Enhancement of Protective Packaging Films with Cyclic Olefin Copolymers (COC)

Paul D. Tatarka
Polyplastics USA, Inc.
Farmington Hills, MI
Outline

- What is COC, Properties & Applications?
- Protective Packaging
- Protective Packaging: Key COC Performance Benefits
- Conclusions
What is COC, Properties & Applications?
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

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

Ethylene \( \rightleftharpoons \) Cyclopentadiene \((C_5H_6)\) \( \rightarrow \) Norbornene

Ethylene \( \rightleftharpoons \) Metallocene Catalysis

Cyclic Olefin Copolymer – COC
**COC - Basic Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
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<tbody>
<tr>
<td>Glass transition temperatures, °C(°F)</td>
<td>65 - 180 (149 – 356)</td>
</tr>
<tr>
<td>Modulus of elasticity, MPa (kpsi)</td>
<td>1800 – 3200 (260 – 460)</td>
</tr>
<tr>
<td>Tensile strength, MPa (kpsi)</td>
<td>52 - 63 (7.5 - 9.1)</td>
</tr>
<tr>
<td>Density, g/cm³</td>
<td>1.02</td>
</tr>
<tr>
<td>Water uptake, %</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Nitrogen, cc-mil/100 in² × day, 23°C/0RH</td>
<td>0.5</td>
</tr>
</tbody>
</table>

- Excellent heat resistance
- Dimensional stability
- High gloss
- Resistant to alcohols, acids, bases, polar solvents
- High purity, low leachables
- Low water transmission rate
- Compatible N2 for PE & PP enables recyclability
TOPAS® COC – Market Segments

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

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

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Protective Packaging
What is Protective Packaging?

Protective packaging materials must be designed to protect the enclosed contents from damage from any variety of causes, such as moisture, shock and vibration during transportation and distribution.


<table>
<thead>
<tr>
<th>Protective Packaging Types:</th>
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<tbody>
<tr>
<td><strong>Paper</strong></td>
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<tr>
<td>Crumpled Void Fill, Padded Sheets</td>
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<tr>
<td><strong>Cardboard</strong></td>
</tr>
<tr>
<td>Corrugated, Boxes &amp; Profiles</td>
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<tr>
<td><strong>Foams</strong></td>
</tr>
<tr>
<td>EPS &amp; starch-based peanuts, mold-in-place urethanes, LDPE &amp; HDPE foamed sheet and planks</td>
</tr>
<tr>
<td><strong>Inflatable Plastic Films</strong></td>
</tr>
<tr>
<td>Void Fill Structures; Cellular Cushioning, Pillows and Bubble Sheets.</td>
</tr>
</tbody>
</table>
Key Benefits:
- Low N₂ & Air Permeation
- Stiffness & Strength
- Easy Tear & Cutting
- Improve Seal Strength
- Good Appearance
- Low Moisture Permeation
- Reclaim internally
- Postconsumer recycle with PE
Protective Packaging:
Key COC Performance Benefits

Protective packaging is an excellent example to showcase COC as effective and efficient polyethylene modifier.
Benefit (1): Nitrogen & Water Permeation

TOPAS 8007F-600 samples were analyzed on a MOCON Multi-Tran 400 Instrument utilizing a TCD sensor. Sources: Permeability Properties of Plastics and Elastomers, Massey, 2nd Edition; various datasheets; internal data.

COC has very low nitrogen and air permeability, without the compromising moisture sensitivity of other high barrier materials.
Benefit (2): Stiffness Enhancement

Benefits for Protective Packaging:
- Enable thinner films
- Reduce stretching & deformations
- Improve machine handling
- Enable faster converting speeds

MD Tensile Modulus:
- 5-10% COC increases stiffness significantly.
- Similar linear response among polyolefins
- Efficient and effective
Benefit (3a): Cutability Enhancement

Benefits for protective packaging:
- Stronger films
- Less film distortion during cutting
- Cleaner, easier, more reliable separation along perforations

Tensile Properties:
- MD & TD Tensile Stress at Break improves
- Tensile elongation at yield is influenced by orientation
- 5-10% wt. COC reduces elongation at yield significantly
- Potential for downgauging
Benefit (3b): Linear Tear Enhancement

Benefits for Protective Packaging:
- Controlled directional linear tear
- Cleaner separation along perforations
- Less distortion

Tear Properties:
- “Bulky” COC structure enables molecular chain alignment
- Elmendorf Tear is influenced by TD & MD orientation
- 10-20% wt. COC reduces TD and MD Elmendorf Tear significantly
Benefit (4a): Heat Sealing Enhancement

Benefits for protective packaging:
- Stronger seals
- Broader heat seal window

Heat Sealing Properties:
- 10-30% COC improves ultimate seal strength
- 10-30% COC improves hot tack force
- Slight increase of SIT to 110°C
Benefit (4b): Seal Initiation vs. Modulus

COC significantly improves film modulus without compromising seal initiation temperature.
Benefit 5: Reclaim & Recycle

Benefits for reclaiming in house:
- COC is compatible with PE at typical levels
- Reclaim can be used in any layer
- Minimal effect on optics
- Does not degrade like other barriers

Recycling/Sustainability:
- Compatible with PE film recycling
- No compatibilizers required
- Less waste due to predictable tear
- Potential for downgauging
Protective Packaging: PE-COC Structures

**Polyolefin Materials**
- LDPE, HDPE, prefer LLDPE (any comonomer)

**Monolayer**
- 5-20% COC

**Three Layer**
- 5-20% COC in both skin layers
- 0-30% COC; more in core layer depending on nitrogen/air barrier requirements; reclaim

**Five Layer (A-B-C-B-A)**
- A: 5-20% COC
- B: 30-70% COC; more depending on barrier requirements
- C: 0-30% COC as needed; reclaim

**Other Considerations:**
- COC eliminates the need for nylon and EVOH for extended shelf-life products.
- More extruded layers enables efficient distribution of COC in the film, tailored mechanical properties, and lower cost.
Conclusions:
COCEnhances Protective Packaging

**Mechanical Properties**
- Added stiffness of softer polymers
- Improve strength
- Reduce film extensibility and distortion
- Controllable film cutting, tear and perforation separation
- Enable downgauging

**Barrier & Environment**
- Very low permeability to nitrogen and air
- Low moisture absorption
- Insensitive to changes in relative humidity
- Facilitates reclaim and recycling

**Seal Properties**
- Improved seal strength, hot tack with broader temperature window
TOPAS® COC Modifies Billions of Pounds of Polyethylene -- One Pound at a Time

How Can We Help You?

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