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Bottle and Container Enhancements Using Cyclic Olefin Copolymers

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TOPAS® Cyclic Olefin Copolymer (COC)
Your Clear Advantage

Outline

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- Introduction to TOPAS® COC – The Basics
  - Market Segments
  - What is COC?
  - Viscoelastic Properties
  - Chemical Resistance
- Multilayer Extrusion Blow Molding (EBM) with COC
- Reheat ISBM: HDPE-COC
- Conclusions

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The Basics

TOPAS® COC – Market Segments

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Healthcare & Diagnostic

Cartridges, syringes, vials, drug delivery devices, microplates, microfluidic devices, cuvettes, bio-chips, PCR

Consumer Electronics

Mobile light guides, windows, touch screens; lenses, sensors, flat panel displays; antennas

Packaging and Films

Food, healthcare, protective and optical films; containers and closures in personal care and consumer markets

Packaging with Cyclic Olefin Copolymers (COC)

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Value Propositions

- Stiffness & Strength
- Thermoformability
- Transparency & Gloss
- Temperature Resistance
- Barrier – Water, Alcohol, Acid, Nitrogen, Helium
- Chemical Resistance
- Sustainability
- Low Adsorption
- Low Orientation Stress
- Heat Sealing

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COC Is Amorphous

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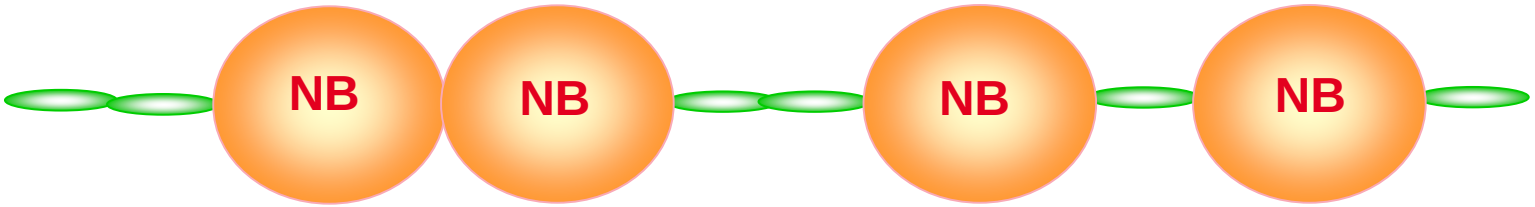
COC molecule is a chain of small CH_2-CH_2 links randomly interspersed with large bridged ring elements

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

Cyclic Olefin Copolymer - Synthesis & Structure

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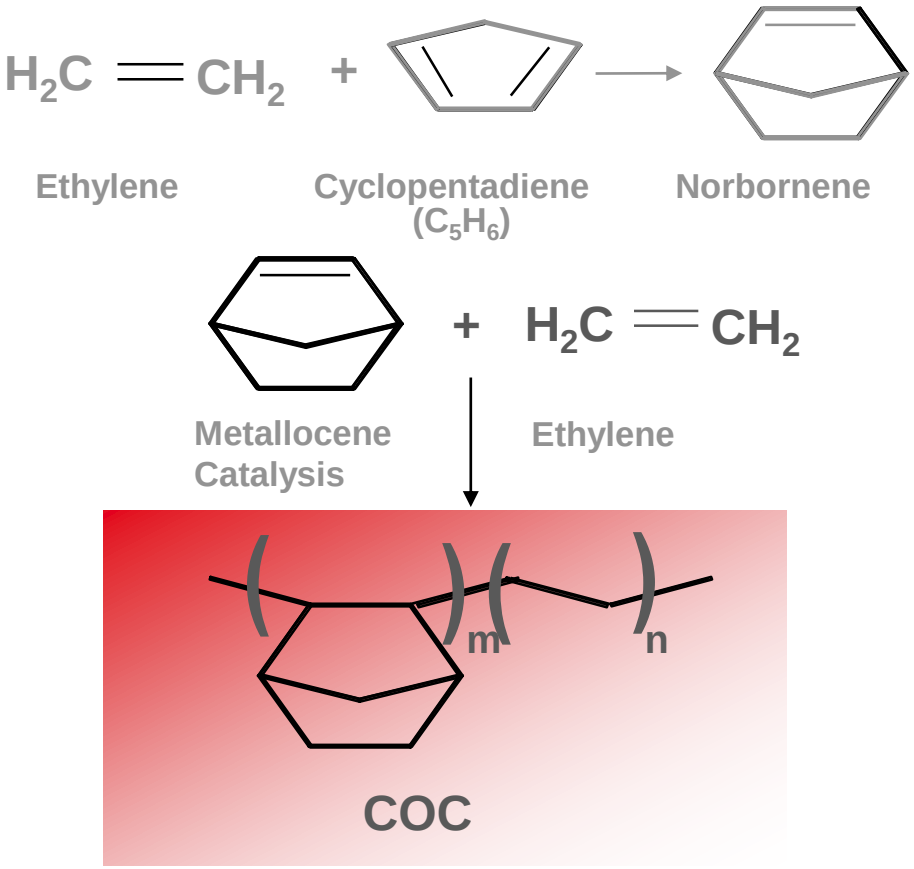

- Readily available raw materials
- Highly efficient catalyst
  - Low usage
  - Catalyst removed as part of process
  - High purity product
- Amorphous
- Crystal clear

TOPAS® COC – Viscoelasticity

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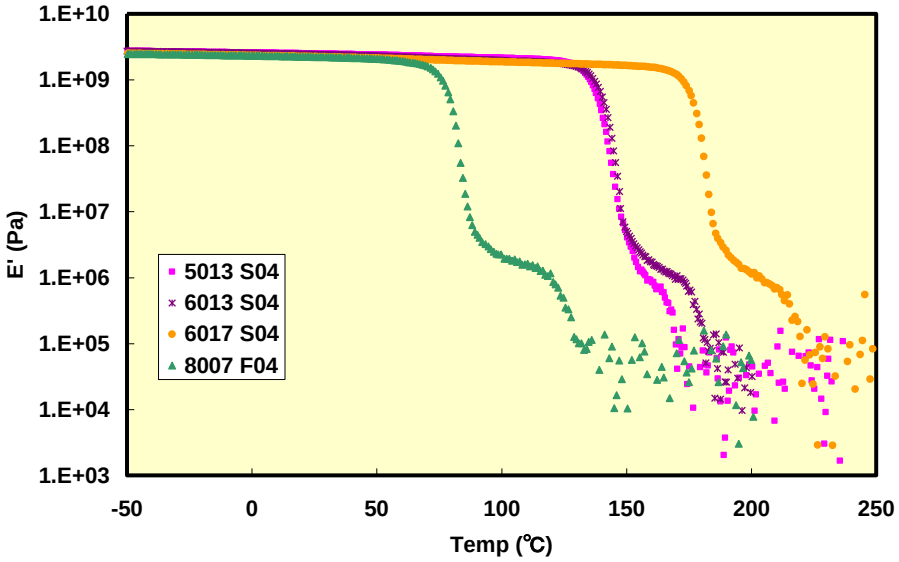
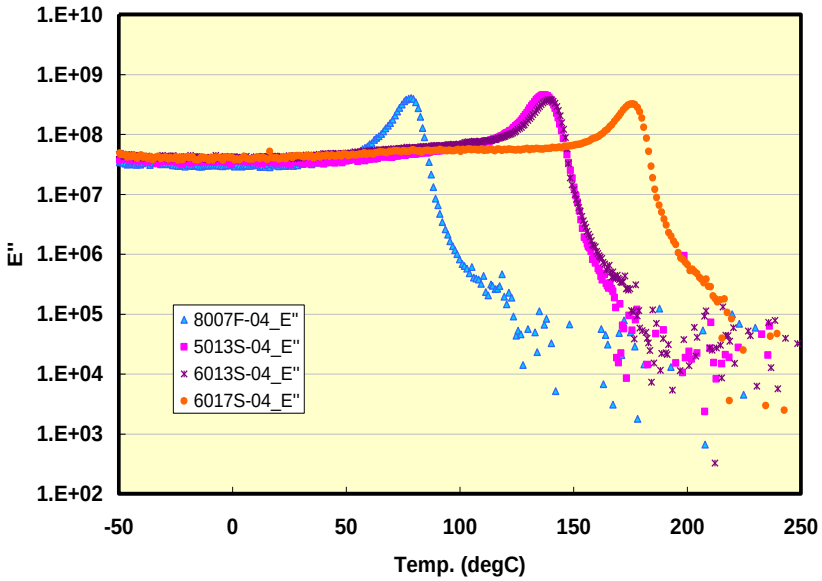


storage elastic modulus

Mechanical properties stable up to glass transition temperature



loss elastic modulus

TOPAS® COC - Chemical Resistance

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pH < 7 (acidic / aqueous)		pH = 7 (neutral / aqueous)		pH > 7 (basic / aqueous)	
hydrochloric acid 36 %	+	Water	+	sodium hydroxide 50 %	+
sulfuric acid 40 %	+	Aqueous solution of soap	+	ammonia (aq. sol.) 35 %	+
nitric acid 65 %	+	saline solution	+		
acetic acid > 94 %	+				

Polar organic solvents		Aromatic solvents		Non-polar organic solvents	
ethanol, methanol, butanol, isopropanol, (short chain alcohols)	+	Benzaldehyde	○	Pentane, hexane, heptane etc. (alkanes)	-
Acetone, butanone (short chain ketones)	+	Toluene	-	Gasoline (petrol ether)	-
		Benzene	-	Norbornene	-
		Chlorinated Solvents	-	Mineral Oil	-

Other	
Oleic Acid	-

+ resistant, increase of weight < 3% or loss of weight < 0,5%, elongation at break not substantially altered

○ limited resistance, increase of weight 3-8% or loss of weight 0,5-5%, elongation at break reduced by < 50%

- not resistant, increase of weight > 8% or loss of weight > 5%, elongation at break reduced by > 50%

TOPAS® COC is resistant to acids, alcohols, bases and polar solvents

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Multilayer Extrusion Blow Molding (EBM)

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Multilayer High Gloss EBM Bottle

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- Description:
  - High shine in cost effective process
- Value Proposition:
  - Optimize shine
  - Structures:
    - 20/ 80 COC / HDPE
    - COC/ HDPE + regrind/ HDPE
  - Processing ease
  - Environmentally & recycle friendly
- TOPAS® Grade:
  - 8007F-600

Color depth perception due to high shine

Chemical Resistance for Hair Dye Bottles

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- **Description:**
  - Enhance chemical resistance to sustain shelf life
- **Value Proposition:**
  - Chemical Resistance
    - Alcohols & acetone
    - Ammonia, hydrogen peroxide
  - Optimal moisture barrier to extend shelf life
  - No paneling - stiff walls
  - Environmentally & recycle friendly
  - Eliminate post-fluorination
- **TOPAS® Grade:**
  - 8007F-600

Chemical resistance for sustained product life

Keys to Sucessful EBM with TOPAS® COC

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- Preference for Multilayer vs. Monolayer Blends
  - Maintain melt strength
  - Maintain impact strength of HDPE
  - Structures:
    - COC/HDPE; COC/HDPE/COC; COC/HDPE+ recycle/COC
- COC Extrusion Process Guidelines to Eliminate Unmelts
  - Proper screw design is essential:
    - Barrier screw with mixing section
    - > 28:1 L/D
    - > 60 mm diameter
  - Reverse temperature profile (add heat early)
    - Pre-heat COC pellets in dryer
  - Blend COC with 10 – 20 % TOPAS® E-140
  - Lab scale extruders can make COC look bad
- Polish Bottle Mold if High Gloss is Desired

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HDPE-COC

Reheat Injection Stretch Blow Molding (ISBM)

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Benefits of HDPE Reheat ISBM vs. HDPE EBM

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- Light Weighting
  - Orientation and ordered molecular alignment provides stiffness
  - Reduce container weight by 20 – 40 percent
- Superior Bottle Finish
  - Improve consistency of thread dimensions
  - Improve surface detail
- Improve Aesthetics
  - Reduce haze
  - Increase gloss
- Reduce Waste
  - Less purge & shorter start-up times
  - No flash trim
- Improve Container Performance
  - Eliminate weld lines
  - Reduce pinhole leaks and drop impact failures
- Potential for Very Fast Production Rates
  - > 6X increase in bottles/hour/machine

Segmentation: NA HDPE Blow Molding Market

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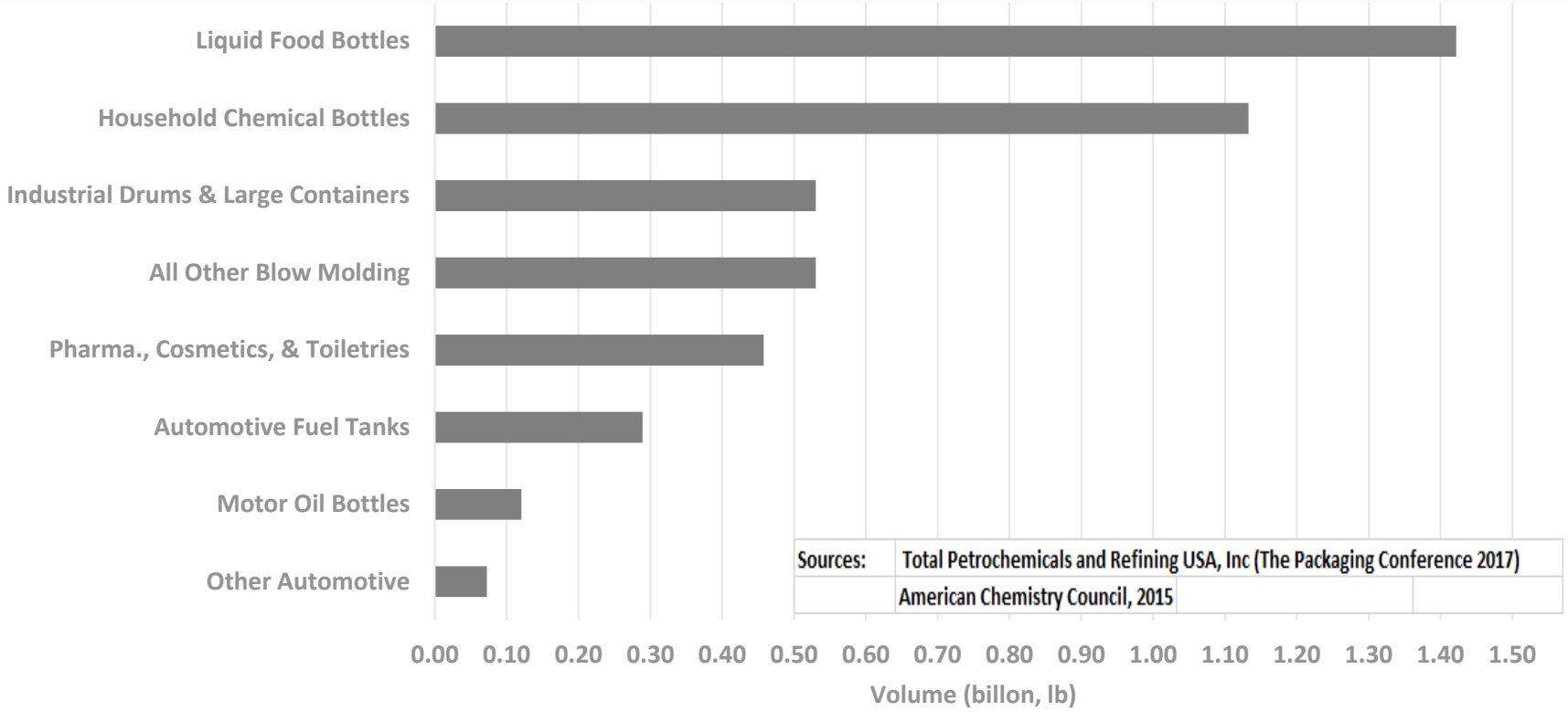

Annual Sales (2014): 4.6 billion lb.
EBM Bottle Estimate (TAPI): 1.9-2.4 billion lb.
Large untapped market for HDPE reheat ISBM!

Limitations of HDPE for Reheat ISBM

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- **Deficiency of HDPE in Reheat ISBM Process**
  - **HDPE *DOES NOT* strain harden**
  - **Reheat ISBM HDPE bottles are difficult to manufacture, requiring precise temperature control**
    - **Stretching temperature process window 1–3°C**
    - **Slower rates and poor yield compromises process economics**
  - **Good & bad bottles can be made independent of process conditions**

PE-COC Strain Hardening – Illustrative Example

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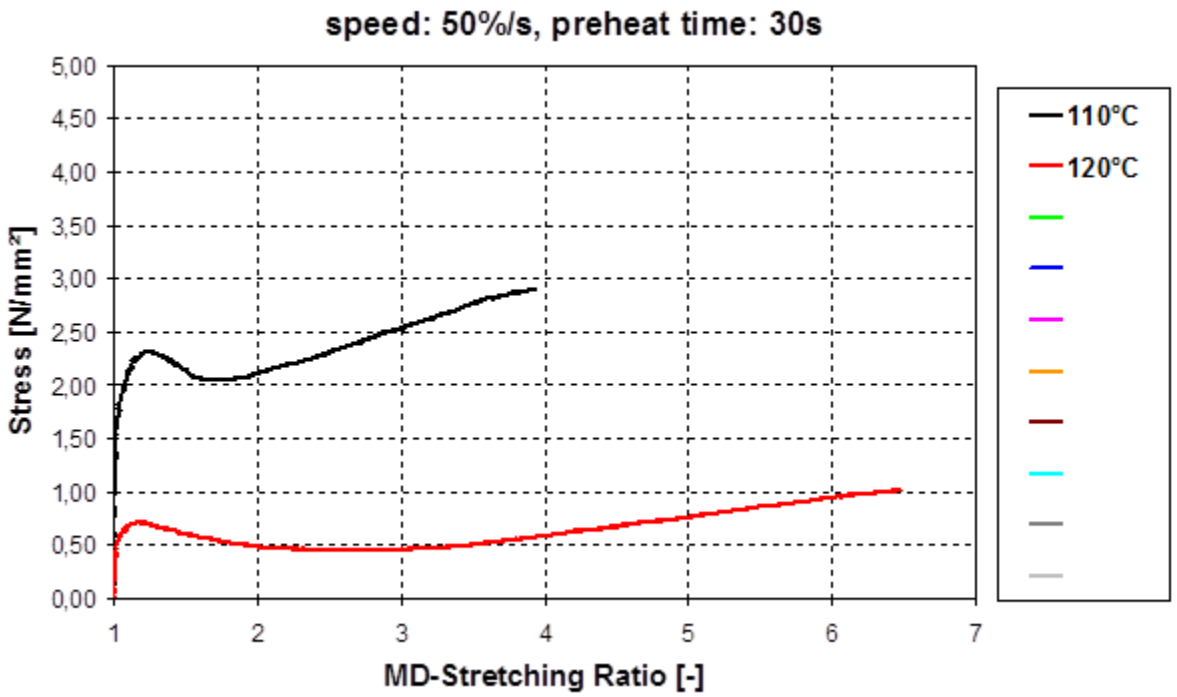

Five-Layer (290 µ): PE/COC-78/PE/COC-78/PE (LLDPE)
Layer Ratio: 4/14/64/14/4
Biaxially stretched at 4 x 4 & 6.5 x 6.5 (Bruckner-Karo)
Strain Hardening: Gradual increase in stress during stretching

Why Add COC to HDPE for Reheat ISBM?

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- HDPE w/COC ***DOES*** strain harden
- Strain hardening enables uniform stretching over broad temperatures.
- Improve ISBM process for HDPE bottles w/ COC ("flip a switch"):
  - Broaden stretching temperature process window > 10°C
  - Substantial increase to productivity and yield

Container Properties

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Top Load

Force (lb_f) at 1.0-inch Deflection

HDPE	HDPE / 10% COC-1	HDPE / 15% COC-1	HDPE / 15% COC-2
29.4	23.5	18.3	35.6

Bruceton Staircase Drop Impact Test

Mean Failure Height (inch)

Drop Temperature & Orientation	HDPE	HDPE / 15% COC-2	HDPE / 17% COC-2
23°C Vertical	>96	>96	>96
4°C Vertical	>96	>96	>96
4°C Horizontal	57	60	51

Material Distribution

Wall Thickness (mil)

Bottle Height (in)	HDPE	HDPE / 15% COC-2	HDPE / 17% COC-2
8.00	11	13	15
6.90	10	13	12
5.00	13	23	18
4.10	16	23	21
2.60	36	18	21
1.60	22	17	17
1.00	18	17	15
0.40	22	21	16
Average	18.5	18.1	16.9
Standard Deviation	8.4	4.0	3.1

- COC content & Tg has positive effect on top load & drop impact performance
- COC reduces wall thickness variation

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HDPE-COC Reheat ISBM

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- Study Benchmarks
  - Sidel SB01 Blow Molding Machine
  - Rate: 300 – 400 BPH
  - 1-litre, 31-gram container
  - Defects:
    - HDPE ~60%
    - HDPE-COC ~20%
- Further Optimization:
  - Pre-form molding conditions
    - Warmer is preferred
  - Pre-form design
    - Axial and hoop stretch ratios
  - IR heating optimized for PET, not HDPE
  - HDPE responds differently than PET!

Conclusions:

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- Unique properties of COC improves processing and performance of HDPE in blow molding:
  - Amorphous
  - Heat resistance
  - Strength & stiffness
  - Low haze & high gloss
  - Strain hardening

- COC-HDPE for EBM
  - High gloss & improved aesthetics
  - Chemical resistance

- ISBM HDPE w/ COC containers offers four compelling advantages:
  - Light weighting (>25% reduction)
  - 4X – 6X faster production rates versus EBM
  - Improvement in mechanical properties
  - Chemical resistance

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