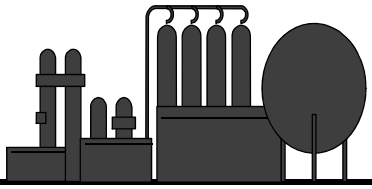


Chevron Phillips Chemical Company LP

Extrusion Coating of Polyethylene & Polypropylene

Kelly R. Frey
Chevron Phillips Chemical Company LP

TAPPI Extrusion Coating Course
August 24-26
Charleston, SC

Learning Outcomes

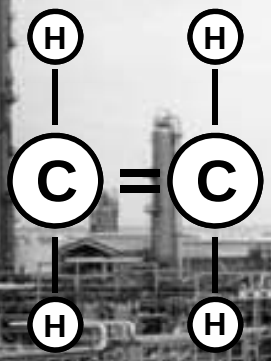
- Description of polyethylene.
- Different types of polyethylene resins used in extrusion coating.
- Overview of polyethylene manufacturing processes.
- Understand key PE properties such as MI, Density, MW, MWD, LCB & Rheology and how these properties relate to both processing and finished properties.
- Description of polypropylene.
- How to process polypropylene in extrusion coating.

Extrusion Coating
A Demanding Process!

- Process at temps up to 630F!
- Oxidize (burn) surface to achieve chemical bond to substrate.
- Extrude in air gap with unsupported edges.
- Draw down to 1/100th of original thickness or less in milliseconds.
- Polymer acceleration rate, in air gap, similar to going from 0-60mph in less than 0.5s!
- All of this with minimal neck-in, stable edges, EBR, good gauge profile, no web breaks, minimal smoke, inclusion free, pinhole free & good release from chill roll….

Polyethylene to the rescue!!!

What is Polyethylene?



ETHYLENE

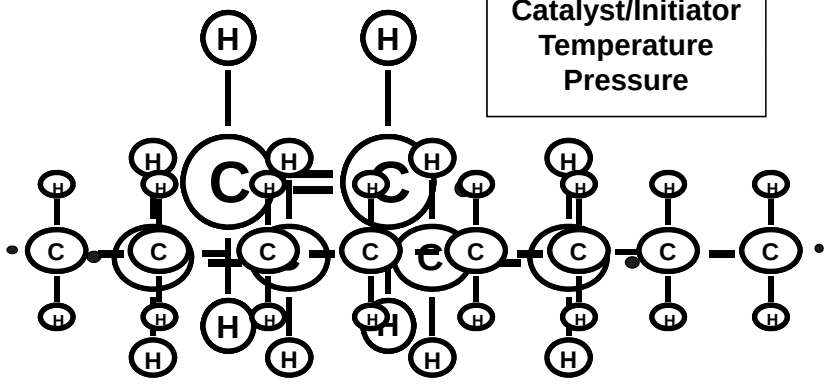
Colorless Gas
Odor = Slightly Sweet
Origins = Refinery Gas & Liquefied Petroleum Gases
Mol. Wt. = 28

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

* World Petrochemical Review (Oct 2005)

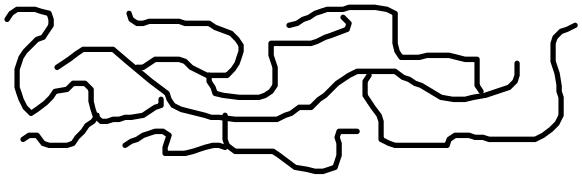
Polyethylene Reaction

Catalyst/Initiator
Temperature
Pressure

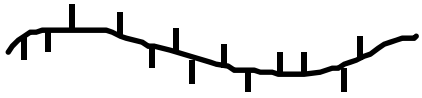


Polyethylene Structures

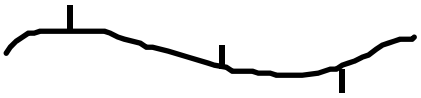
LDPE



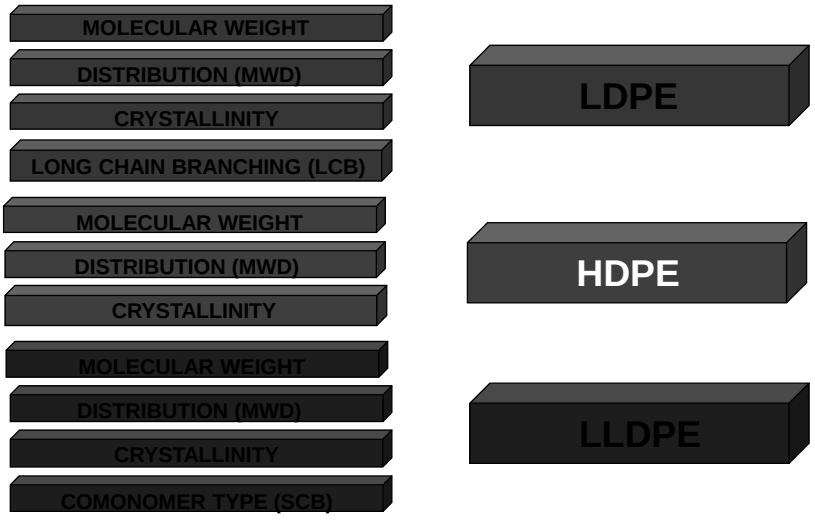
LLDPE



HDPE

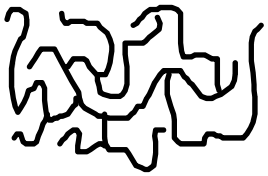


Basic Molecular Properties
Resin Type



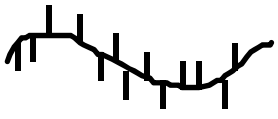
LDPE

- LDPE is characterized by long chain branching.
  - Density range from 0.915 to 0.925 g/cc
- Autoclave grades offer excellent melt strength for minimal neck-in and excellent drawdown in extrusion coating.
- Typical Applications:
  - Liquid Packaging
  - Snack Foods / Laminations
  - Pouch Stock
  - Folding Carton / Cup Stock
  - Sealant Layers



LLDPE

- LLDPE is characterized by short chain branches.
  - Density range from 0.916 to 0.925 g/cc
- Enhanced toughness, tear, puncture and stiffness are some attributes over LDPE.
- Typical Applications:
  - Institutional Foods
  - Balloon Films
  - Non-wovens
  - Enhanced Packaging

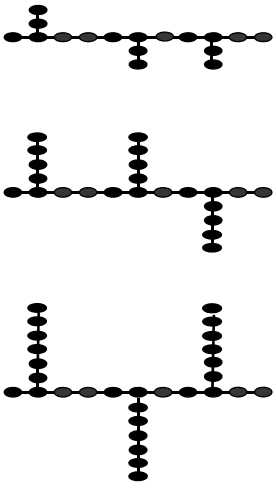


LLDPE
Comonomer Type

COMONOMER TYPE

Comonomer type refers to the number of carbons contained in the side chain attached to the main polymer backbone.

Comonomers for LLDPE

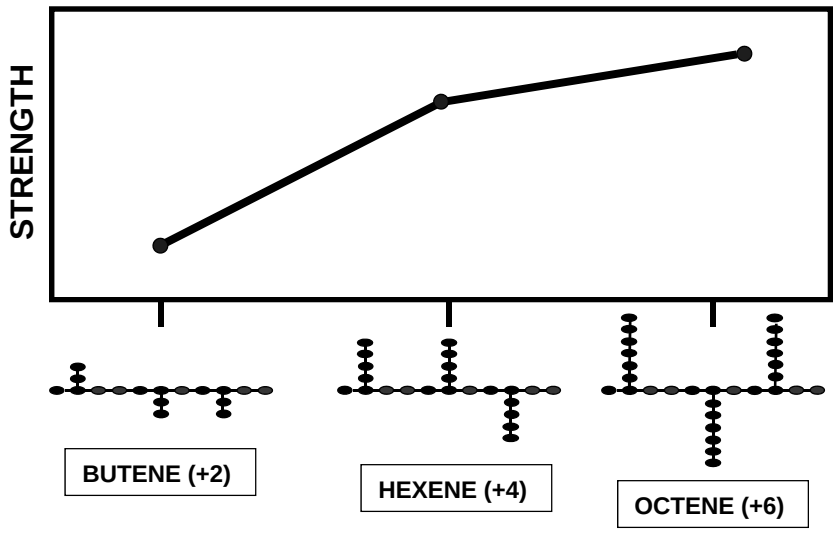


Butene (+2)

Hexene (+4)

Octene (+6)

Effect of Comonomer on Properties

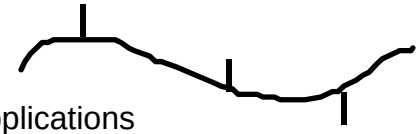


Metallocene LLDPE's

- Metallocene LLDPE developed for improved abuse resistance (tear, dart, and spencer impact properties), hot tack and heat seal.
- Some tie properties, e.g. OPP.
- Two types of metallocenes:
  - » Plastomers and enhanced LLDPE's
    - Plastomers density <0.915
    - mLLDPE density >0.915

HDPE

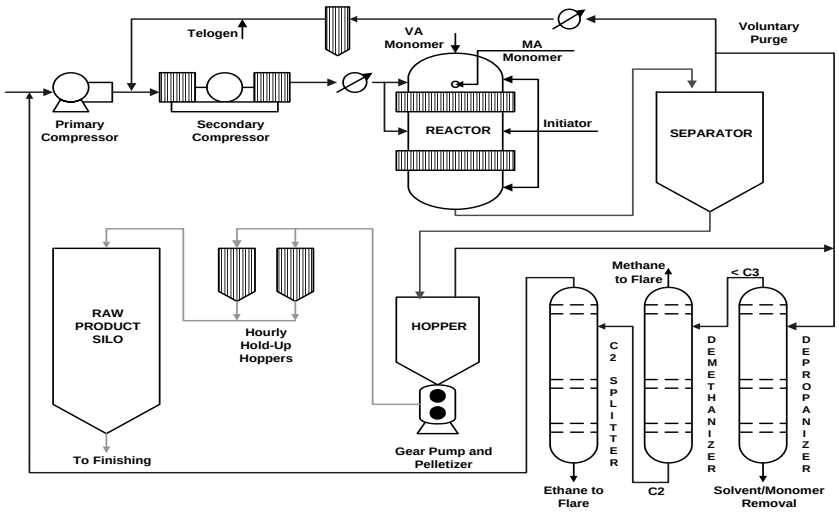
- HDPE is also characterized by short chain branches.
  - Density range from 0.940 to 0.965 g/cc
- Improved MVTR, grease resistance, temperature resistance, higher stiffness and lower COF over LDPE.
- Typical Applications:
  - Release Liners
  - Temperature Resistant Applications
  - Multi-wall Bags
  - MVTR Applications



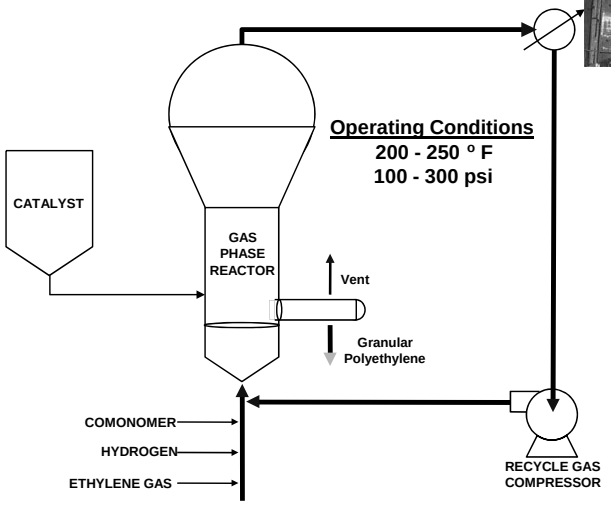
Resin Manufacturing Processes

	LDPE	LLDPE	HDPE	mLLDPE	Copolymer
Autoclave	X				X
Tubular	X				
Particle Form		X	X	X	
Gas Phase		X	X	X	
Solution Form		X	X	X	

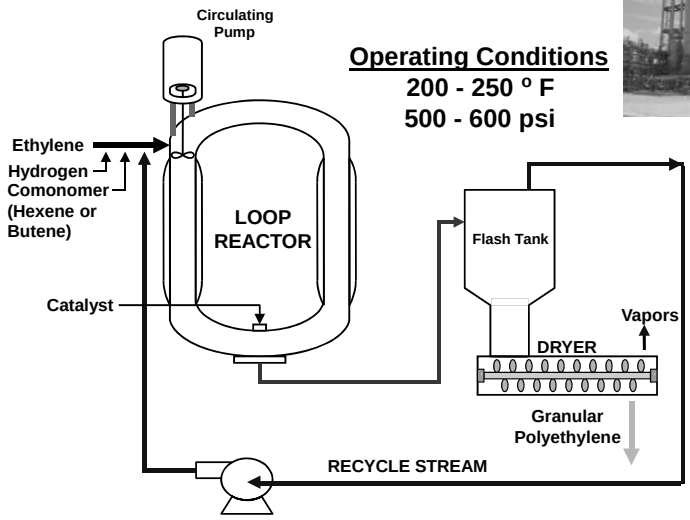
High Pressure Autoclave



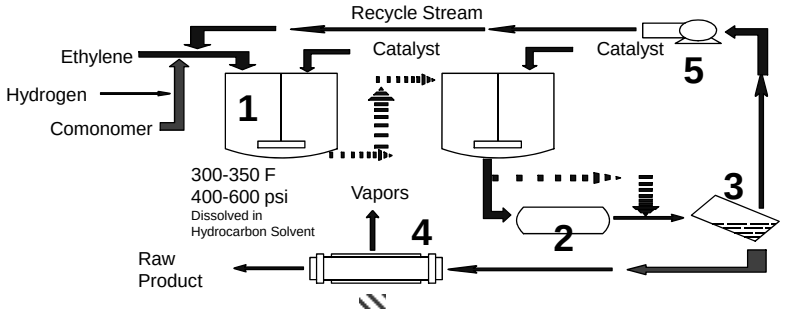
Low Pressure Gas Phase



Low Pressure Slurry



Low Pressure Solution



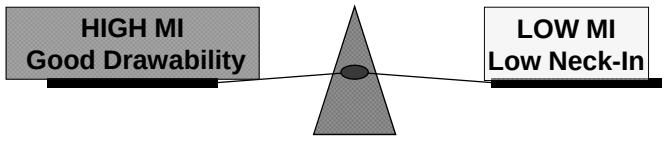
1. **Stirred Reactors**
2. **Filtration**
3. **Separator**
4. **Drier**
5. **Compressor**

Critical Polyethylene Properties

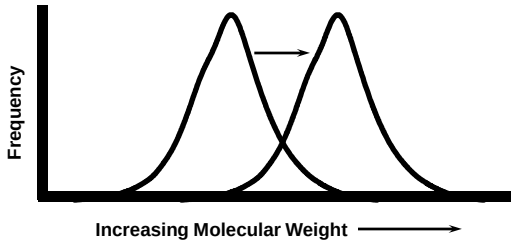
- Melt Index / Mol. Wt.
- Density / Crystallinity
- Molecular Weight Dist.
- Long Chain Branching
- Rheology

Melt Index (MI)

- Melt Index is a simple and traditional measure of polymer flow (viscosity).
- This flow value correlates with molecular weight.
  - the higher the molecular weight, the lower the melt index.
- Higher melt index resins are used for lower coating weights.
- Higher melt index resins have a higher degree of neck-in.



Basic Molecular Properties
Effect of MWw (Melt Index) on Properties



As <u>Weight Average Molecular Weight</u> Increases These Properties

<u>Increase in Ave. Mol. Wt.</u>

- Impact Strength
- Tensile Strength
- Heat Seal Strength
- Heat Seal Range
- Melt Strength
- Chemical Resistance
- TD Tear Strength
- Seal Initiation
- Puncture Resistance
- Ext. Load / Amps/ Back Pressure

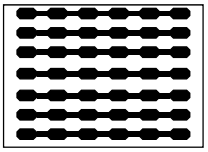
Melt Index

<u>Decrease in Ave. Mol. Wt.</u>

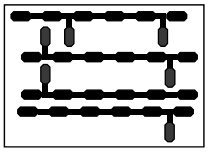
- Melt Index
- Processability (Ease of Flow)
- Melt Extension / Drawdown
- Neck-in
- Edge Bead

Density

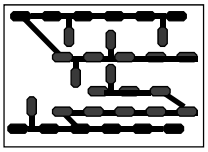
- Density is a measure of the crystallinity of the polymer.
- Higher density polymers have more closely packed molecules and are more stiff in nature.
- Lower density polymers have loosely packed molecules and are more flexible.
- Density is measured as the weight of material occupying a specific volume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



No Branching – High Density

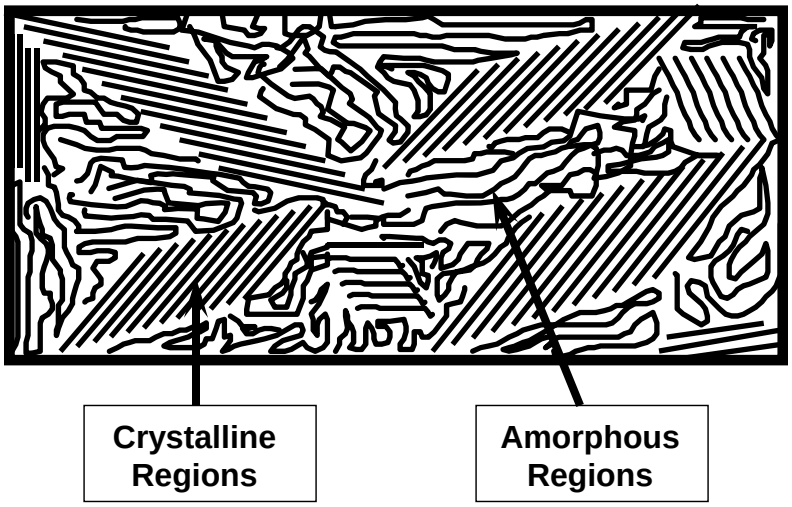


Short Chain Branching – Med Density

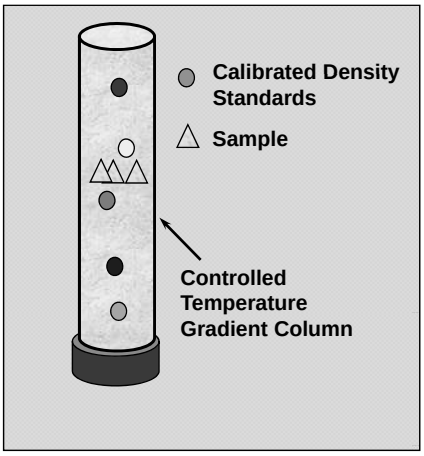


Short & Long Chain Branching – Low Density

Crystalline and Amorphous Structure



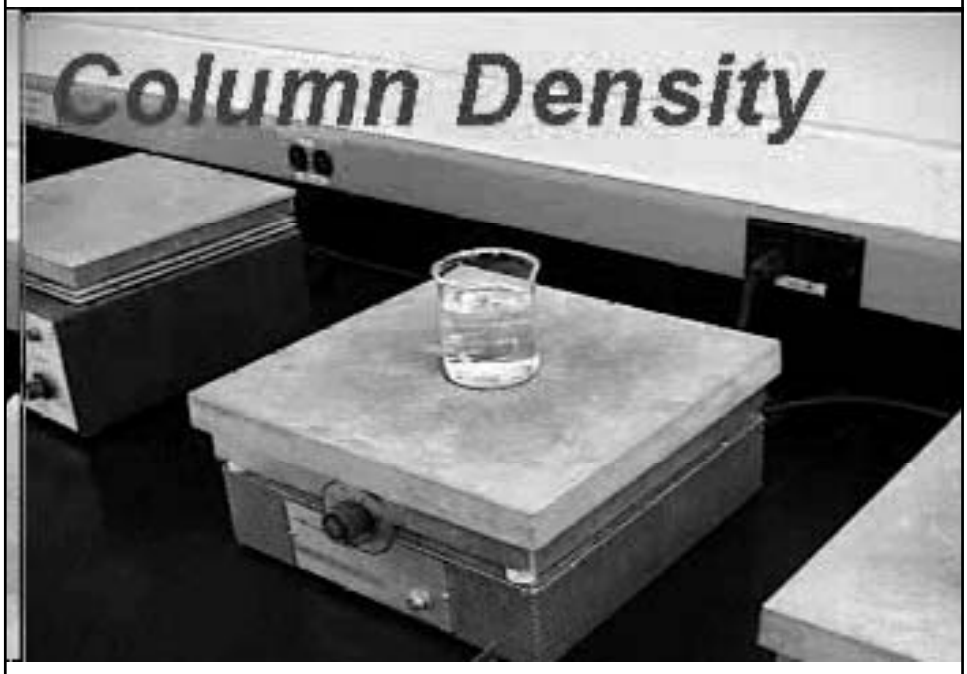
Density Test



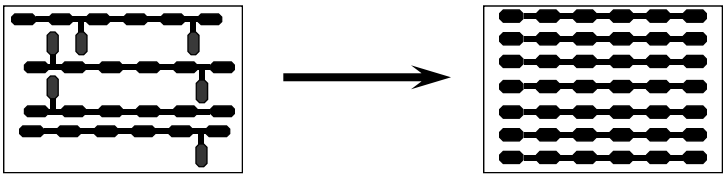
Density is an indirect measure of the crystallinity of a polymer.

Standard Procedure : ASTM D1505
Units = g/cc

Other accepted techniques for measuring density include ultrasonic velocity and buoyancy (densimeter).



Effect of Crystallinity (Density) on Properties

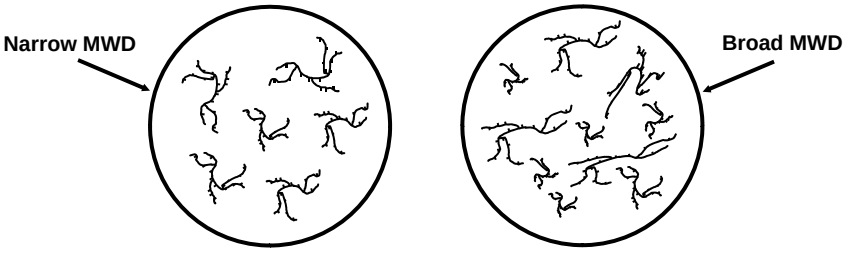


As Crystallinity Increases These Properties

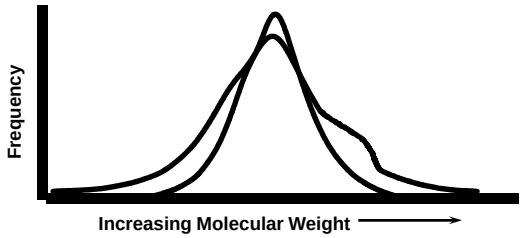
Increase		Decrease
Density	Chemical Resistance	MD Tear Strength
Stiffness	Heat Resistance	Impact
Tensile Strength	Wrinkling Tendency	Puncture Resistance
Softening Point	Seal Initiation Temp.	COF
Dead Fold	Barrier (Moisture,	Optics (Clarity)
Curl	Light, & Grease)	

Molecular Weight Distribution

- Molecular weight distribution (MWD) is a measure of the fractions of the various molecular weights in a polymer.
- Polymers can be produced to have a narrow or broad molecular weight distribution with the same average molecular weight.



Effect of MWD on Properties



As <u>Molecular Weight Distribution</u> Increases These Properties

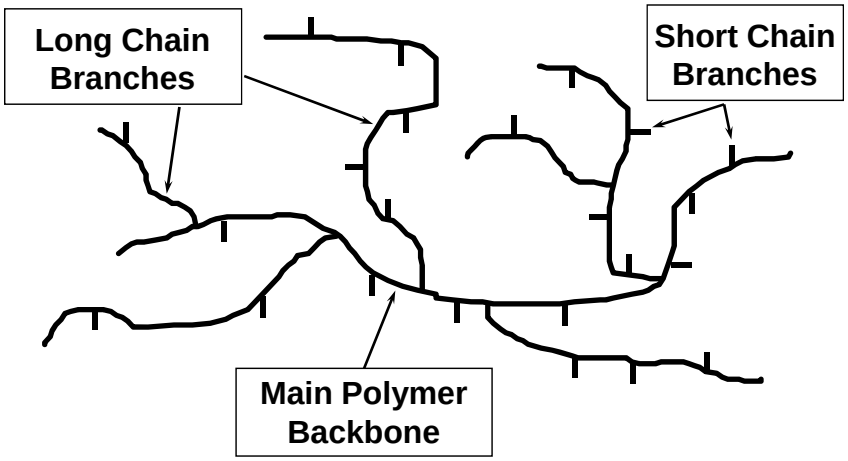
<u>Increase</u>	**<u>Decrease</u>**
Processibility Melt Strength & Stability Lower Neck-in	Backpressure & Motor Load* Melt Extension Reduced Draw Physical Properties Puncture – Tear - Tensile

Long Chain Branching

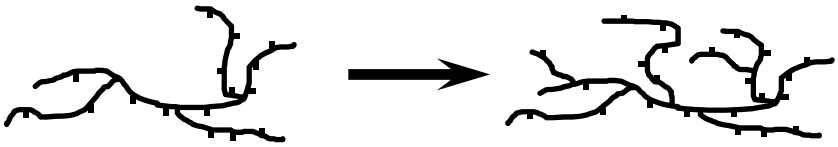
Long Chain Branching

Refers to the amount of long chains (those greater than ~150 carbons long) that are attached to the main polymer backbone. Critical for melt strength in extrusion coating.

Long Chain Branching Illustration



Long Chain Branching on Properties



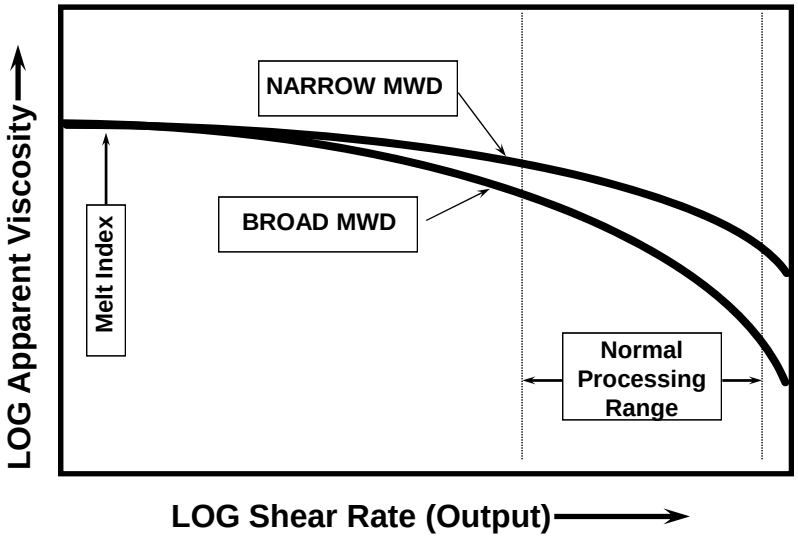
As the Degree of Long Chain Branching Increases These Properties

Increase	Decrease
Processability	Drawdown
Melt Stability	Impact & Puncture
Edge Tear Tendency	Gloss (Poor Optics)
Haze (Poor Optics)	
Die Swell	

Rheology

- The study of flow is called rheology.
- Different polymers have different rheological properties.
- A rheometer is used to measure rheology.
  - Measures changes in viscosity caused by changes in flow rate.
- So what does it mean to you ?
  - Rheology data can tell you how the polymer will extrude relative to other polymers.
  - Excellent tool for coextrusion (viscosity matching).

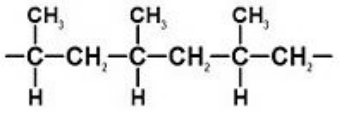
Effect of MWD on Processing



Polyethylene Summary

- LDPE – excellent processing, general purpose resin.
- LLDPE – strength
- HDPE – temp resistance, moisture and grease barrier.
- LDPE produced via high pressure processes and LLDPE & HDPE lower pressure processes.
- PE is characterized by:
  - Melt Index (Mw)
  - Density (crystallinity
  - Rheology (MWD & Branching)
- **When to use PE (LDPE)?...Whenever Possible!**

Polypropylene
Why use PP in E/C?



- Higher Temp Resistance than PE
- Grease Resistance
- Stiffness & Abrasion Resistance
- MVTR Similar to HDPE
- Adhesion to PP Substrates

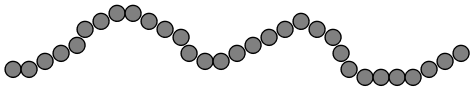
….challenge to process.

Polypropylene

- Three Basic Types of PP
  - Homopolymer
  - Random Copolymer
  - Impact Copolymer
- Little Density Difference
- Properties Dependent on Level of Comonomer

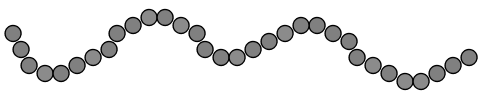
Polypropylene Homopolymer

- **Polypropylene Homopolymer**
  - Produced from propylene only, no comonomer
  - Wide range of MFR (fractional to 120)
  - High stiffness, low elongation
  - High melt temperature, 165° C
  - High heat deflection temperature
  - Lowest impact of the PP types
  - Most commonly used in extrusion coating
  - Melt stabilized for E/C by addition of LDPE or by x-linking.



Polypropylene Random Copolymer

- Random Copolymer
  - Uses ethylene as a comonomer, usually in the 2-5% range
  - MFR range 2-35
  - “Softer” than homopolymer
  - Better impact than homopolymer
  - Lower melt temperature, ~148° C
  - Better seal than a homopolymer



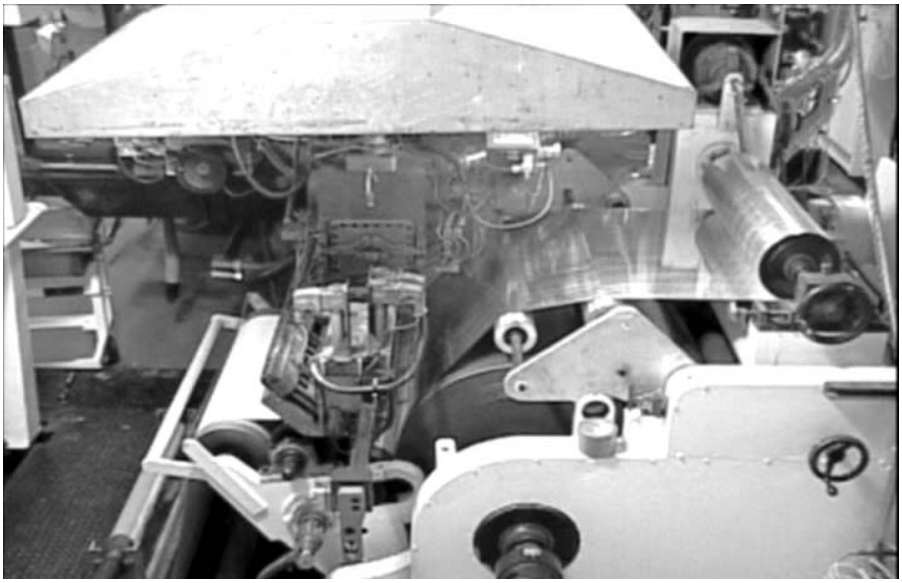
Processing PP in E/C

- More heat in feed zone
- Does not oxidize like LDPE
  - Minimize A.G., **Increase Line Speed**, Die Position Towards Substrate & Hotter Chill Roll
- Mechanical Adhesion – Increase Nip Pressure
- Process cooler (590F) to minimize neck-in and stabilize edges.

PP Summary

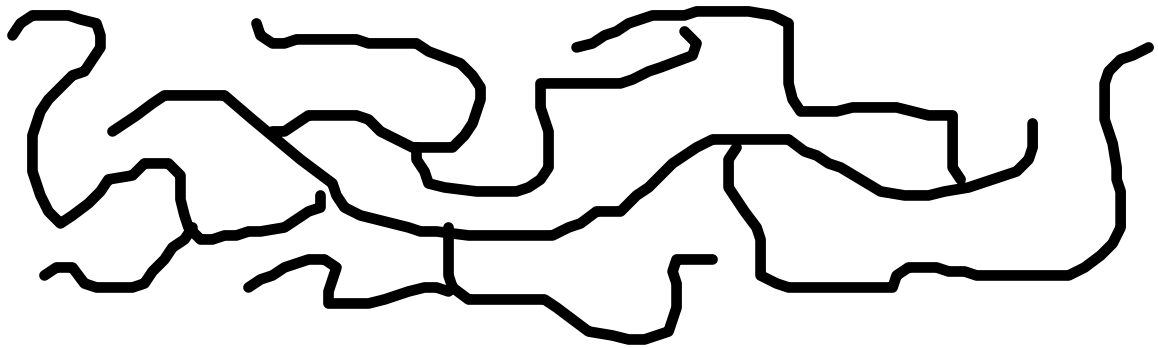
- More heat in feed zone

Thank-You!

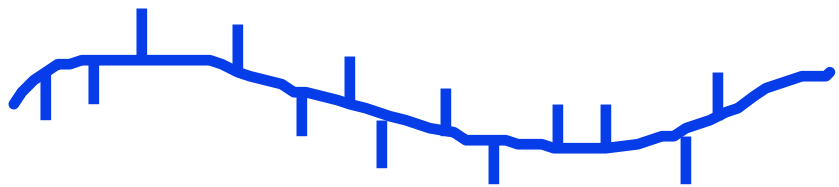


Polyethylene Structures

LDPE



LLDPE



HDPE

Basic Molecular Properties
Resin Type