Enhanced Bimodal PE makes the impossible possible

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Borstar Technology

- Dual reactor, bimodal process
- Broad molecular weight distribution
  - Combines good processability and good mechanical strength
- Tailored comonomer addition
  - Low taste & odour
  - Improved low temperature properties
- Wide range of MFR and densities achievable

### Table

<table>
<thead>
<tr>
<th>Fraction %</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processability, melt strength, swell, orientation development</td>
<td></td>
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<tr>
<td>Taste, Odour, Migration</td>
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<tr>
<td>Smoke,</td>
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<tr>
<td>Lubricant</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Mechanical strength tie molecules</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

1. To be avoided
2. Necessary to bring down processing forces (extrusion) and to protect fraction (4) from being degraded. To avoid melt fracture (poor surface properties). This fraction is, however, mechanically weak and has to be reinforced by (4).
3. Necessary to get high enough tie chain concentrations for toughness and strength.
4. Impact melt strength and modify rheological behaviour of the polymer melt.
What is Different?

Enhanced Bimodal PE  LDPE  LLDPE  m-LLDPE
Bimodal PE Process Technologies

- **Loop - GP solution**
  - *Borstar*
  - whole density range accessible
  - short transition times

- **GP - GP**
  - *Unipol II*
  - *Evolue*
  - *Spherilene*
  - whole density range accessible
  - long transition times

- **Double slurry loop**
  - *Atofina*
  - *Solvay*
  - *Showa Denko*
  - no LLDPE
  - Limited product design possibilities

- **Dual/triple slurry tank**
  - *Hostalen*
  - *Mitsui CX*
  - *Equistar-Maruzen* (Nissan)
  - *JPE* (Nippon)
  - no LLDPE
  - higher costs
  - outdated technology

- **Dual/triple solution**
  - *Dowlex*
  - *Adv. Sclairtech*
  - *Equistar* (= old DuPont)
  - no high MW products
  - higher costs

(Comments: Borealis Licensing)
101 Enhanced Bimodal PE applications

What is impossible?

- It is difficult to make commercial LLDPE film products in existing film production machines, without any major restrictions or modifications. In one moment produce >250 micron film product and in the next make 15 micron film products!
It is possible!

• With the use of Enhanced PE from Borouge

★ FB2230
★ FB2310
Enhanced PE has unique properties that makes it possible

- … to downgauge 20 to 30% or more and still maintain or improve mechanical properties compared with traditional LDPE and LDPE/LLDPE blends.

- … for our customers to improve their profit by simplifying the production, reduce logistic costs and improve production regularity.

- … with Enhanced PE products to produce most film applications with existing production equipment.
What is impossible?

- It is difficult to produce a wide range of high quality films with high clarity and excellent mechanical properties films in conventional blown film lines.
It is possible!

- by use of Enhanced MDPE in the core layer and mLLDPE + LDPE in the skin layers.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (20%)</td>
<td>mLLDPE + LDPE (90:10)</td>
</tr>
<tr>
<td>B (60%)</td>
<td>Enhanced MDPE + mLLDPE (80:20)</td>
</tr>
<tr>
<td>A (20%)</td>
<td>mLLDPE + LDPE (90:10)</td>
</tr>
</tbody>
</table>

*Haze = 6.7%  *Gloss = >100  *Dart drop = 200 g  *MD- tear = 1.6 N  *1% Sec. Modulus = 310 MPa  *Hot-tack = 3.4 N
What is impossible?

• ... to make a FFS shipping sack with balanced properties, like film stiffness, creep resistance, excellent heat sealing, correct friction, high film impact, high fold impact and acceptable tear resistance and to be able meet all requirements by further downgauging.
It is possible!

• With Enhanced MDPE and mLLDPE
Enhanced MDPE + mLLDPE is an excellent concept combination for HDSS

Mono blend:
60% Enhanced MDPE + 40% mLLDPE
Enhanced MDPE + mLLDPE is an excellent combination for HDSS

- Film thickness (120±5my)
- Outside friction (>0.35<0.60)
- Creep70 (<15%)
- Creep23 (<10%)
- Sealing range (>10°C)
- MD-tear (>10N)
- 2-Sigma (<8%)
- Stiffness (>250MPa)
- Film impact (>550g)
- Fold impact (>450g)
- Delta impact (<20%)

Specification vs. Enhanced MDPE + mLLDPE (60:40)
Enhanced MDPE + mLLDPE is an excellent combination for HDSS

ABC/ Coex.
A: mLLDPE
B: 60% Enhanced MDPE + 40% mLLDPE
C: 50% Enhanced MDPE + 50% mLLDPE
Enhanced MDPE + mLLDPE is an excellent concept for HDSS

- Film thickness (120±5my)
- Outside friction (>0.35<0.60)
- Creep70 (<15%)
- Creep23 (<10%)
- Sealing range (>10°C)
- MD-tear (>10N)
- Delta impact (<20%)
- 2-Sigma (<8%)
- Stiffness (>250MPa)
- Film impact (>550g)
- Fold impact (>450g)

Specification: mLLDPE/ Enhanced MDPE+mLLDPE(60:40)/ Enhanced MDPE+mLLDPE(50:50)
What is impossible?

• … to make compression packaging films for insulation materials (rockwool and glasswool) with optimal balance in film stiffness (1% Sec modulus), creep resistance, heat sealing (Hot-tack), impact, puncture and MD- tear resistance!
It is possible!

- With Enhanced Bimodal MDPE/HDPE, mLLDPE and EBA
Enhanced MDPE + mLLDPE and EBA
a unique combination

Coex mLLDPE / Enhanced MDPE / EBA (MI = 0.3, BA = 3%)
Enhanced MDPE + mLLDPE and EBA
a unique combination

Average film thickness (45 +/- 5 my)
Creep Resistance. Creep23
(<8%/ 0.8 kg load, 24 h)
Hot-tack Force (>3 N)
Sealing Range (>20 C)
Film Stiffness TD/ 1% Sec. modulus
(>300 MPa)
TD/ Stress at yield (>25 MPa)
MD/ Tear Resistance (>1.5 N)
Film Impact (>200 g)

Commercial/ spec.  Borealis Solution

*Haze = 6.7%  *Gloss = >100  *Dart drop = 200 g  * MD- tear = 1.6 N  *1% Sec. Modulus = 310 MPa  * Hot-tack = 3.4 N
What is impossible?

- It is difficult to produce moisture barrier Polyethylene film with balanced properties like film stiffness, moisture barrier, heat sealing, film impact, fold impact, MD- tear resistance and friction and to substitute PE/Al – laminates for FFS packaging of moisture sensitive materials.
It is possible!

- This Enhanced PE combination will meet the requirements for moisture barrier < 0.8 g H2O/m², 24h, 38°C, 90% RH.

250 my FFS film
## Enhanced PE as main component in 3 layer coextruded lamination film

<table>
<thead>
<tr>
<th>Substrate</th>
<th>PET / PA / Al / OPP (typically 10 - 15 micron)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Enhanced PE with C6, C8, mPE, LD</td>
</tr>
<tr>
<td>B</td>
<td>Enhanced PE as preferred core layer</td>
</tr>
<tr>
<td>A</td>
<td>Enhanced PE with C6, C8, mPE, LD</td>
</tr>
</tbody>
</table>

- Enhanced PE backbone for strength and stiffness with tailored surface layers to fit requirements
- High clarity and Gloss achievable in coextrusion
- Extrusion of mPE rich films with excellent bubble stability
- Lower seal initiation temperatures & high strength sealing
- Outstanding mechanical properties
- Stiffness (for FFS packaging and stand up pouches)
Enhanced MDPE brings sealing advantages

- All Films in chart (right)
  - Same sealing layer composition of C8/LDPE
  - Variable content of FB2310 in other layers

- With higher % Enhanced MDPE:
  - Broader sealing window
  - Higher hot tack force
  - Seal strength.
  - Faster conversion with no seal breaks
  - Low gel count to avoid seal leakage

- Cost reduction through less usage of expensive sealing materials
  - Enhanced MDPE enhances properties of other thin heat seal layers eg C8, mPE

Due to Enhanced MDPE melt strength – supports sealing layer and avoids deformation

<table>
<thead>
<tr>
<th>Enhanced MDPE total content</th>
<th>0%</th>
<th>17%</th>
<th>30%</th>
<th>57%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot tack strength, N @ 125 deg C</td>
<td>2.5</td>
<td>2.7</td>
<td>3.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Sealing “window” at 2.5 N, °C</td>
<td>118-125</td>
<td>115-130</td>
<td>115-135</td>
<td>110-135</td>
</tr>
</tbody>
</table>
Coextruded Collation Shrink Films

- **Film thickness** = 40 - 45µ

- **Film structure**
  - Outer layer = LDPE (0.8MI)
  - Core layer = Enhanced MDPE
  - Inner layer = LDPE (0.8MI)

  Thickness Ratio = 1:2:1

- **Functional Requirement**
  - Good collation and holding force
  - Good film strength and stiffness

- **Why Enhanced MDPE fits**
  - Good processability
  - Good shrink properties
  - Good film strength and stiffness

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<thead>
<tr>
<th></th>
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<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>LDPE</td>
<td>Enhanced MDPE</td>
<td>LDPE</td>
<td></td>
</tr>
<tr>
<td>25%</td>
<td>50%</td>
<td>25%</td>
<td></td>
</tr>
</tbody>
</table>
Typical Monolayer Shrink Films

Heinz in NZ (with bottom tray)

- **Film structure**: Monolayer 40µm (used to be 55µm)
  - Blend: 60% LDPE (MFR 0.3)
  - 30% Enhanced MDPE
  - 10% HDPE

**Requirements**

- Shrinkage
  - MD 70%
  - TD 10%
- Good Retention / High Cold Shrink Force
- Balance of strength, toughness and stiffness

**Key advantages with Enhanced MDPE**

- Down gauging, better performance with thinner film
- Improved retention / very high cold shrink force
- Low hot shrink force, No hole burning
- Freedom to tailor the shrinkage properties with Enhanced MDPE rich blends
Enhanced PE in lamination: Pet Food Bags

- Enhanced PE Benefits
  - broader sealing range
  - higher film stiffness
  - improved mechanical properties
  - cost saving and gauge reduction without compromising package integrity
  - Stand up performance
  - Runnability on FFS machine

- Enhanced MDPE used in core layer to improve film stiffness and mechanical properties

- Typically the core layer represents 40-60% of the total film thickness

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<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>mPE</td>
<td>Enhanced MDPE</td>
<td>Enhanced LLDPE</td>
</tr>
<tr>
<td>LDPE</td>
<td>mPE</td>
<td>85/15%</td>
</tr>
<tr>
<td>60/40%</td>
<td></td>
<td>85/15%</td>
</tr>
</tbody>
</table>
Enhanced PE in lamination: Large size detergent bags

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced LLDPE</td>
<td>Enhanced MDPE</td>
<td>Enhanced LLDPE</td>
</tr>
<tr>
<td>mPE</td>
<td>mPE</td>
<td>75/25%</td>
</tr>
<tr>
<td>75/25%</td>
<td>75/25%</td>
<td></td>
</tr>
</tbody>
</table>

- Increased stiffness => Rigidity and handling
- High ESCR => Shelf life and no breakage
- Toughness/seal strength => Less product spoilage
- Matt surface => Ease of conversion and filling
- Low migration and additive level => Low taste and odour => Compliance to food packaging
- Runnability FFS machine
- Drop test
Enhanced PE in lamination: Wheat Flour Packaging (10kg)

- **Film Structure:** PE/PET (100µ / 12µ)

- **PE Film Structure**
  - Outer layer = C8LLDPE + LDPE (90:10)
  - Core layer = Enhanced LLDPE
  - Inner layer = mLLDPE + LDPE (90:10)
  - Thickness Ratio = 1:1:1

- **Requirement**
  - Good impact strength
  - Excellent seal strength
  - High clarity

- **Other similar applications**
  - Packaging of rice
  - White cement
Enhanced PE in lamination: Salt Packaging (1kg)

- Film Structure: PE/PET (39µ / 10µ )
- PE Film Structure
  - Outer layer = mLLDPE + LDPE (85:15)
  - Core layer = Enhanced LLDPE
  - Inner layer = mLLDPE + LDPE (85:15)
  - Thickness Ratio = 1:1:1
- Requirement
  - Excellent seal strength
  - High clarity
- Other similar applications
  - Packaging of detergent powder