Presentation Agenda

1. What is Bimodal Polyethylene?
2. The cases of Pipe, Blow Moulding & Film segments
3. Sibur Solutions
Frederic ALARCON
Biography

30 years of experience in the polymers industry

Working with majors in international context
BP Chemicals, INEOS, Innovene, Sibur

Range of management roles
Project Mg, Product Mg, R&D, Customer relationships, Technology Licensing, Contract negotiations
Product Segmentation
MI - Density coverage

Annealed density (kg/m³)
MI 2.16 (g/10 min)
Bimodal Polyethylene European Demand 2022

Source: AMI Consulting Report Sibur LLC, June 2019
Bimodal HDPE

- Reduced impact strength, fumes
- Processability, stiffness
- Matrix
- ESCR and creep resistance
  - Mechanical strength
  - Melt strength during extrusion

Molecular weight (= polymer chain length)

- Bubble stability
  - No sagging
Hexene-1

Innovene S State of the Art Technology

Hexene-1 bimodal configuration

Molecular weight (= polymer chain length)

Homopolymer

Copolymer

Reduced impact strength, fumes

Processability, stiffness

Matrix, no contribution

ESCR and creep resistance

Mechanical strength

Melt strength during extrusion

Matrix, no contribution

Homopolymer

Copolymer

Molecular weight (= polymer chain length)

1

2

1

2

bimodal configuration
Key Features for Bimodal resins

1. Advanced quality resins
2. Downgauging potential
3. Sustainable product solution

Film
- Monomodal
- Bimodal

Pipe
- Monomodal
- Bimodal

Blow moulding
- Monomodal
- Bimodal
Blow Moulding case
Blow Moulding offer

Food packaging/Small blow molding

Large blow molding

Commodity

- Fresh milk
- Detergent
- Cosmetic

- Small containers
- Large containers
- IBC
- Car Fuel tank
- Drums

Molecular weight (HLMI, g/10 min)

90 60 30 10 6 4 2
Bimodal Blow Moulding

The way to light weighting but …

die swell is much lower
Innovene™ S = superior bimodal HDPE

Bimodal the best balance between Rigidity & Environmental Stress

Cracking Resistance

<table>
<thead>
<tr>
<th>ESCR</th>
<th>Reference Chromium monomodal</th>
<th>Competitor 1</th>
<th>Competitor 2</th>
<th>Sibur HD03580 SB</th>
</tr>
</thead>
<tbody>
<tr>
<td>(F50 BTT 50°C, 100 %, ASTM D1693)</td>
<td>22 h</td>
<td>51 h</td>
<td>87 h</td>
<td>250 h</td>
</tr>
</tbody>
</table>

954-955 kg/m³

958-960 kg/m³

Bimodal products

Blow moulding

Monomodal

Bimodal
Sibur HD 03580 SB
Best in class bimodal
Small Blow Moulding Resin
HD Film Case
Sibur
HD 80520 FE
HMW
bimodal film
benchmarking

Extrudability
Bubble stability

Dart Impact
MD Tear
TD Tear

- Sibur HD 80520 FE
- Competitor 1
- Competitor 2
- Competitor 3
Pipe Segment
Pipe applications: The key features

- Fast growing market particularly in Far East
- Highly technical segment, product & conversion
- Compliance with International Standards
PE100 should be a compound

All ISO & EN standards for drinking water and gas transport (ISO 4427, ISO 4437, EN12201 and EN1555) specify the use of pigmented compounds (= ready to use compounds)

ISO definition for compound

homogeneous extruded mixture of base polymer (PE) and additives, i.e. antioxidants, pigments, UV-stabilizers and others, at a dosage level necessary for the processing and use of components conforming to the requirements of this International Standard
Black Compounds / Pipes Production

- Ziegler Catalyst HDPE (PE100)
- HDPE natural
- HDPE black
Trends in pressure pipes market

- PE63
- PE80
- PE100
- PE100RC (Low Sag PE100, 2.5 m)

Performance level:
- 1970
- 1980
- 1990
- 2000
- 2010
- 2015
Standard Hydrostatic Pressure test PE 80 / PE 100

\[ \sigma \text{ Burst stress Mpa} = \sigma_c \]

- **20°C PE100**: 10 MPa at 50 Ys
- **80°C PE100**: 8 MPa at 50 Ys
- **PE80**: 80°C

**HDPE Type 2**

Time to failure in 50 years:

- **10^{-1}**
- **1**
- **10**
- **10^2**
- **10^3**
- **10^4**
- **10^5**
- **10^6 h**
- **50 years**
PE100 benchmarking

ESCR requirement

PE100

PE100RC

Innovene S PE100
PE100RC

Resistant to Crack PE100 designed for alternative installation techniques

PE100
Requires sand bed protection

PE100RC
Sandless Laying

Sand protection might represent up to 50% of the total cost!
SIBUR production capability
State of the Art production technologies

5 polyolefin plants
(PP, LDPE, LLDPE, HDPE)

1480 kTa
total PP capacity

1770 kTa
total PE capacity

30 grades
portfolio

ZAPSIB — AMONG WORLD’S LARGEST POLYOLEFIN COMPLEXES**

**IHS
PolyLab — Sibur’s Application R&D Center

**Location**
on the territory of Skolkovo Innovation Center

**Building area**
5350 m²

**Instrument base**
processing lines, test equipment

**PADC mission**
- Development of new grades
- Technical support, promotion of developed grades
- Quality improvement of manufactured grades
- Complaint management

**Processing machinery**
- Injection molding lines (35, 60, 160 t)
- Blow Molding line
- Pipe Extrusion line
- Cast and Blown Film lines
- Thermoforming line
- Compound extruder line

**Laboratory equipment**

**General Testing Methods**
- Physicochemical material properties
- Physical, Optical material properties

**Product Testing**
- Injection Molding
- Pipes
- Films & Fibers
- Extrusion & Blow Molding
## HIGH-DENSITY POLYETHYLENE for Film Applications

<table>
<thead>
<tr>
<th>Grade</th>
<th>Density g/cm³</th>
<th>MFI g/10 min (21.6 kg)</th>
<th>Key features</th>
<th>Recommended applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD 10500 FE</td>
<td>0.950</td>
<td>10</td>
<td>Broad molecular-weight distribution</td>
<td>Pouches, bags, pre-packaging and industrial packaging</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High melt strength</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High tensile, puncture and tear strength of the film</td>
<td></td>
</tr>
<tr>
<td>HD 80520 FE</td>
<td>0.952</td>
<td>8</td>
<td>Bimodal grade</td>
<td>Films for lamination, shrink wraps and pouches</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Improved organoleptic properties</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Improved processability</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High stability of tubular sheeting</td>
<td></td>
</tr>
</tbody>
</table>

## HIGH-DENSITY POLYETHYLENE MMW for Blow Moulding Applications

<table>
<thead>
<tr>
<th>Grade</th>
<th>Density, g/cm³</th>
<th>MFI g/10 min</th>
<th>Load kg</th>
<th>ESCR hours</th>
<th>Key features</th>
<th>Recommended applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD 02550 SB</td>
<td>0.955</td>
<td>0.2</td>
<td>2.16</td>
<td>50*</td>
<td>HDPE grade with average molecular weight, having an optimal balance of properties for manufacturing a wide range of blown products</td>
<td>Bottles and containers up to 30 liters for storage and transportation of household detergents, oil and liquid foods</td>
</tr>
<tr>
<td>HD 03580 SB</td>
<td>0.958</td>
<td>0.3</td>
<td>2.16</td>
<td>250**</td>
<td>HDPE bimodal grade with excellent crack resistance and high resistance to aggressive media</td>
<td>Bottles and containers up to 30 liters for storage and transportation of household detergents, perfumery and cosmetics</td>
</tr>
</tbody>
</table>
# HIGH-DENSITY POLYETHYLENE HMW for Blow Moulding Applications

<table>
<thead>
<tr>
<th>Grade</th>
<th>Density g/cm³</th>
<th>MFI g/10 min (21.6 kg)</th>
<th>Load, kg</th>
<th>ESCR hours</th>
<th>Key features</th>
<th>Recommended applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD 10530 LB</td>
<td>0.953</td>
<td>10</td>
<td>21.6</td>
<td>&gt;1,000*</td>
<td>HDPE grade with high molecular weight, high ESCR and high impact strength</td>
<td>Mid-size and large-size containers with capacity from 1 to 60 liters for storage and transportation of aggressive media</td>
</tr>
<tr>
<td>HD 19550 LB</td>
<td>0.955</td>
<td>1.9</td>
<td>21.6</td>
<td>&gt;100**</td>
<td>HDPE grade with high molecular weight</td>
<td>Large-size containers (210-227 l drums) for storage and transportation of aggressive media</td>
</tr>
<tr>
<td>HD 60502 LB</td>
<td>0.950</td>
<td>6</td>
<td>21.6</td>
<td>&gt;1,000*</td>
<td>HDPE grade with high molecular weight and UV stabilization</td>
<td>IBC containers with capacity up to 5,000 liters</td>
</tr>
</tbody>
</table>

* BTT (Bell telephone test) stress crack resistance, 100% Igepal 50°C, ASTM 1693
** BTT (Bell telephone test) stress crack resistance, 10% Igepal 50°C, ASTM 1693
PE HD03580 SB

PE HD03580 SB – is a high density polyethylene with hexene copolymer and bimodal structure providing an outstanding balance of environmental stress crack resistance (ESCR) and stiffness, high rigidity, easy processing and high impact strength. This grade usually allows significant down gauging and is particularly well suited for chemical and detergent market, where a good environmental ESCR is required.

### BASIC CHARACTERISTICS

- **Density, 23 °C, g/cm³**
- **ESCR, F50, 100%, h**
- **Izod impact strength, 23°C, kJ/m²**
- **MFR, 2,16 kg, g/10min**
- **MFR, 5 kg, g/10min**

### CHARACTERISTICS OF FINISHED PRODUCTS (BOTTLE 1L)

- **Drop-test, 6m, -40 C,** ％
- **Top-load, N**
- **Die swell, 2,16 kg,** ％

### BIMODAL VS UNIMODAL

- **Increased environmental stress cracking resistance (more than 700 hours)**
- **Finished products lightweighting**
- **Bimodal structure**
- **Die swell**
- **Lower melt flow rate at 5 kg**

- Suitable for packaging chemicals, household goods, oil, cosmetics and pharmaceuticals
- Cost savings in the production of finished products without loss of performance
- Advanced processability for different volumes and complex design finished products
- Easy transition from unimodal product without forming tool adjustment (die, mandrel)
- Improved mechanical properties compared to competitive grades
# HIGH-DENSITY POLYETHYLENE for Pipe Applications

<table>
<thead>
<tr>
<th>Grade</th>
<th>Density, g/cm³</th>
<th>MFI g/10 min (5 kg)</th>
<th>Key features</th>
<th>Recommended applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD 03594 PE</td>
<td>0.959</td>
<td>0.3</td>
<td>PE100+ carbon black pipe grade Bimodal grade Low level of volatile components</td>
<td>Pipes for pressure gas and potable water supply</td>
</tr>
<tr>
<td>HD 02604 PE</td>
<td>0.960</td>
<td>0.24</td>
<td>PE100+ carbon black pipe grade Bimodal grade Low sagging</td>
<td>Large diameter pressure pipes</td>
</tr>
<tr>
<td>HD 03594 RC</td>
<td>0.959</td>
<td>0.29</td>
<td>PE100RC carbon black pipe grade Bimodal grade Low level of volatile components Enhanced crack resistance;</td>
<td>Gas and water supply, alternative (trenchless) installation methods, multilayer pipes</td>
</tr>
<tr>
<td>HD 03490 NP (PE)</td>
<td>0.950</td>
<td>0.30</td>
<td>Natural colour bimodal grade produced with PE 100+ technology</td>
<td>Free-Flow pipes for drainage, cable jackets, outer cover, heat pipe</td>
</tr>
</tbody>
</table>
**HD 03490 NP (PE)**

HD 03490 NP (PE) – is a high density 1-hexene copolymer with a bimodal molecular weight distribution providing excellent processability and superior mechanical properties. The grade combines high stiffness and long-term strength with outstanding creep resistance. It is produced by the same technology as PE100.

### COMPARISON OF BASIC CHARACTERISTICS

<table>
<thead>
<tr>
<th>Property</th>
<th>HD 03490 NP (PE) SIBUR</th>
<th>SIBUR</th>
<th>Inpipe 100 Kyyanly</th>
<th>Borealis HE3490-LS-H (RC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, g/cm³</td>
<td>80,55</td>
<td>71,76</td>
<td>73,49</td>
<td></td>
</tr>
<tr>
<td>Melting temperature, °C</td>
<td>202</td>
<td>202</td>
<td>207</td>
<td>206</td>
</tr>
<tr>
<td>MFR ratio under load</td>
<td>202</td>
<td>202</td>
<td>207</td>
<td>206</td>
</tr>
<tr>
<td>OIT, min</td>
<td>21,6 / 5 kg</td>
<td>21,7</td>
<td>22,1</td>
<td>22,2</td>
</tr>
<tr>
<td>Elongation at break, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Key benefits:**
- A bimodal product made using technology similar to the PE100 class
- Resistance to crack propagation, high performance of the final product
- Processing at the same level as for similar grades
- Long term hydrostatic strength (MRS)
- New product, not yet MRS certified. Samples have been sent to a certification laboratory
- Strain hardening

### COMPARISON OF PIPE CHARACTERISTICS

<table>
<thead>
<tr>
<th>Property</th>
<th>HD 03490 NP (PE) SIBUR</th>
<th>SIBUR</th>
<th>Inpipe 100 Kyyanly</th>
<th>Borealis HE3490-LS-H (RC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Stress, MPa</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation at break, %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure resistant, h</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slow crack propagation, h</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rapid crack propagation,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bar</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Requirements of standards</th>
<th>Inpipe 100 Kyyanly</th>
<th>SNOLEN EP 0.26/51 N</th>
<th>HD 03490 NP SIBUR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melt T</td>
<td>207</td>
<td>206</td>
<td>202</td>
</tr>
<tr>
<td>Rotation</td>
<td>228,7</td>
<td>213,2</td>
<td>202,6</td>
</tr>
<tr>
<td>Melt P</td>
<td>261</td>
<td>214</td>
<td>214</td>
</tr>
<tr>
<td>Load</td>
<td>76</td>
<td>77</td>
<td>80</td>
</tr>
<tr>
<td>SEI</td>
<td>0,222</td>
<td>0,208</td>
<td>0,208</td>
</tr>
</tbody>
</table>

The pipes were produced with diameters of 32 and 110 mm, SDR11. Line productivity up to 110 kg / h. We recommend the implementation of the HD 03490 NP (PE) grade without restrictions for the production of free-flow pipes and elements of domestic drinking water supply systems. All released lots meet the specification and are recommended for shipment to the Russian Federation, China, Europe, Turkey. In terms of key quality parameters and processing technology, the material corresponds to benchmarks. Key benefits:
- The client does not have to reconfigure the equipment modes when switching to SIBUR materials.
PolyLab is equipped to simulate key polyolefin processing technologies

- **Rigid packaging**
  - Production by:
    - Injection molding
    - Extrusion blow molding
    - Thermoforming

- **Films**
  - Film production by:
    - Biaxial orientation
    - Blown film
    - Cast extrusion

- **Pipes and fibers**
  - Pipe and fiber production:
    - Pipe extrusion
    - Multifilament yarn production

- **Compounds**
  - Compound and premix production
    - Pilot batches for testing at the customer’s site
    - Lab batches for processing segments
    - Model compound testing

- Polyolefin consumption in Russia (2018): **3.3 Mt**
PolyLab equipment

Blown film line
POLYREMA Reifenhäuser

- Output up to 300 kg/h
- Film width: до 1300 mm
- Film thickness: 25 – 200 µm
- Quantity of extruders: 3
- Layers: 3
- Main processing materials: LDPE, LLDPE, HDPE, copolymers

Blow moulding line
Kautex KEB 10

- Bottle 1L. Main processing materials: PP/HDPE
- Weight 54 g, Cycle time 15 s
- Jerrycan 10L. Main processing materials: HDPE
- Weight: 380 g, Cycle time: 33 s

Pipe extrusion line
KraussMaffei

- HDPE, PP-R, PP-B pipes Ø 32 &110 mm, SDR 11 / 17,6 / 33
- Output 100 kg/h
PolyLab has a large testing capacity

About 100 units of testing equipment for material and final articles analysis

R&D base development (SIBUR): focused on final articles analysis – customer relevance

Complex material assessment:

Basic tests
Basic physical and mechanical testing of polymer pellets

Analytical tests
Polymer chemical composition and structure study

Final articles testing
Final articles application testing
PolyLab testing laboratory

Analytical tests
- GPC, HPLC, GC
- DCS, DMA, TG
- FT-IR
- Optical & Electron Microscopy

Application tests
- Top load
- Drop test
- MRS
- FNCT, ESCR
- Barrier properties
- Sealing properties
- Dart drop testing
- Impact resistance, tear resistance

Basic tests
- Mechanical testing
- Optical testing
- Rheological testing
- Thermal testing
SIBUR develops recycling projects within the corporate Sustainable Development Strategy 2025

Our mission: Change ourselves and change the world for the better

Our values
We become better every day
Solid team
Mutual respect
Safety without compromise
Partnership
Smart result

SIBUR sustainable development strategy 2025

- Responsible business
- Protection of environment
- Society and partnership
- Sustainable product portfolio
- Lower climate effect

Our input in global agenda
Sustainability International Initiatives

SIBUR participating

- United Nations Global Compact
- Responsible Care®
- PlasticsEurope
- cefic
- CEFLEX
- Operation Clean Sweep®

SIBUR considering

- Alliance to End Plastic Waste
- The Ocean Cleanup
- Ellen MacArthur Foundation
- Minderod Foundation
THANK YOU