Polyethylene & Polypropylene in Flexible Barrier Packaging

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PE = Barrier
Learning Outcomes

- How polyethylene & polypropylene is used in barrier packaging.
- Barrier properties of PE & PP.
- Properties of PE which affect barrier performance.
- How film & coating processing influences barrier performance.
How does PE & PP fit into flexible barrier packaging?

- By itself (monolayer)...
- Combined (coex or lamination)…
How Does PE & PP Provide Barrier?

- Polyethylene is used by itself or combined with other materials to create a torturous path to create a barrier.
- Polyethylene and polypropylene can have good-moderate moisture barrier properties.
- HDPE MVTR grades are higher in density and can provide improved moisture barrier over LDPE and PP.
- Good moisture barrier can be achieved with monolayer HDPE MVTR grades.
How Does PE & PP Provide Barrier?

- Fair moisture barrier can be achieved with monolayer LDPE grades.
- Polyethylene and polypropylene have poor oxygen (gas) barrier but good-moderate moisture barrier properties.
PE & PP MVTR Properties
Using PE & PP for Barrier

- PE & PP can be combined (blended, coexed, or laminated) with other materials for exceptional MVTR & OTR.

- PE & PP properties and processing methods influence barrier properties.
What is Polyethylene?

ETHYLENE

Colorless Gas
Odor = Slightly Sweet
Origins = Refinery Gas & Liquefied Petroleum Gases
Mol. Wt. = 28

World Capacity*
128 Million Tons. (2005 est.)

* World Petrochemical Review (Oct 2005)
Polyethylene Reaction

Catalyst/Initiator Temperature Pressure
Polyethylene Structures

LDPE

LLDPE

HDPE
Basic Molecular Properties
Resin Type

MOLECULAR WEIGHT
DISTRIBUTION (MWD)
LONG CHAIN BRANCHING (LCB)
CRISTALLINITY

MOLECULAR WEIGHT
DISTRIBUTION (MWD)
CRISTALLINITY

MOLECULAR WEIGHT
DISTRIBUTION (MWD)
COMONOMER TYPE (SCB)
CRISTALLINITY

LDPE
HDPE
LLDPE
Critical Polyethylene Properties

- Melt Index / Mol. Wt.
- **Density / Crystallinity**
  - Morphology (shape, size & distribution of the PE molecules & crystals)
- Molecular Weight Dist.
- Long Chain Branching
- Rheology
Density

- Density is a measure of the crystallinity of the polymer.
- Higher density polymers have more closely packed molecules and are more stiff in nature.
- Lower density polymers have loosely packed molecules and are more flexible.
- Density is measured as the weight of material occupying a specific volume (g/cc).
Crystalline and Amorphous Structure

Crystalline Regions

Amorphous Regions
Density Test

Density is an indirect measure of the crystallinity of a polymer.

- Calibrated Density Standards
- Sample
- Controlled Temperature Gradient Column

Standard Procedure: ASTM D1505
Units = g/cc

Other accepted techniques for measuring density include ultrasonic velocity and buoyancy (densimeter).
Column Density
Increase in Crystallinity (Density) Affects Other Properties

As Crystallinity Increases These Properties

<table>
<thead>
<tr>
<th>Increase</th>
<th>Decrease</th>
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<tbody>
<tr>
<td>Density</td>
<td>MD Tear Strength</td>
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<tr>
<td>Stiffness</td>
<td>Impact</td>
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<tr>
<td>Tensile Strength</td>
<td>Puncture Resistance</td>
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<tr>
<td>Softening Point</td>
<td>COF</td>
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<tr>
<td>Dead Fold</td>
<td>Optics (Clarity)</td>
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<td>Curl</td>
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<td></td>
<td>Chemical Resistance</td>
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<td>Heat Resistance</td>
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<tr>
<td></td>
<td>Wrinkling Tendency</td>
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<tr>
<td></td>
<td>Seal Initiation Temp.</td>
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<td>Barrier (Moisture, Light, &amp; Grease)</td>
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Crystallinity

- For polyethylene, the degree of crystallinity has the largest influence on barrier properties.
  - Randomly oriented, large crystals, create the most tortuous path.
- % crystallinity can be measured and is influenced primarily by polymer type, but also by processing.
  - LDPE/LLDPE ~ 30% - 55% crystallinity
  - HDPE up to 85% crystallinity
- In addition to % crystallinity, morphology (alignment, shape & dimensions of crystals), also affects barrier performance.
- Processing methods also influence the degree of crystallinity and polymer morphology, which will also directly affect barrier properties.
- Types of processing methods....
Cast Film Process

Produces high barrier structures by coextruding PE & PP with high barrier materials, predominantly nylon and EVOH.
Blown Film Process

Produces high barrier structures by coextruding PE & PP with high barrier materials, predominantly nylon and EVOH. Also produces good moisture barrier monolayer films using HDPE MVTR grades.
# Film Process Comparison

<table>
<thead>
<tr>
<th></th>
<th>CAST FILM</th>
<th>BLOWN FILM</th>
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<tbody>
<tr>
<td>Capital Cost</td>
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<td>✔️</td>
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<tr>
<td>Output</td>
<td>✔️</td>
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<tr>
<td>Gauge Control</td>
<td>✔️</td>
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<td>Optical Properties</td>
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<tr>
<td>Retrofit to Coex</td>
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<td>✔️</td>
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<tr>
<td>Additive Loading</td>
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<tr>
<td>Film Strength</td>
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<td>✔️</td>
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<tr>
<td>Biax Orientation</td>
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<td>✔️</td>
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<tr>
<td>MVTR Barrier</td>
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<td>✔️</td>
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</tbody>
</table>
Processing Conditions Affecting Barrier

- Slower Quench Rate
  - Larger More Random Crystals
  - Better MVTR

- Higher Blow-up Ratio
  - More Biaxial Orientation
  - Better MVTR

- Lower Draw Down Rate
  - More Biaxial Orientation
  - Better MVTR
HDPE MVTR Grade Blow Film
HDPE MVTR

Gauge (mils)

g/100in²/day

BUR = 1.5

BUR = 2.5

HDPE MVTR Grade Blow Film
Extrusion Coating Process
Barrier Considerations in Extrusion Coating

- HDPE must be blended or coextruded with LDPE for processability in extrusion coating.
- Blending with highly branched LDPE extrusion coating grades disrupts crystallinity and reduces barrier.
- Most orientation is in machine direction (similar to cast film). Lack of biax orientation reduces barrier compared to MVTR blown film.
- Properties dependent on level of comonomer
- Some applications only require “moderate” barrier and LDPE or HDPE in extrusion coating can work (e.g. sugar pouch).
Extrusion Coating MVTR

Blend
Coex

HDPE

% HDPE

g-mil/100in²/day

0 2 04 06 08 0

0 0.5 1 1.5 2 2.5

0 20 40 60 80
How to Destroy Barrier in Extrusion Coating
Non-Polarized

Matte Side
Summary

- PE & PP are used directly or indirectly in flexible barrier packaging.
- To achieve oxygen (gas) barrier, PE & PP are typically coextruded or laminated with other materials.
- HDPE MVTR grades provide good moisture barrier properties.
- Manufacturing methods and process conditions influence barrier properties.
Thank You

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Please remember to turn in your evaluation sheet...