Fibremod™

Fibre reinforced polypropylene for light, integrated, high performing solutions
Building on Borealis’ unique Borstar® technology and their experience in polyolefins of more than 50 years, Borealis and Borouge provide innovative, value creating plastics solutions for the infrastructure - pipe systems and power and communication cables - automotive and advanced packaging industries. In addition, Borealis offers a wide range of base chemicals from melamine and plant nutrients to phenol and acetone.

Borealis and Borouge are leading providers of chemical and innovative plastics solutions that create value for society. With sales of EUR 7.5 billion in 2012, customers in over 120 countries, and 5,300 employees worldwide, Borealis is owned 64% by the International Investment Company (IPIC) of Abu Dhabi and 36% by OMV, the leading energy group in the European growth belt. Borealis is headquartered in Vienna, Austria, and has production locations, innovation centres and customer service centres across Europe and
the Americas. Through Borouge, a joint venture between Borealis and the Abu Dhabi National Oil Company (ADNOC), one of the world’s major oil and gas companies, the company’s footprint reaches out of the Middle East to Asia Pacific, the Indian sub-continent and Africa, where it is also Borealis’ exclusive distributor. Established in 1998, Borouge employs approximately 1,600 people, has customers in more than 50 countries and headquarters in Abu Dhabi, UAE and Singapore.

Currently Borealis and Borouge have a manufacturing capacity of more than 5.4 million tonnes of polyolefins (polyethylene and polypropylene) per year. An additional 2.5 million tonnes is scheduled to come on-stream by the end of 2013, creating the world’s largest integrated polyolefins plant. Both companies continue to invest to ensure that their customers throughout the value chain, around the world, can always rely on superior products and security of supply.
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Glass fibre reinforcement of polypropylene

PP-SGF (short glass fibre reinforced polypropylene)

PP-SGF is commonly used in a wide range of automotive and appliance applications. Produced as compounds on co-rotating twin screw extruders, the combination of specially sized short glass fibres, the PP matrix and the chemical coupling define the final material properties. They are usually converted to parts using various injection moulding technologies, including complex processes such as injection compression moulding or injection foam moulding.

The Borealis portfolio covers a wide range of products from 10% to 40% filled standard glass fibre grades to tailor-made special products with optimised polymer matrix, glass fibre or glass fibre/filler mixture contents and stabilisation for very demanding applications. Borealis has many years of experience in developing the balanced recipes to meet customer demands, to use the best production technology for optimal product performance and to support customers in material conversion.

PP-LGF (long glass fibre reinforced polypropylene)

PP-LGF is a group of glass fibre reinforced products which are produced by pultrusion to achieve increased fibre length in both pellets and final parts. The glass fibres are typically arranged parallel in the pellets, all having the same length as the pellet itself.

Borealis has 20 years’ experience in developing and producing this type of polypropylene material and has developed its own proprietary processing technology for production. This technology leads to high quality products in terms of fibre impregnation and a broad range of fibre and matrix combinations for tailor-made solutions. The product portfolio covers glass fibre contents from 20% to 60%, with grades customised to provide for the highest stiffness and strength at elevated temperatures, with outstanding energy absorption in high speed deformation. Typically PP-LGF grades have excellent flowability for smooth processing and uniform shrinkage behaviour.

PP-LGF pultrusion pellet injection moulding process

A PP-LGF pellets
B single screw extruder
C special LGF screw
D optimised runner system
E injection moulding tool
As a progressive step to clarify product type identification, simplify comparison and focus selection, Borealis and Borouge have brought together their fibre reinforced polypropylene (PP) material grades and consolidated them under a single family name, Fibremod™, and unified nomenclature. Principally, though not exclusively, Fibremod glass fibre reinforced materials are designed for the higher performance demands of automotive and appliance applications. They provide the complete spectrum of mechanical and chemical resistant property combinations to offer the widest range of solution possibilities that can deliver time and cost savings through greater processing efficiency, parts integration and end-use performance, as well as reductions in part application weight and energy and material consumption.

Global availability

PP-SGF is produced at Borealis and Borouge plants in Monza (Italy), Beringen (Belgium), Itatiba (Brazil), Shanghai (China), and in North America via toll compounding. PP-LGF is produced in Monza, as well as via toll compounding.

Fibremod consolidated strengths

Fibremod global nomenclature

<table>
<thead>
<tr>
<th>Pos. 1</th>
<th>Pos. 2</th>
<th>Pos. 3</th>
<th>Pos. 4-5</th>
<th>Pos. 6-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymer type</td>
<td>MFR range</td>
<td>Filler content</td>
<td>Numerical index</td>
<td>Application index</td>
</tr>
<tr>
<td>H - Homopolymer</td>
<td>B: &gt; 0.8 - 2.5</td>
<td>0: 0 - 9%</td>
<td>U: Under the bonnet</td>
<td></td>
</tr>
<tr>
<td>G - Glass fibre</td>
<td>C: &gt; 2.5 - 5</td>
<td>1: 10 - 19%</td>
<td>AI: Automotive interior</td>
<td></td>
</tr>
<tr>
<td>H - Homopolymer</td>
<td>D: &gt; 5 - 10</td>
<td>2: 19 - 29%</td>
<td>AE: Automotive exterior</td>
<td></td>
</tr>
<tr>
<td>B - Block copolymer</td>
<td>E: &gt; 10 - 15</td>
<td>3: 30 - 39%</td>
<td>HP: High performance</td>
<td></td>
</tr>
<tr>
<td>M - Mineral filled</td>
<td>F: &gt; 15 - 20</td>
<td>4: 40 - 49%</td>
<td>WG: White goods</td>
<td></td>
</tr>
<tr>
<td>E - Elastomer modified</td>
<td>G: &gt; 20 - 30</td>
<td></td>
<td>SF: Short fibre</td>
<td></td>
</tr>
<tr>
<td>W - other or combinations</td>
<td></td>
<td></td>
<td>LF: Long fibre</td>
<td></td>
</tr>
</tbody>
</table>
Overview glass fibre reinforced portfolio

Short or long glass fibre?
At-a-glance selection of advantages and benefits

- **Short glass fibre**
  - Flexibility in production (multiple location - global availability)
  - Flexibility in base polymers – wider variety of performance
  - Wide conversion window
  - Less sensitive to welding lines (greater design freedom)
  - Good surface properties
  - Good organoleptic properties (such as smell)

- **Long glass fibre**
  - Borealis proprietary technology leading to high fibre impregnation
  - Outstanding energy absorption
  - High strength
  - Ideal for applications requiring: enhanced impact, temperature and fatigue resistance, while maintaining a high stiffness.
  - Low shrinkage
  - Low shrinkage anisotropy (warpage)
Standard fibre reinforced grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Fibre type</th>
<th>Density (kg/m³)</th>
<th>MFR 230°C/2.16kg (g/10min)</th>
<th>Tensile modulus 23°C (MPa) &amp; Charpy notched 23°C (kJ/m²)</th>
<th>Typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibremod GB205U</td>
<td>SGF</td>
<td>1,040</td>
<td>2</td>
<td>4,800 / 11</td>
<td>Has long-term heat resistance making it ideal for engine covers, fans and shrouds but also bumper brackets. UL listed</td>
</tr>
<tr>
<td>Fibremod GE277AI</td>
<td>SGF</td>
<td>1,040</td>
<td>12</td>
<td>4,900 / 11</td>
<td>This grade is ideal for foaming with high flowability therefore optimal for instrument panel carriers and other thin-wall structural parts</td>
</tr>
<tr>
<td>Fibremod GB311U</td>
<td>SGF</td>
<td>1,130</td>
<td>2</td>
<td>6,800 / 11</td>
<td>This grade has excellent dimensional stability making it the grade of choice for air filter housings, lamp housings as well as appliance applications</td>
</tr>
<tr>
<td>Fibremod GD310U</td>
<td>SGF</td>
<td>1,120</td>
<td>7</td>
<td>7,200 / 10</td>
<td>A high flow material ideal for under-the-bonnet applications needing high heat resistance</td>
</tr>
<tr>
<td>Fibremod GB364WG</td>
<td>SGF</td>
<td>1,120</td>
<td>2</td>
<td>6,900 / 12</td>
<td>This grade is ideal for tubes, basements and housings for the appliance business and is approved for food contact</td>
</tr>
<tr>
<td>Fibremod GB366WG</td>
<td>SGF</td>
<td>1,120</td>
<td>2</td>
<td>6,900 / 12</td>
<td>This grade is UL approved to UL94 and UL 746B and ideal for applications like detergent containers and pump housings in washing machines and other white goods</td>
</tr>
<tr>
<td>Fibremod GF368WG</td>
<td>SGF</td>
<td>1,120</td>
<td>20</td>
<td>7,000 / 10</td>
<td>Is a glass fibre reinforced PP compound with excellent detergent resistance and high flowability</td>
</tr>
</tbody>
</table>

Success story: Appliances

Delivering long-term performance with excellent impact resistance

**Fibremod GB366WG** is a 30% chemically coupled short glass fibre reinforced PP compound that offers enhanced performance in tough in-service application components. It was developed especially for applications in the appliances industry.

**Typical applications**
- High stress parts such as tubs in washing machines
- Functional parts including pumps and basements
- Housings

**Key advantages**
- Ideal for replacing stainless steel and polyamide (PA) parts with lower density therefore offering significant weight reductions
- Improved flexibility of design, assembly and welding compared to stainless steel, leading to fewer manufacturing steps
- Long-term performance with excellent stiffness and impact resistance, together with absence of corrosion
- Includes specifically designed detergent stabilisation
- Has excellent processability and offers a significant increase in productivity and energy savings
- Reduction of water consumption versus steel and offers easier recycling
- Benefits throughout the value chain, with long-term durability, no discolouration and UL approved also UL 2157
- No moisture absorption
# High stiffness fibre reinforced grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Fibre type</th>
<th>Density (kg/m³)</th>
<th>MFR 230°C/2.16kg (g/10min)</th>
<th>Tensile modulus 23°C (MPa) &amp; Charpy notched 23°C (kJ/m²)</th>
<th>Typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibremod GD301FE</td>
<td>SGF</td>
<td>1.140</td>
<td>4</td>
<td>7,500 / 12</td>
<td>This grade has excellent balanced mechanical performance making it the material of choice for a wide range of applications from pedal carriers to lower bumper stiffeners</td>
</tr>
<tr>
<td>Fibremod GB306SAF</td>
<td>SGF</td>
<td>1.180</td>
<td>2</td>
<td>9,000 / 11</td>
<td>This grade has a special stabilisation package for long-term high heat stabilisation making it ideal for under-the-bonnet applications like air intake manifolds</td>
</tr>
<tr>
<td>Fibremod GB307HP</td>
<td>SGF</td>
<td>1.180</td>
<td>2</td>
<td>9,000 / 11</td>
<td>Has long-term heat resistance making it ideal for engine covers, fans and shrouds, e-boxes and air intake manifolds</td>
</tr>
<tr>
<td>Fibremod GB477HP</td>
<td>SGF</td>
<td>1.230</td>
<td>2.7</td>
<td>10,000 / 12</td>
<td>With its excellent stiffness this material can be used for various structural parts like front-end carriers, gear housings and pedal carriers</td>
</tr>
<tr>
<td>Fibremod GB303HP</td>
<td>LGF</td>
<td>1.120</td>
<td>2</td>
<td>7,400 / 23</td>
<td>Due to its excellent combination of properties this material can be used for components exposed to high heat and loads</td>
</tr>
<tr>
<td>Fibremod GB402HP</td>
<td>LGF</td>
<td>1.240</td>
<td>2</td>
<td>9,000 / 28</td>
<td>Excellent mechanical properties even at high temperature and therefore a good solution for front-end carriers</td>
</tr>
</tbody>
</table>

## Success story:

### VW Air Intake Manifold

#### Challenges
- Long-term high temperature and chemical resistance
- Vibration resistance combined with high fatigue performance
- Operating temperature cycles between -40°C and 120°C, with a peak temperature of 140°C

#### Solution
**Fibremod GB306SAF**, a 35% short glass fibre reinforced high performance PP compound (patented composition)

#### Benefits
- Technical alternative to polyamide at lower system costs
- 15% weight saving
- Better dimensional stability
- Significantly improved acoustic behaviour – 5dB sound damping 1-5 KHz
- Lower production costs
- Material performance not dependent on humidity

## Success story:

### Renault X91 Laguna Front-end Module

#### Challenges
- Replace LGF PP compound
- Optimise stiffness/impact balance
- Easy processing
- Low creep

#### Solution
**Fibremod GB477HP**, a 40% short glass fibre reinforced PP compound

#### Benefits
- Ready-to-use grade
- Utilisation of existing tool
- Good dimensional stability
- Improved system cost efficiency
Success story: GM and Fiat group pedal carrier

**Challenges**
- Replacement of polyamide
- Material with good toughness performance, narrow tolerance and gap, good creep behaviour and high stiffness up to 80°C
- High crash and safety requirements

**Solution**
Fibremod GD301FE, 30% short glass fibre reinforced PP compound.

**Benefits**
- Min. 15% weight reduction
- 10% lower system costs
- Improved processing
- No pre-drying, no conditioning necessary
- Mouldable using existing polyamide tools

High impact fibre reinforced grades

<table>
<thead>
<tr>
<th>Grade</th>
<th>Fibre type</th>
<th>Density (kg/m³)</th>
<th>MFR 230°C/2.16kg (g/10min)</th>
<th>Tensile modulus 23°C (MPa) &amp; Charpy notched 23°C (kJ/m²)</th>
<th>Typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibremod GB215HP</td>
<td>LGF</td>
<td>1,040</td>
<td>2</td>
<td>5,300 / 19</td>
<td>This material is ideal for foamed applications like instrument panel carriers</td>
</tr>
<tr>
<td>Fibremod GD302HP</td>
<td>SGF</td>
<td>1,160</td>
<td>3.3</td>
<td>5,600 / 24</td>
<td>The excellent impact performance of this grade gives it an ideal fit for applications like seat structures</td>
</tr>
<tr>
<td>Fibremod GB402HP</td>
<td>LGF</td>
<td>1,240</td>
<td>2</td>
<td>9,000 / 28</td>
<td>Excellent mechanical properties even at high temperature and therefore a good solution for front-end carriers, dashboard carriers and other structural parts</td>
</tr>
<tr>
<td>Fibremod GB601HP</td>
<td>LGF</td>
<td>1,470</td>
<td>Depending on dilution</td>
<td>Undiluted: 15,000 / 24</td>
<td>This material is ideal for the dilution process. The customer has the option of adjusting the fibre content to the requirement of the end product. Undiluted GB601HP has excellent stiffness and impact behaviour with good surface quality</td>
</tr>
</tbody>
</table>

Success story: BMW Rear Seat Carrier

**Challenges**
- Replacement of a hybrid steel-PUR concept
- Reduce system costs
- Short development time

**Solution**
Fibremod GD302HP, a 30% short glass fibre reinforced PP compound.

**Benefits**
- 35% weight saving
- Excellent impact behaviour
- Low warpage and high dimensional stability
- Close co-operation with Borealis’ technical and CAED team
- Contribution to cost effectiveness
Special performance grade

Reinforcing polypropylene with a combination of glass fibre and mineral filler, results in material with low warpage behaviour and good surface quality.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Fibre type</th>
<th>Density (kg/m³)</th>
<th>MFR 230°C/2.16kg (g/10min)</th>
<th>Tensile modulus 23°C (MPa) &amp; Charpy notched 23°C (kJ/m²)</th>
<th>Typical applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibremod WE380HP</td>
<td>20% GF / 10% Mineral</td>
<td>1.130</td>
<td>13</td>
<td>4,950 / 16</td>
<td>This grade has very good flowability, high heat resistance, with good surface aesthetics making it the material of choice for applications ranging from engine covers to structural carriers</td>
</tr>
</tbody>
</table>

Dilution concepts for long glass fibre grades

As an alternative to ready-to-use LGF materials, Borealis also offers a highly filled PP-LGF grade (Fibremod GB601HP) that can be diluted with pure unreinforced Borealis polypropylene grades directly on the conversion machine, which enables greater flexibility in the material's performance.

Using the correct mixture of grades very special performance can be achieved and the glass fibre content can be easily adjusted by the converter to the individual application’s requirements. This technology can help to reduce product complexity at the customer’s when producing a number of different applications. Because part of the responsibility for the material is shifted to the converter, close co-operation with Borealis is recommended during application development and production.

Recommended base resins to dilute GB601HP:

<table>
<thead>
<tr>
<th>Grade</th>
<th>Density (kg/m³)</th>
<th>MFR 230°C/2.16kg (g/10min)</th>
<th>Tensile modulus (MPa)</th>
<th>Charpy impact notched 23°C (kJ/m²)</th>
<th>Special properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE002AE</td>
<td>905</td>
<td>11</td>
<td>1,100</td>
<td>70</td>
<td>High impact (especially for 20% LGF dilution), low volatile content</td>
</tr>
<tr>
<td>BJ400HP</td>
<td>908</td>
<td>100</td>
<td>1,550</td>
<td>4</td>
<td>Good impact / stiffness balance, low volatile content</td>
</tr>
<tr>
<td>HF955MO</td>
<td>905</td>
<td>20</td>
<td>2,200</td>
<td>3</td>
<td>Excellent stiffness, low VOC &amp; FOG values</td>
</tr>
<tr>
<td>HK060AE</td>
<td>905</td>
<td>125</td>
<td>1,600</td>
<td>1</td>
<td>Excellent flowability with long term heat stabilisation</td>
</tr>
</tbody>
</table>
Success story: BMW Instrument Panel Carrier

Challenges
● Low creep
● Excellent foam structure
● Good crash and impact performance

Solution
Dilution system based on:
60% long glass fibre reinforcement
1/3 Fibremod GB601HP
2/3 EE002AE

Benefits
● Weight reduction
● Contribution to cost effectiveness
● Very good dimensional stability
● Excellent impact resistance
● Strong support from Borealis’ CAED and technical services

Direct long fibre reinforced thermoplastics (D-LFT)

D-LFT technology involves material generation and conversion on one machine without an intermediate pelletising step. The polymer is fed to the compounding, melted, mixed with endless fibres which are cut in the compounding and the combined materials are provided for injection or compression moulding. The objective and benefit of this technology is to create the maximum fibre length in the final part and therefore the highest strength and energy absorption. Working in very close contact with customers, Borealis supports this technology with its expertise in material and compounding know-how. Special unreinforced polypropylene grades are offered, including coupling, stabilisation and colour or just the base polymers for highly individual customer solutions.

Success story: Skoda Superb Front-end Carrier

Challenges
● To replace the pre-existing steel solution
● Material has to support the D-LFT process

Solution
● 5% WG068AE, additive masterbatch especially for the LFT process
● 65% HK060AE, ideal for the production of PP-GF composites in the direct LFT compression and injection moulding process
● 30% glass roving

Benefits
● Lower weight than previous steel solution
● Easier processability
● Stable material quality
● Excellent price/performance ratio
Structural foam solutions

Glass fibre is ideal for foaming due to:
- The high number of nucleation points for the gas bubbles – giving good cell structure
- The ideal mechanical properties of the material matrix

Benefits of foamed glass fibre reinforced material include:
- Density reduction
- Low warpage
- Good dimensional stability

Borealis provides various modelling and simulation supports specifically for foamed parts, for example:

Special specimen for foamed parts

Specially designed biaxial impact set-up:
- Diameter of specimen support increased from 40mm to 100mm
- Specimen size increased from 60x60mm to 150mm diameter
- Not clamped

Special Abaqus Plug-in

The Borealis plug-in for Abaqus translates the properties of a homogenous part with uniform thickness, to a foamed structure with varying thicknesses resulting from the foaming process.
Success story: VW Golf Foamed Instrument Panel Carrier

Challenges
- Lightweight construction
  - Low initial wall thickness
  - High flowability
  - Material needs to enable Structural Foam Injection Moulding (SFIM)
- IP carrier with integrated passenger airbag module
  - High stiffness/impact balance required
- As the backbone of the Class-A interior component it requires
  - High dimensional stability
  - High weld strength
- Material needs to enable short cycle times

Solution
Fibremod GE277AI, a 20% chemically coupled high performance glass fibre reinforced PP compound for injection moulding

Benefits
- Combines high flowability with a high stiffness/impact ratio
- Specifically designed to be processed with SFIM

Modelling and simulation

Glass fibre reinforced polypropylene grades are by nature complex in structure and therefore require extended efforts for engineering. Computer aided methods reliably predict the final part qualities of the conversion processes (shrinkage, warpage etc), as well as the fibre orientation distribution. Based on these results, the Integrative Simulation Approach computes on a local scale the material behaviour as the basis for simulating performance of the final application. Borealis has established the latest testing standards for PP-GF grades and is committed to further enhancing application performance prediction methodologies.
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