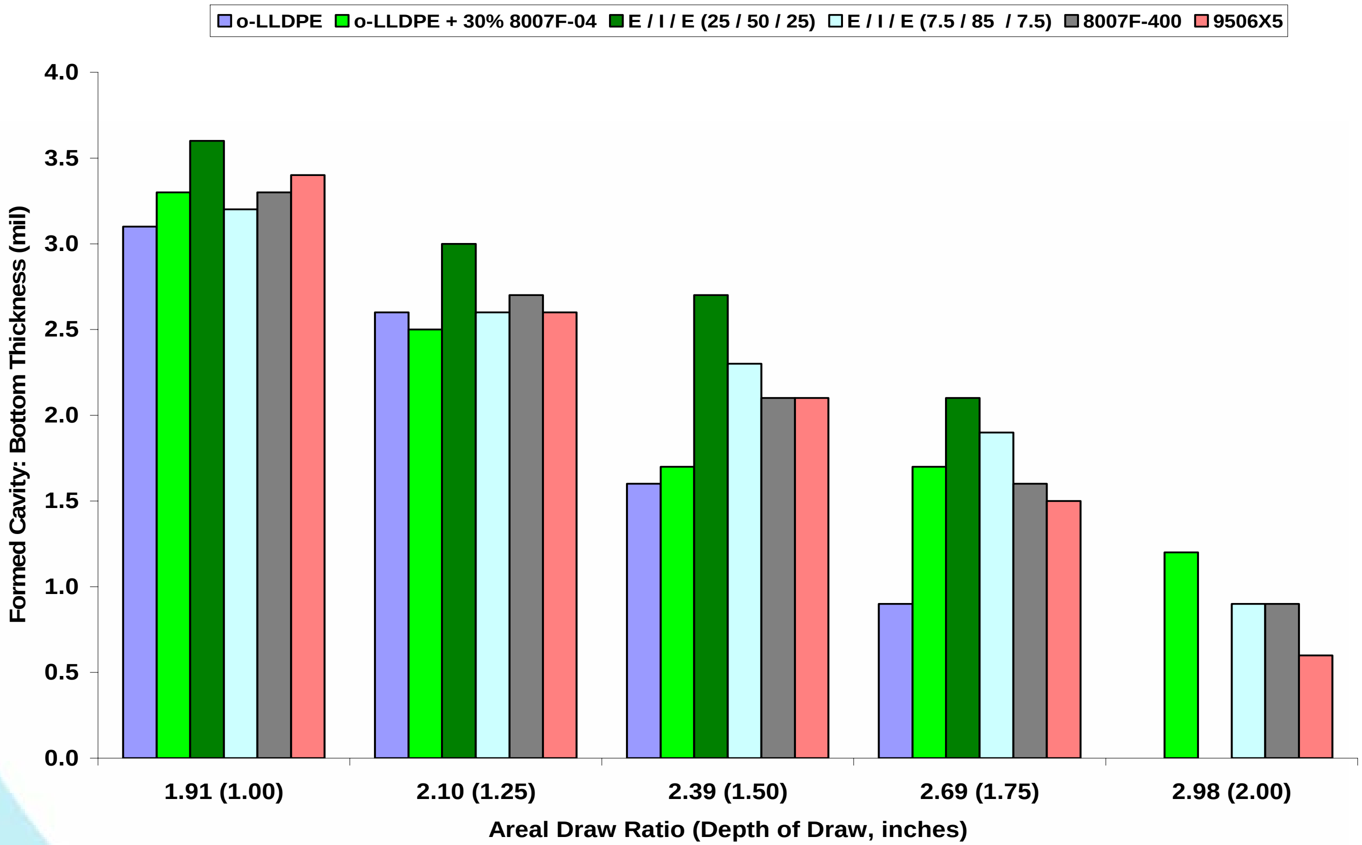


Ionomeric Films Have Low Gauge Variation

COCs In LLDPE Significantly Reduces Gauge Variation

COCs & Ionomeric Films Have Similar Performance

Formed Cavity: Bottom Thickness

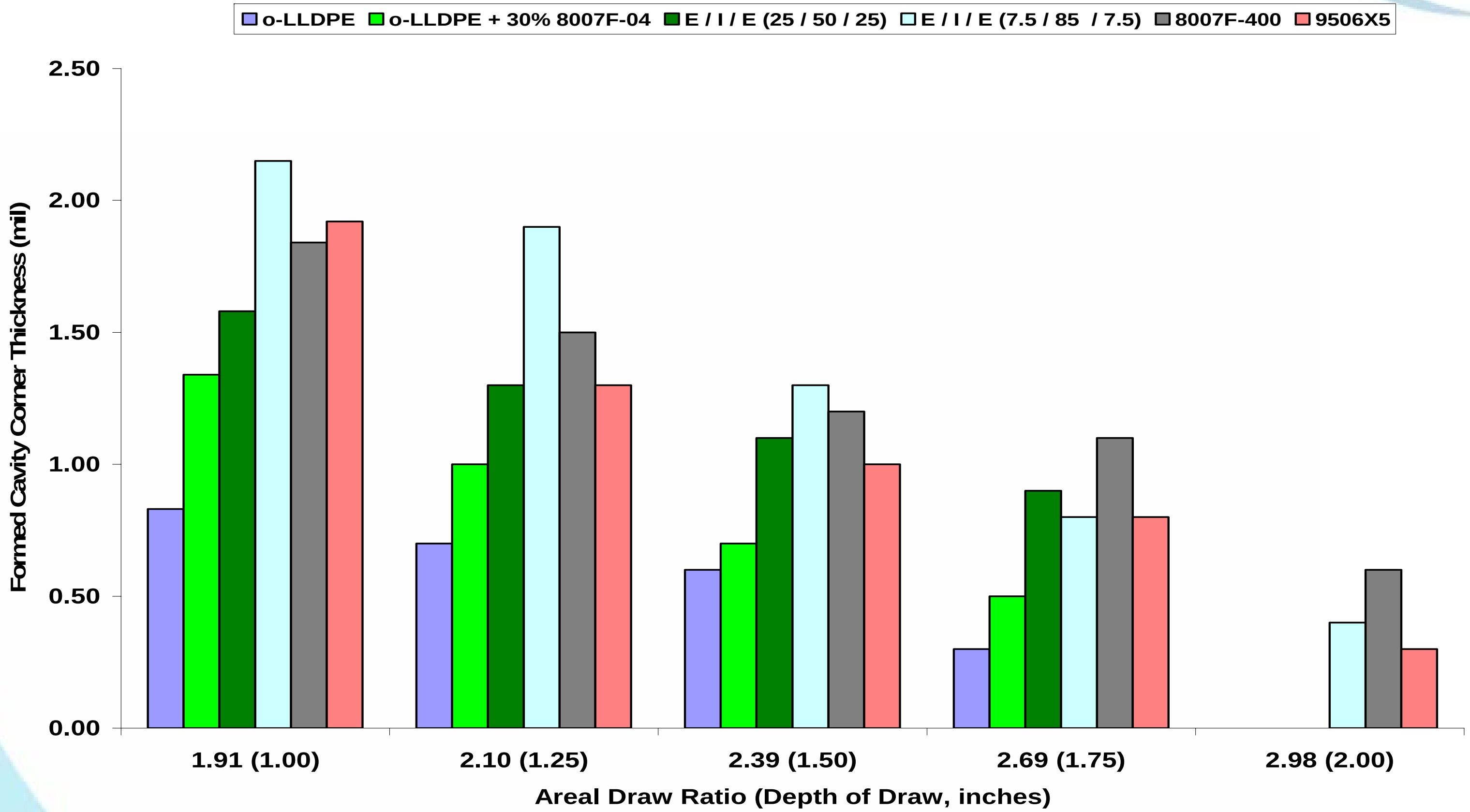


Equivalent to Average Gauge of Formed Cavity

COCs In LLDPE Increase Bottom Thickness At High Draw Ratios

Ionomeric Films Are Thickest Across Most Draw Ratios

Formed Cavity: Corner Thickness

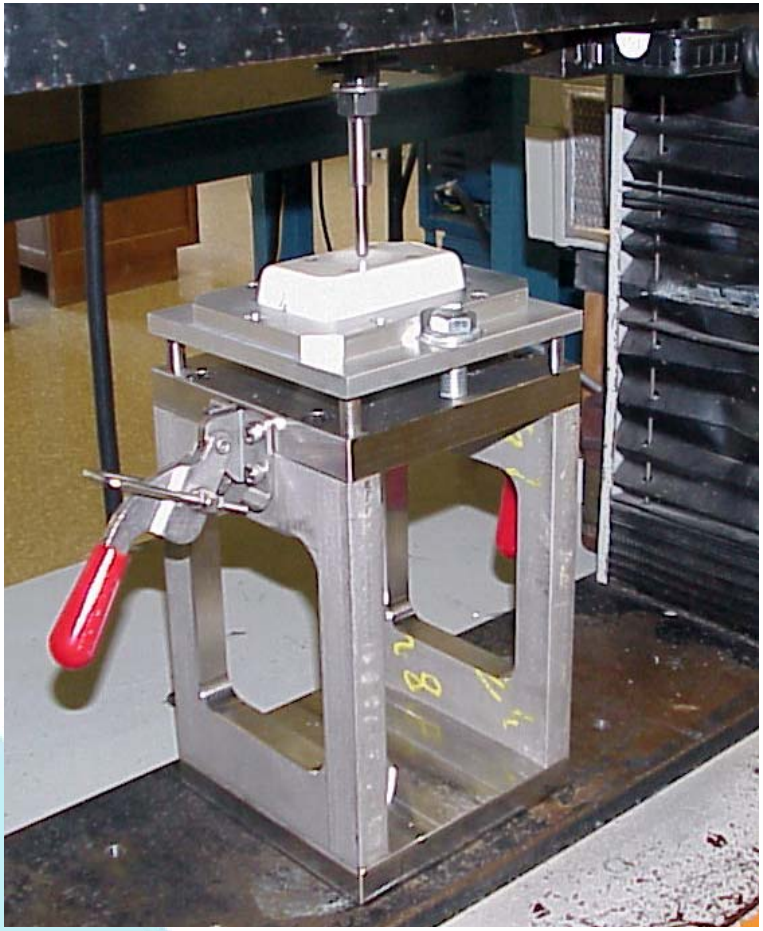


Ionomeric Films Have Excellent Corner Thickness

COCs In LLDPE Increase Corner Thickness At Most Ratios

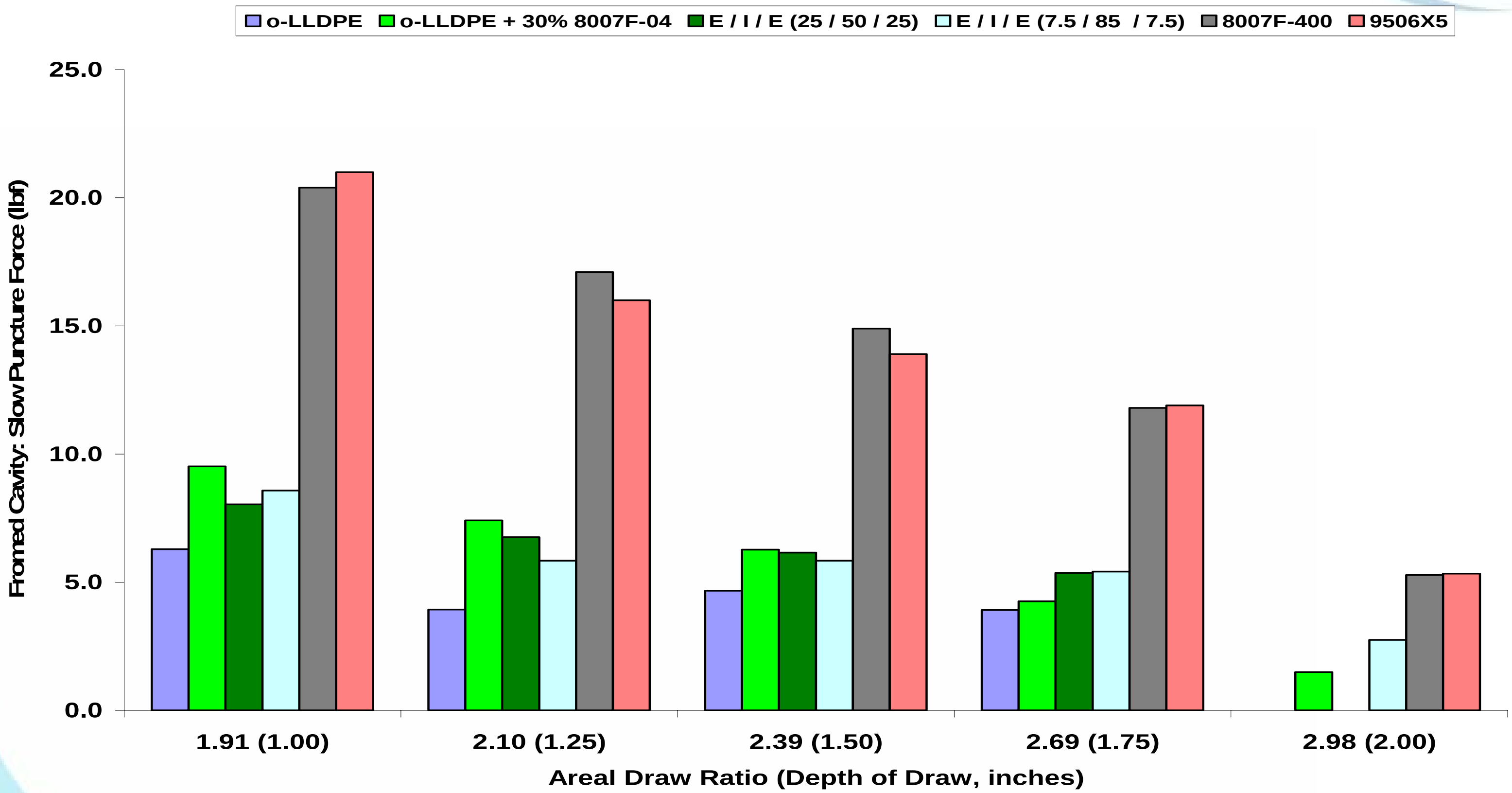
COC Is Superior To Ionomer At High Draw Ratios

Cavity Puncture Tool: Bottom & Corner



Flexible Tool Configuration Enables Accurate Measurement of Puncture Resistance of Formed Cavities

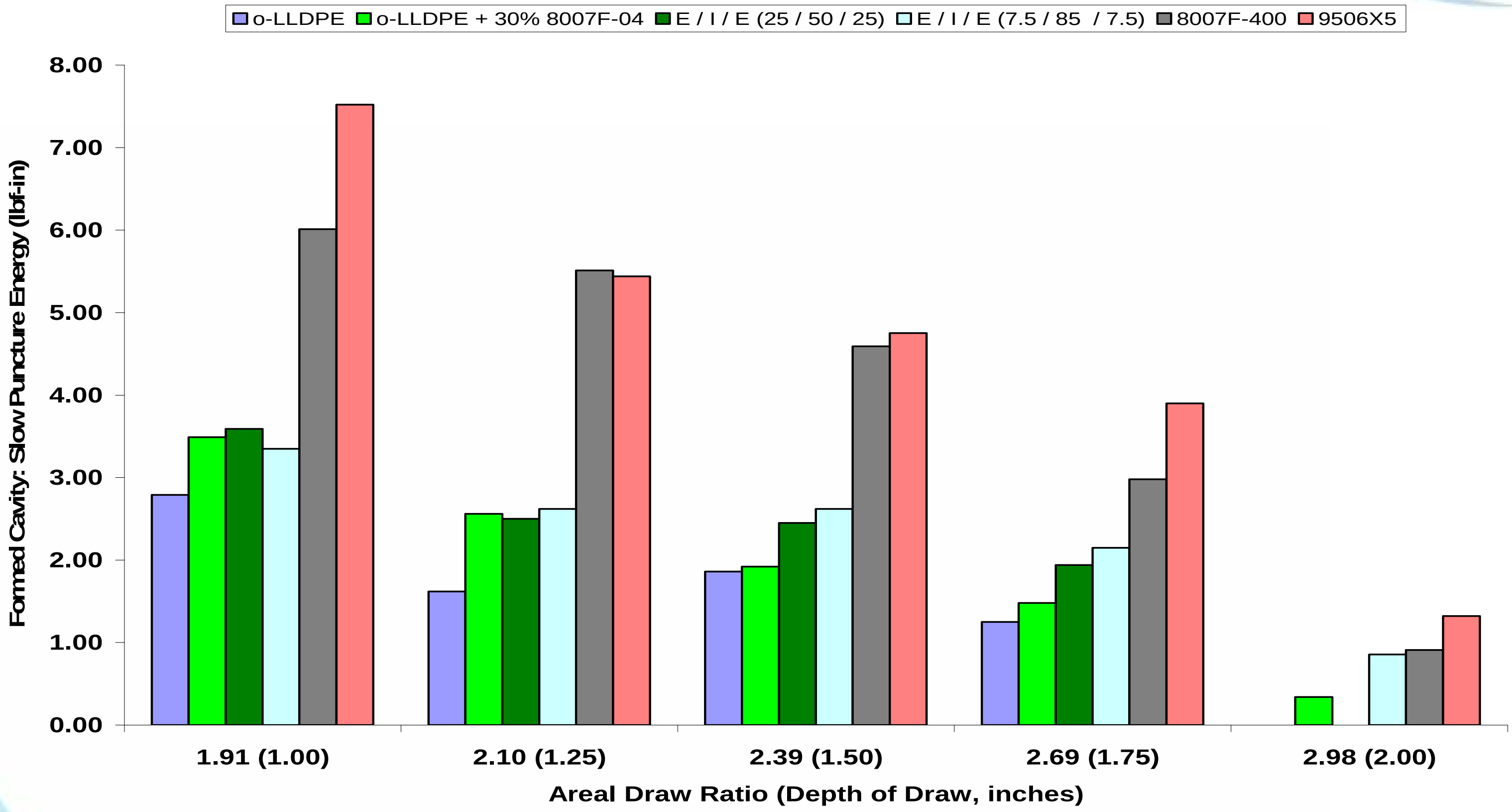
Formed Cavity: Puncture Force



COCs Offer Superior Puncture Resistance vs. Ionomer

COCs Enhance Puncture Resistance of LLDPE Across Range of Areal Draw Ratios

Formed Cavity: Puncture Energy



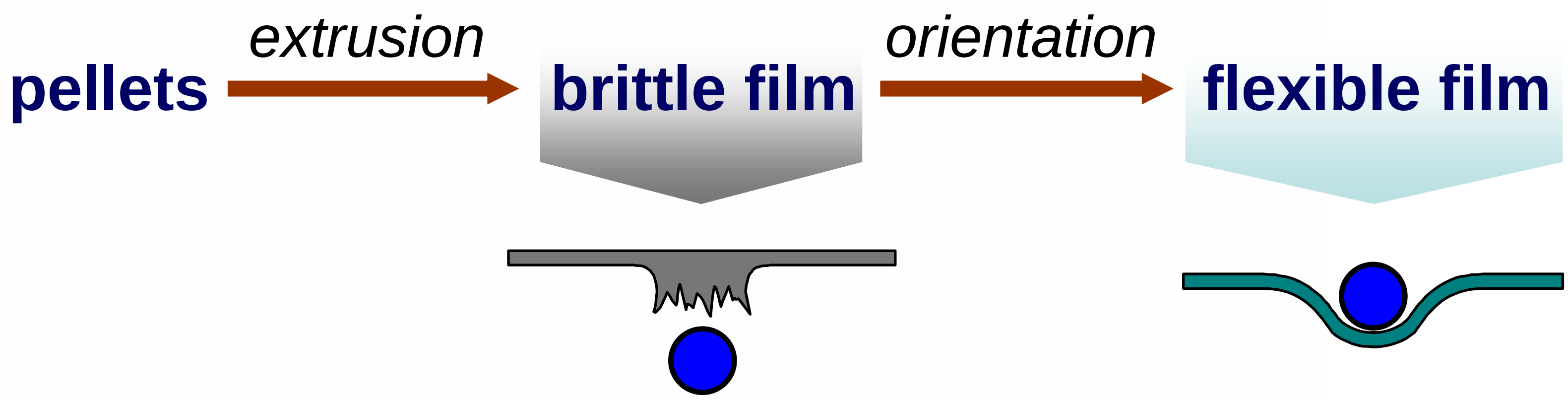
COCs Offer Superior Toughness vs. Ionomer
COC Enhances Toughness of Thermoformed LLDPE
COC Enhances Draw Depth Capacity of Forming Films

COC Benefits For Forming Films

- Improve Thermoformability & Enhance Package Integrity with Less Gauge Variation & Good Dimensional Stability
- Enable Downgauging 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?

Oriented COC Films



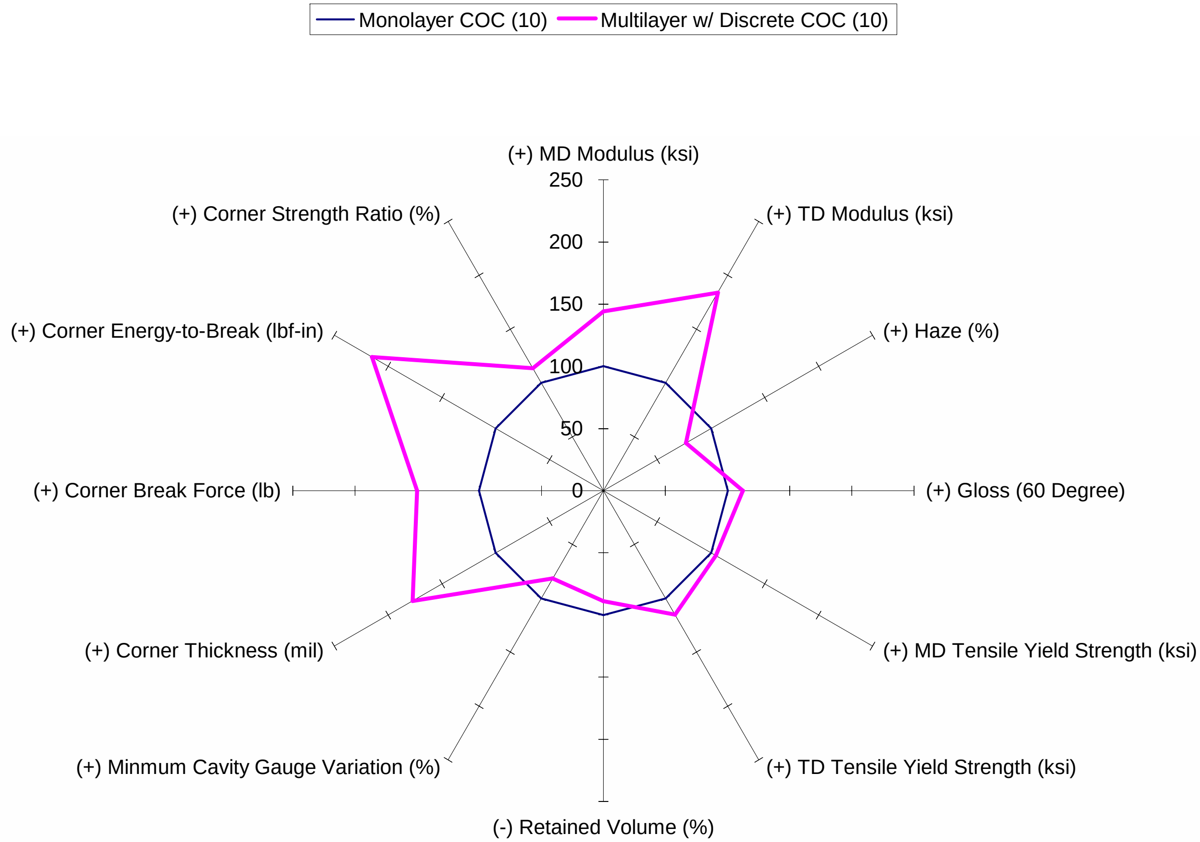
Mechanical Properties	*unoriented*	*oriented*	*» Factor*
Modulus of elast. (N/mm^2)	2100-2200	2800-3800	×1.5
Tensile strength (N/mm^2)	50-60	100-180	×2.5
Elongation at break (%)	3-5	50-100	×20

Monolayer vs. Discrete Layer Forming Films

Comparative Forming Film Structures

COC	Monolayer	Multilayer
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

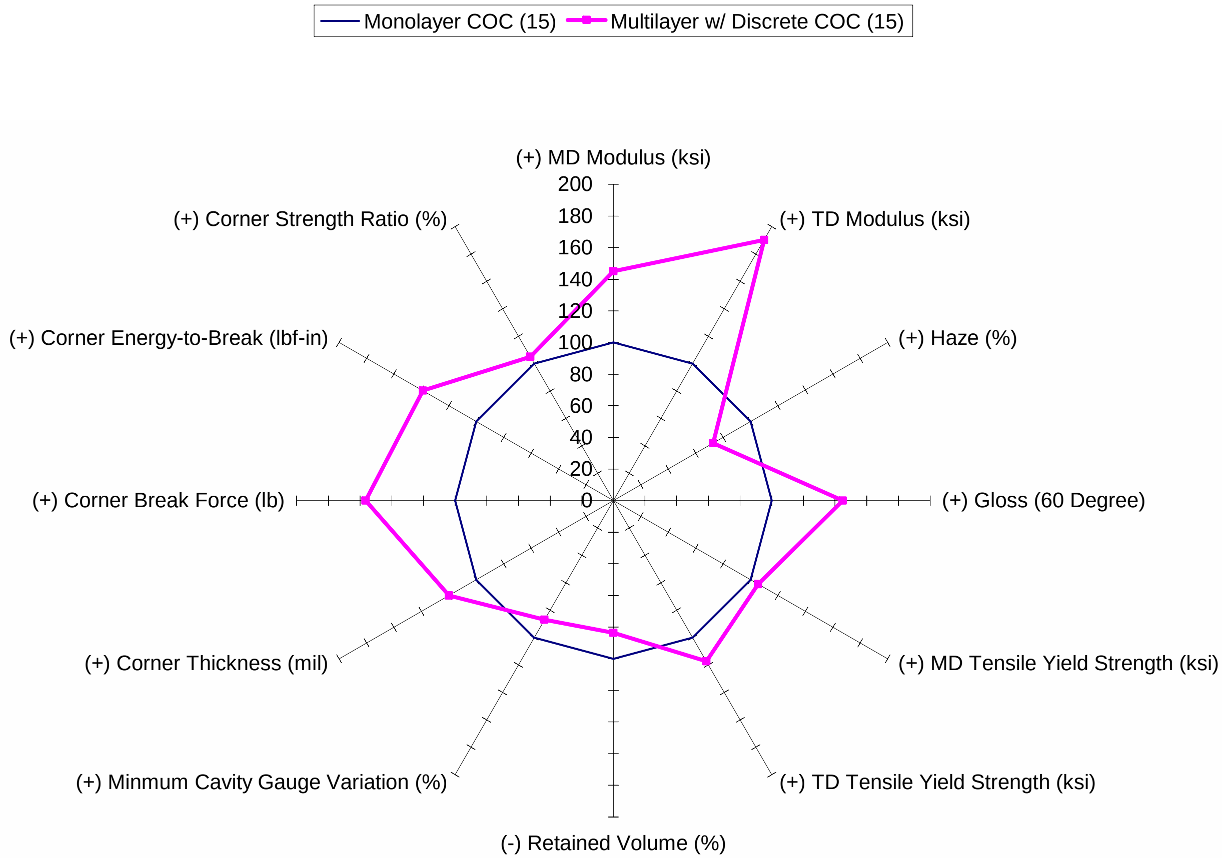
6-mil Monolayer Blend vs. Multilayer Discrete



10% COC Discrete Layer Construction Offers Improvement to Most Properties

Best Enhancement: Formed Tray Corner Puncture

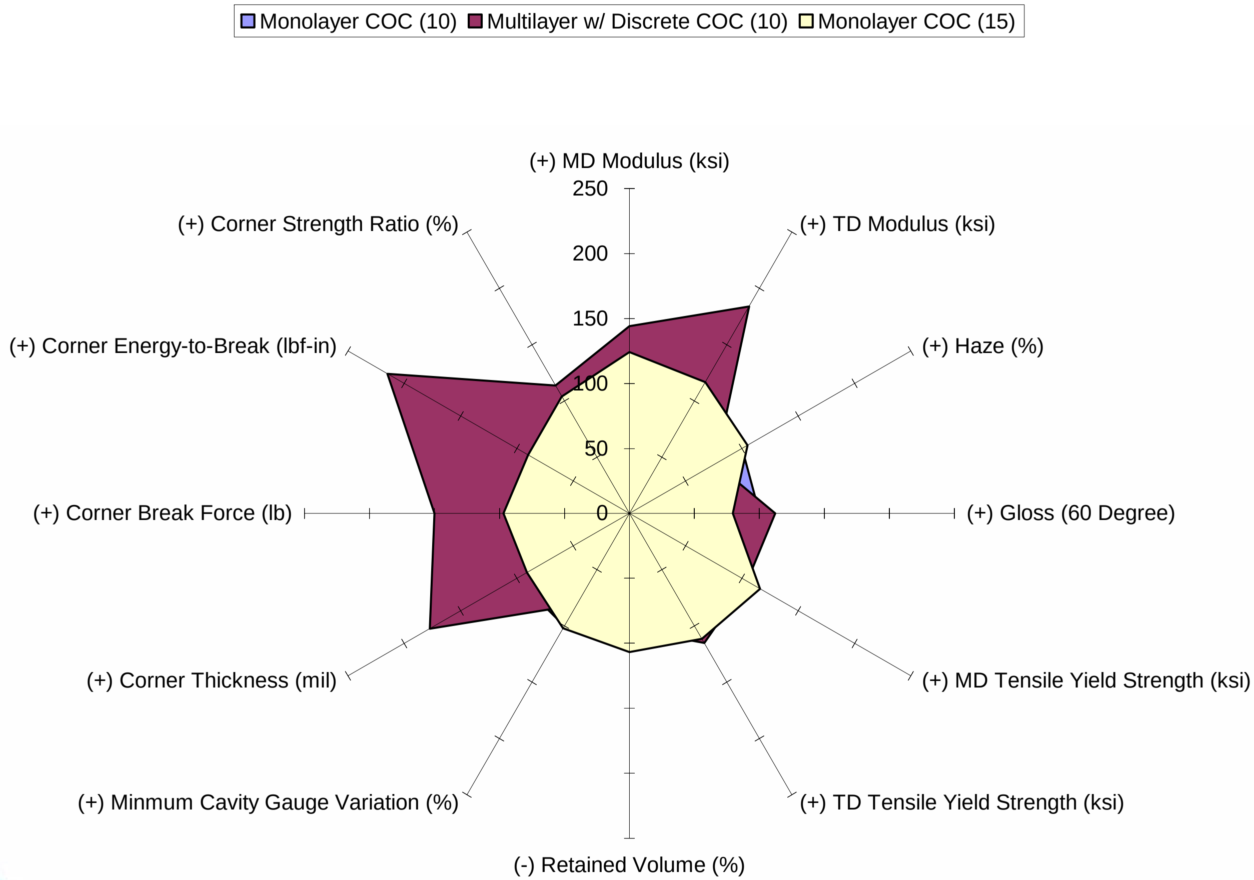
6-mil Monolayer Blend vs. Multilayer Discrete



15% COC Discrete Layer Construction Offers Improvement to Most Properties

Best Enhancements: Modulus & Formed Tray Corner Puncture

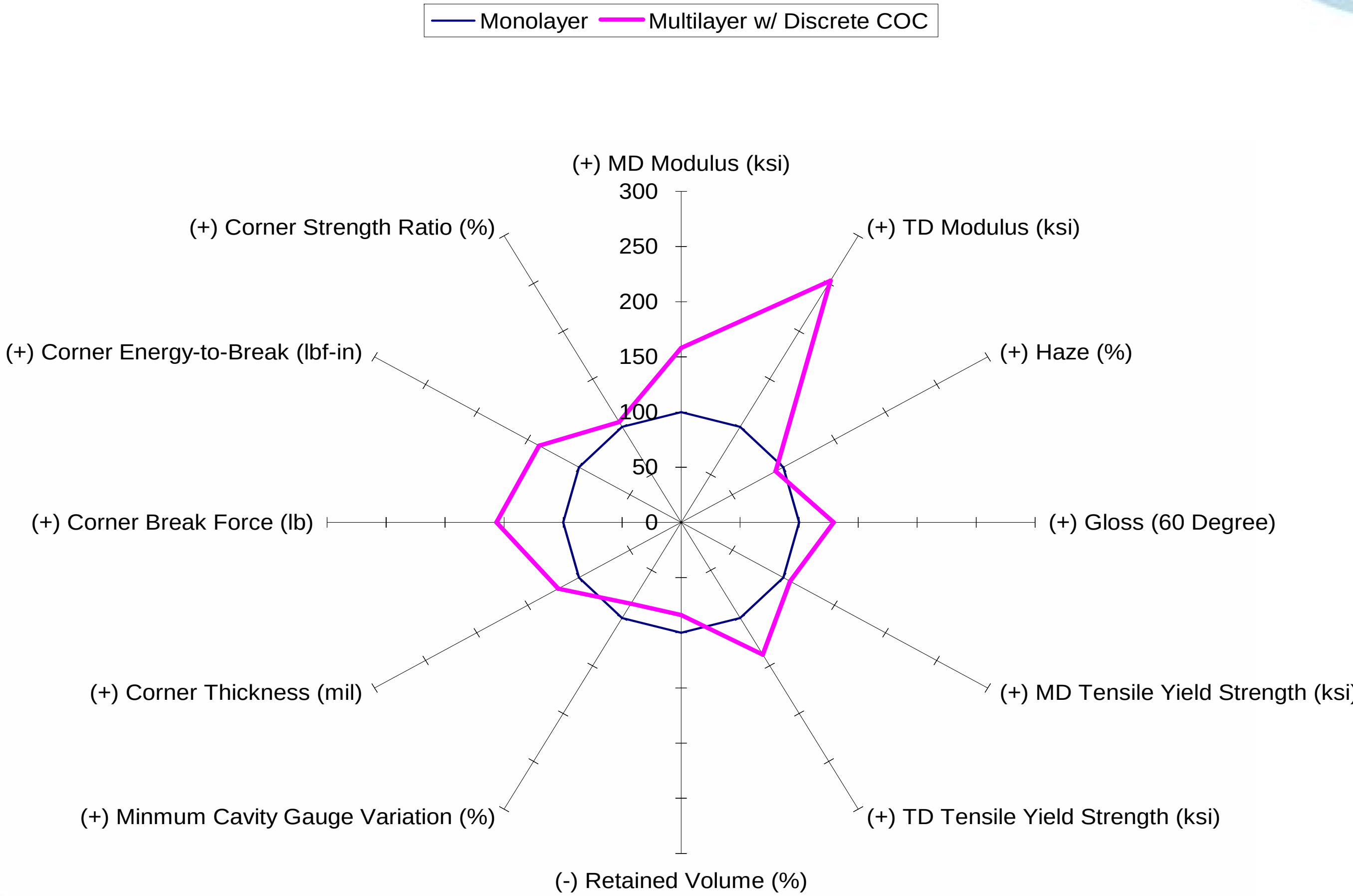
15% COC Monolayer vs. 10% COC Multilayer



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

Best Enhancements: Modulus & Formed Tray Corner Puncture

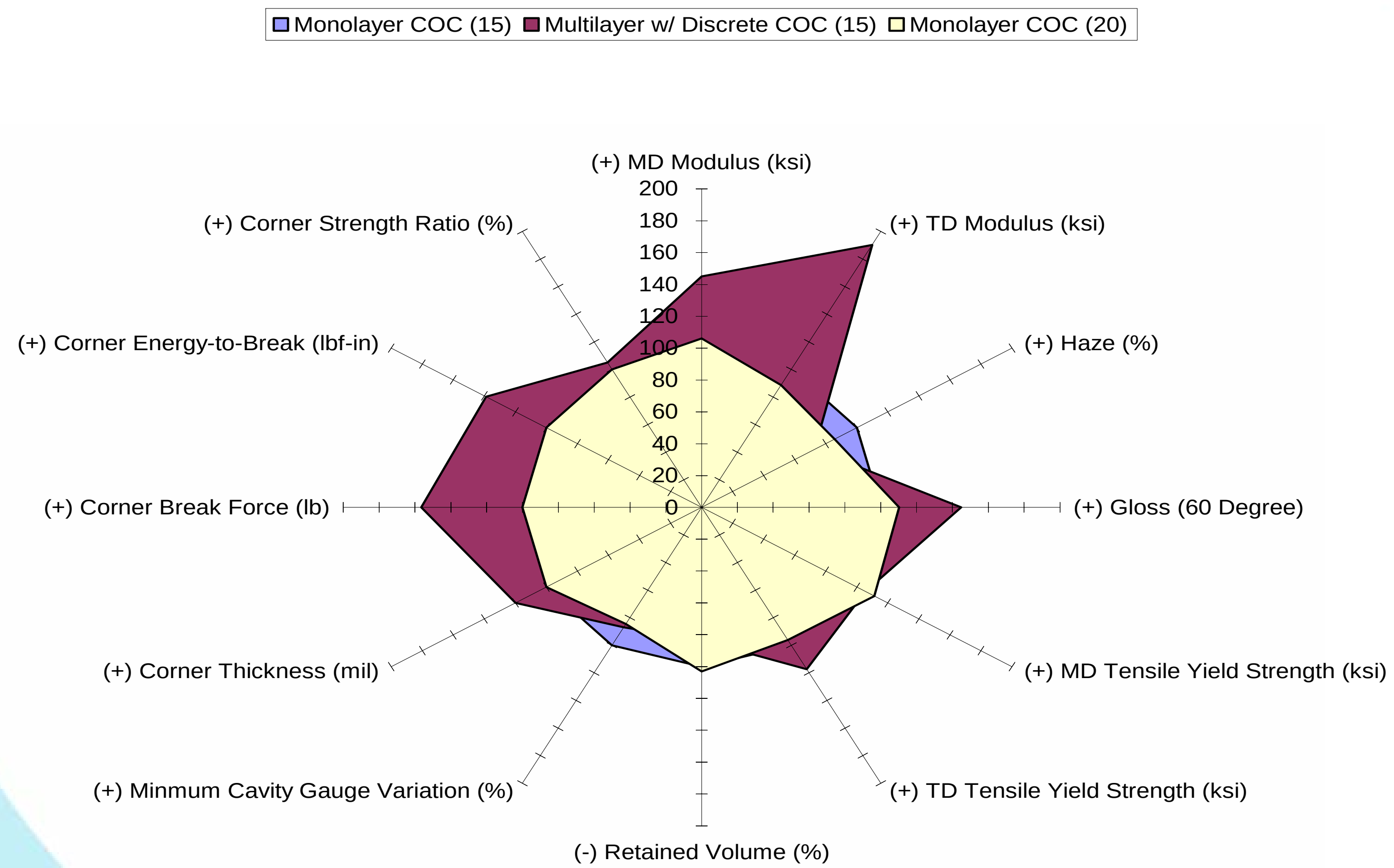
6-mil Monolayer Blend vs. Multilayer Discrete



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**

Any questions?

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.

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.