Ultramid® Structure

Recommended by leading testers.

Ultramid® Structure in the web:
www.ultramid-structure.basf.com
### Ultramid® Structure

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**Ultramid® Structure**

High-performance polyamide with long-glass fiber reinforcement

BASF offers long-glass fiber reinforced polyamides under the trade name **Ultramid® Structure**. This product group with its specific range of properties opens up new possibilities when it comes to metal replacement. The resulting 3D fiber network is a leap forward in performance for certain properties in comparison with short-glass fiber reinforced polyamides (Fig. 1).

![Graph](image_url)

**Fig. 1:** Long-glass fiber reinforced polyamides offer a benefit in the stiffness/toughness ratio

This makes **Ultramid® Structure** particularly suitable for applications in parts exposed to high levels of stress in mechanical and automotive engineering, in power tools and household appliances as well as in the leisure and sports sector, for example in:

- **energy absorption structures** (crash absorbers, applications in seats and interior components in vehicles)
- **structural components with demands on greater stiffness at elevated temperatures and reduced creep behavior** (chassis and bearings)
- **components which have to be robust in industry, handcraft and sports**
- **fixing elements used in the construction sector**
Product range

The Ultramid® Structure grades are based on PA6 and PA66 matrix materials which are supplied with different additives and degrees of fiber reinforcement. More details about the individual products can be found in the Ultramid® product range.

<table>
<thead>
<tr>
<th>Ultramid®</th>
<th>PA</th>
<th>Chemical structure</th>
<th>Melting point [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultramid® B</td>
<td>6</td>
<td>polycaprolactam – NH(CH₂)₆CO</td>
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<tr>
<td>Ultramid® A</td>
<td>66</td>
<td>polyhexamethylene adipinamide – NH(CH₂)₆NHCO(CH₂)₄CO</td>
<td>260</td>
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<tr>
<td>Ultramid® C Copolyamides</td>
<td>66/6</td>
<td>copolymer of hexamethylene diamine adipic acid and caprolactam</td>
<td>243</td>
</tr>
<tr>
<td>Ultramid® D</td>
<td>–</td>
<td>special polymer</td>
<td>254</td>
</tr>
</tbody>
</table>

Table 1: Ultramid® grades

A brief description of the range of Ultramid® Structure is provided in Table 2. The associated product values can be found in Table 3 on page 17.

**Ultramid® Structure** B3WG8 / G10 / G12 LF  
PA6, long-glass fiber reinforced, stabilized, high heat aging resistance, can only be supplied in black, less suitable if high demands are placed on the electrical properties of the parts

**Ultramid® Structure** B3EG8 / G10 / G12 LF  
PA6, long-glass fiber reinforced, impact-modified and stabilized, with increased impact strength and elongation at break

**Ultramid® Structure** B3ZG9 LF  
PA6, long-glass fiber reinforced, high heat aging resistance, can only be supplied in black, less suitable if high demands are placed on the electrical properties of the parts

**Ultramid® Structure** A3WG8 / G10 / G12 LF  
PA66, long-glass fiber reinforced, high heat aging resistance, can only be supplied in black, less suitable if high demands are placed on the electrical properties of the parts

**Ultramid® Structure** A3EG8 / G10 / G12 LF  
PA66, long-glass fiber reinforced, stabilized, inherent light color, increased resistance to heat aging, weather and hot water, can be used for electrical applications

**Ultramid® Structure** C3WG10 / G12 LF  
Co-polyamide, long-glass fiber reinforced, can only be supplied in black, less suitable if high demands are placed on the electrical properties of the parts

**Ultramid® D3EG12 HMG LF**  
Special polyamide, long-glass fiber reinforced, reduced water uptake, very good surface quality

Table 2: Brief description of different Ultramid® Structure grades
Unique property profile

The main feature of the long-glass fiber reinforced Ultramid® Structure is its unique property profile (Fig. 2):

- very stiff and strong at high temperatures
- excellent low-temperature impact strength
- much better creep and fatigue behavior
- much higher energy absorption and improved crash performance compared with conventional short-glass fiber polyamides

In addition to the outstanding mechanical properties, parts made of Ultramid® Structure benefit from its higher heat distortion resistance, the considerably reduced warpage (as much as -50%) and the excellent surface quality.

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Fig. 2: The property range of Ultramid® Structure compared to a standard short-glass fiber reinforced PA (glass fiber content of 50%).
Fiber network of long fibers

The manufacture of Ultramid® Structure initially produces continuous, fully impregnated plastic strands in a process known as pultrusion. In a second step, these are trimmed to a granule length of about twelve millimeters (Fig. 3).

In injection molding and similar to that of short glass fiber-reinforced plastic, a three-layer structure with border layers higher oriented in flow direction and a vertically oriented core layer forms. However, because of the long fibers and the resulting melt properties a more isotropic material is made. The main difference to short glass fiber-reinforced plastic is the three-dimensional network which is formed by the long fibers and which is developed directly in injection molding.

The fiber network forms the skeleton and remains even after ashing of the plastic (Figs. 4 and 5). This structure gives the end product its tremendous mechanical properties at both low and high temperatures. It is also responsible for the fact that creep behavior and energy absorption closely match those of the metals without losing the traditional advantages of a plastic.
Mechanical properties

Thanks to their length and the spatial overlap in the three-dimensional fiber skeleton, the long glass fibers create a reinforcing structure which is capable of carrying more load via the fibers due to the mechanical interlooping. This shows itself in the form of the material advantages described below.

Stiffness

One outstanding property of Ultramid® Structure is its higher stiffness compared with short-glass fiber reinforced polyamide at elevated temperature. In particular in a conditioned state, long-fiber reinforced polyamides show a higher stiffness (Fig. 6).

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**Stiffness**

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![Graph showing modulus of elasticity of short-fiber and long-fiber reinforced PA66](image-url)

Fig. 6: Comparison of the modulus of elasticity of short-fiber and long-fiber reinforced PA66
Parts are frequently subjected to multiaxial stresses. As a result of the high anisotropy of short-glass fiber reinforced polyamides, it can occasionally be difficult to produce a balanced design. Long-glass fiber reinforced material allows a better balance here (Fig. 7). Another advantage of long-fiber material is the almost linear behavior through to fracture. This means that parts made of Ultramid® Structure show smaller deformations at higher stresses. The visible difference in the elongation at break can also be attributed to the fiber skeleton and the mutual mechanical hindrance of the fibers.

Fig. 7: Stress-strain curves of Ultramid® Structure and PA66, in each case with 50% glass fibers
Impact strength and energy absorption

**Ultramid® Structure** has excellent toughness, particularly at low temperatures. An induced crack is deflected by the glass fiber network in such a way that more energy is consumed by the formation of larger crack areas (Fig. 8, left). This results in an excellent notched impact strength without negative effects on stiffness and strength (Fig. 8, right). This is achieved by the fiber skeleton within the part which, compared with short-fiber reinforced polyamide, results in a much tougher crack behavior.

In order to achieve similar properties in short-glass fiber reinforced polyamides, these must be impact-modified, leading to lower stiffness and strength. In terms of impact strength, **Ultramid® Structure** is superior to the traditional lightweight metals aluminum and magnesium (Fig. 9).
Creep and fatigue behavior

The high performance of Ultramid® Structure can also be seen under permanent static and dynamic loading. Parts made of Ultramid® Structure show lower creep and much slower fatigue behavior than structures made of short-glass fiber reinforced polyamide (Fig. 10). This advantage is obvious in particular at elevated temperatures.

Fig. 10: Creep behavior of Ultramid® Structure compared to short-glass fiber reinforced polyamide, PA66 with 50% glass fibers
In a dynamic fatigue test (Fig. 11), it can be demonstrated that Ultramid® Structure reaches a number of load cycles that is up to 100 times higher compared to a polyamide with short-glass fiber reinforcement (23°C, R=-1, changing load, showcased at a maximum stress of 60 MPa).

**Fig. 11: Fatigue behavior of Ultramid® Structure compared to a standard short-glass fiber reinforced polyamide (50%)**
Warpage

Apart from improving the mechanical properties, the fiber skeleton brings about a lower warpage, as the warpage on a plastic structure determined from 34 individual measuring points shows (Fig. 12).

Fig. 12: Warpage of Ultramid® Structure compared to a standard short-glass fiber reinforced polyamide (50%)
Processing

Gentle processing during the injection-molding process also prevents breaks in the fibers. **Ultramid® Structure** can be processed on conventional thermoplastic injection-molding machines which are fitted with a standard three-section screw and are suitable for processing glass-fiber reinforced polyamides.

The diameter of the screw should be at least 40 mm. An open machine nozzle should be used. Shearing and mixing elements are not advisable because the strong shear causes unwanted shortening of the glass fibers. The screw speed, the back pressure and the injection speed should therefore be kept as low as possible. The hold pressure should also not be set too high. Under correctly configured conditions, a high proportion of long fibers are also obtained in the part (Fig. 13).

Fig. 13: Long-fiber granules during processing
A horizontal temperature profile delivers good results with **Ultramid® Structure** grades which are based on PA6, whereas grades based on PA66 should be processed with a falling temperature profile. In most cases, molded parts made of **Ultramid® Structure** can be produced on existing molds. It is important that the granules arrive in the compression zone already in a soft state. In general, cross sections and radii which are as large as possible are to be preferred in the design of molds. Right-angled deflections where the melt flow is three-dimensionally deformed are to be regarded fairly critically here. Elongation flows appear less critical.

Long-fiber polyamides are frequently viewed critically because of possible wear to molds. However, with the same fiber weight proportion, long-fiber reinforced polyamides contain considerably fewer free, sharp-edged fiber ends which are responsible for wear. Measured in a test, it is apparent that the wear with long-fiber polyamide is 60% less (Fig. 14).

It is assumed just as frequently that long-fiber polyamide shows worse flow than corresponding short-glass grades because of the high glass content and the long fiber. A comparison with the flow spiral shows that **Ultramid® Structure** grades deliver approximately or completely identical results (Fig. 15).

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**Fig. 14: Mold wear – comparison of a short and long-glass grade, PA66 with 50% glass fibers**

**Fig. 15: Comparison of the flowability of Ultramid® Structure grades with corresponding short-glass fiber reinforced grades**
Design of parts using Ultrasim®

BASF’s simulation tool Ultrasim® is used mainly in the design of parts in automotive and mechanical engineering, but also for power tools and household appliances. As well as accurately forecasting the behavior of the part on the basis of injection parameters, fiber anisotropy and load speed, with the mathematical part optimization the best possible design under the given conditions can be determined. With customized models, BASF has extended the calculation tool so that parts that are reinforced with long-glass fibers can also be simulated. An example of this is a crash absorber made of Ultramid® Structure whose specific failure on impact is accurately reproduced and predicted by Ultrasim® (Fig. 16).

Fig. 16: Prediction of the part behavior of a crash absorber made of Ultramid® Structure using Ultrasim®

(left to right: simulation – part – part after ashing)
## Product overview

### Table 3: Product overview and product properties

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<tr>
<th>Properties</th>
<th>Unit</th>
<th>Test method</th>
<th>Condition</th>
<th>A3WG8 LF</th>
<th>A3WG10 LF</th>
<th>A3WG12 LF</th>
<th>B3WG8 LF</th>
<th>B3WG10 LF</th>
<th>B3WG12 LF</th>
<th>C3WG12 LF</th>
<th>D3EG12 LF</th>
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<td>1.3 - 1.7</td>
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<td>ISO 527-1/-2</td>
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<td>ISO 178</td>
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<td>ISO 179 NfeU</td>
<td>dry/cond.</td>
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<td>dry/cond.</td>
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<td>kJ/m²</td>
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<td>dry</td>
<td>26/26</td>
<td>35/-</td>
<td>37/36</td>
<td>24/24</td>
<td>31/-</td>
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<td>Tensile modulus MPa</td>
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<td>9300</td>
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<td>Stress at yield (v = 50 mm/min), stress at break (v = 5 mm/min)</td>
<td>MPa</td>
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<td>dry (80°C)</td>
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<td>%</td>
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<td>2.9</td>
<td>2</td>
<td></td>
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**Table 3: Product overview and product properties**
For your notes
Selected Product Literature for Ultramid®:
Ultramid® - Product Brochure
Ultramid® - Product Range
Ultramid®, Ultradur®, Ultraform® - Resistance against Chemicals

Note
The data contained in this publication are based on our current knowledge and experience. In view of the many factors that may affect processing and application of our product, these data do not relieve processors from carrying out own investigations and tests; neither do these data imply any guarantee of certain properties, nor the suitability of the product for a specific purpose. Any descriptions, drawings, photographs, data, proportions, weights etc. given herein may change without prior information and do not constitute the agreed contractual quality of the product. It is the responsibility of the recipient of our products to ensure that any proprietary rights and existing laws and legislation are observed. (July 2013)

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If you have technical questions on the products, please contact the Ultra-Infopoint:

Ultra Infopoint
+49 621 60-78780
ultraplants.infopoint@bayer.com

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