Engineering plastics and polyurethanes for automotive electrics

Products, applications, typical values

Further information on individual products:

www.ultramid.de

www.ultradur.de

www.ultrason.de

www.plasticsportal.eu/ultraform

BASF

We create chemistry

Engineering plastics and polyurethanes for automotive electrics

1 Engineering plastics and polyurethanes for automotive electrics

Innovation in automotive design is driven by electrical, electronic and mechatronic systems. New driver assistance systems, interconnected mobility and electromobility will accelerate this development even further. Engineering plastics often enable innovative solutions which make electronic systems indispensable when it comes to safety, comfort and energy efficiency in modern vehicle concepts. From a simple fuse to state-of-the-art power electronics there is hardly an application that does not rely on plastics. In fact, through high-performance thermoplastics these applications have often become reliable and economically feasible.

Where electricity flows, plastics have to show excellent electrical properties, good mechanical performance and high dimensional stability under heat. In automotive applications, extremely high requirements such as resistance to media and to weathering as well as heat aging resistance have to be fulfilled. Other recurring topics are miniaturization and weight saving.

Processing technologies and manufacturing processes have to suit mass production and be cost-efficient. Furthermore, components and assemblies have to reliably meet the high quality standards of the automobile manufacturers. On top, customers expect the best possible level of environmental friendliness and resource conservation, e. g. through low emissions along the entire life cycle of a product. Here as well, the right choice of plastics helps to implement sustainable solutions.

The advancing globalization of the automotive and supplier industries requires high-quality plastics that are available in all regions. There is also a growing demand for comprehensive assistance and support provided by development centers and production sites all around the world. BASF is proud to have been a trusted and reliable partner to the automotive industry for many decades and will continue to work on the solutions for the future with leading car manufacturers and automotive suppliers.

Gearbox control unit

2 | Navigation aid

Category	Application	Ultramid®	Ultradur®	Ultraform®	Others
Power supply	Fuse boxes, distributor boxes and relay carriers	9	21		
	Relays, switches and microswitches	10	19	28, 29	
	Blade fuses				Ultrason®
	Wiring harness and fastening materials	10		29	Elastollan®, Elastofoam®
	Generator covers	13			
	Contact and brush holders	13			
	Battery carriers, mounts and cables	10, 14			Elastollan®
Drive	Automatic/DCT[1] transmission control units	11, 44	17		
	Oil sensors	11			Ultrason®
	Temperature/pressure/position/flow sensors	10, 11, 13, 14	17	28	Ultrason®
	Air mass sensors		17, 22, 41		
	Throttle valve actuators	10	17		
	Ignition systems, ignition coils	10	17		
	Fans, shrouds and fan control units	10			
	Cooling/intake air flaps and actuators	10	23	28	
	Camshaft control units and actuators	10	16		
	Coolant pumps and valves	10, 15		28	Ultrason®
	Heating components (charging, EGR[2])	14			Ultrason®
Chassis and brakes	ABS[3]/ESP[4] control units		16, 22		
	ABS wheel sensors and cables	11, 14			Elastollan®
	Electronic parking brake	9	16		
	Electronic steering/power steering	9	16		
	Steering angle and torque sensors		17		
	Position/angle/tilt/yaw rate sensors	11	17	29	
Safety, control and comfort system	Airbag control units and crash sensors		16		
	Comfort, door and seat control units		16, 20		
	Locking systems and radio transmitter keys	12	19, 20	29	Elastollan®
	Dashboard and instrumentation		23	29	Elastollan®, Elastofoam®
	Steering column systems and control stalks	12, 14	19	29	Elastollan®
	Controls and switches	12, 13		29	Elastollan®
	Air conditioning and ventilation		19, 20		
	Electric windows, mirror actuators, sunroof drives	8	19, 20	28, 29	
	Controllers/sensors for assistance systems	10, 11	17		Ultrason®
	Actuators and actuating drives	10	19, 20, 23	28, 29	
	Gears and sliding elements	10	22	28, 29	
	Radar, laser, IR, ultrasonic and video sensor technology	8, 11	17		Ultrason®
Multimedia/ infotainment	Antennae		20		
	Displays				Ultrason®
	Connectors	8, 9	18, 21		Elastollan®
	Loudspeaker grilles and covers			28	

[1] DCT = Dual-Clutch Transmissions, [2] EGR = Exhaust Gas Recirculation, [3] ABS = Antilock Braking System, [4] ESP = Electronic Stability Program

Category	Application	Ultramid®	Ultradur®	Ultraform®	Others
Lighting 	Headlamp reflectors and bezels		21		Ultrason®
	Interior lighting systems				Ultrason®
	Signal lamps				Ultrason®
	Lamp sockets	8			Ultrason®
	IR-transparent components				Ultrason®
	Headlamp levelers and bending light drives	10	21	29	
Fuel system 	Fuel pumps and tank fittings			28	Ultrason®
	Valves and couplings	14		28	
	Tank sensor units			28	Ultrason®
	Fuel pressure and flow sensors	14		28	Ultrason®
	Electrically conductive components (SAE J1645)			28	
	Alcohol/biofuel-resistant components	13, 14		27	Ultrason®
	AdBlue®-resistant components			28	
Plug-in connectors 	Wire-to-wire	8	18, 22		
	Wire-to-board	8, 47	18, 22		Elastollan®
	SRS/Airbag plug-in connectors		18		
	Latches and locking systems	8	19		
	Media-tight connections	8	18		Elastollan®, Elastofoam®
	Press-in contacts/stitch contacts	8	18		Elastollan®
	Commercial vehicle connectors		21		
	Transmission connectors	11			Ultrason®
Electro-mobility, EV/HEV components 	High-voltage connectors and cables	13, 40	26, 40		Elastollan®
	Battery housings and carriers	10, 39	39		Ultrason®
	Cell frames, cell modules	39	39		Ultrason®
	Battery management systems	39, 41	39, 41		
	Chargers, plug-in devices and cables	39, 40	39, 40		Ultrason®, Elastollan®
	Transducers/controllers/power electronics	39, 41	39, 41		Ultrason®
	Battery cooling systems	39		28	
	Auxiliary heaters and heat exchangers	39, 41	41		
	Electric motors, pumps and compressors	15, 39, 41	39	28	
	Engine and alternator mount	8			Cellasto®
Special requirements 	Fire protection FMVSS 302	13	21	27	Elastollan®, Ultrason®
	Flame retardancy UL94-V0/V2	13	21		Ultrason®, Elastollan®
	Flame retardancy ISO 16750	13	21		Ultrason®, Elastollan®
	$CaCl_2$/$ZnCl_2$ resistance	13, 14	21, 22		
	Laser welding, laser transparency	12, 42	16, 23, 42		
	Laser markability	12	16		
	Lead-free soldering, reflow soldering, SMD[5] assembly	13, 46			

[5] SMD = Surface Mounted Device

3 Products and applications

3.1 Ultramid®

BASF's Ultramid® grades are molding compounds based on PA6, PA66, various co-polyamides such as PA66/6 and partially aromatic polyamide. Its outstanding mechanical strength and toughness, proven resistance to different media, its electrical insulating properties and excellent processability make Ultramid® a material that has become firmly established in almost all areas of automotive electrics and electronics.

Ultramid® allows extremely robust designs required in automotive engineering for wire-to-wire and wire-to-board connectors. Its excellent toughness and resistance to vibrations ensure reliable operation, even under adverse environmental conditions.

This also enables robust handling in assembly and maintenance work. The good processability helps to produce complex connectors, latching and locking systems as well as to manufacture them economically in multi-cavity molds. Metal parts, contact pins or cables can be tightly overmolded directly in the mold. Thanks to the excellent toughness and weld line strength, metal contacts can also be pressed into the plastic body and crimp contacts can be clipped in. Elastic seals based on silicone or TPE[6] (e. g. Elastollan®) can be overmolded with good adhesion using multi-component injection molding. The possibility to use snap-fits or film hinges also expands design options for the designer.

Plug-in connectors

[6] TPE = Thermoplastic elastomers

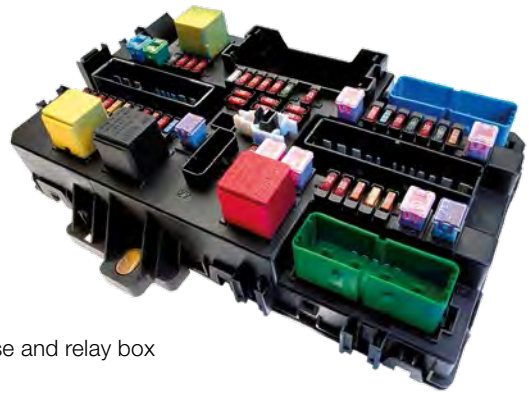
The Ultramid® product range offers tailor-made materials for almost any connector application. Both PA6 and PA66 are available unreinforced or with glass fiber contents from 15 to 50 percent. Various stabilizer systems or impact-modified products make it easier for engineers to optimally meet their requirements. Typical materials for use in connectors are Ultramid® B3EG6 and Ultramid® A3EG7.

Increasingly tougher operating conditions result in more requirements regarding operating temperatures, climate testing, media tightness or vibration strength. Thus, the suitable materials have to be chosen with care. Thanks to BASF's wide range of products and many years of experience, our experts are able to find the best solution for the specified application purpose.

Ultramid® is a proven material for large and complex components such as fuse and relay boxes, which can be installed both in the interior and directly in the engine compartment. Today, these electromechanical units, which are often comprised of several individual modules, are not just used to supply or distribute power and prevent short-circuits.

They also increasingly integrate central control functions. This reduces the complexity of the electrical system and thus the mounting space, weight, and the susceptibility to failure. With the many different design options offered by Ultramid®, optimum solutions can be found for all installation situations. For example, snap-fits simplify the assembly of modules for flexible platform concepts. PA6 is the preferred material when it comes to meet requirements for a long service life. For example, Ultramid® B3WG6 or the impact-modified B3ZG3 have been proven materials for a long time. For housings and covers, special materials filled with glass fibers, glass beads and/or minerals such as Ultramid® B3GK24 or B3WGM24 are also available.

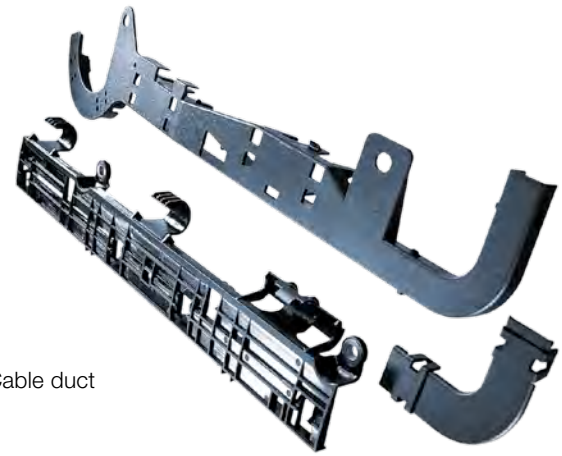
Electric power steering



Fuse and relay box

Highly filled products such as Ultramid® B3WG10 with 50 percent glass fiber content are suitable for components under high mechanical loads. They can be used for example to support or hold heavy starter batteries.

Components made from Ultramid® are perfectly compatible with the fluids and lubricants typically used in automobiles. They often replace even metal parts. The great freedom of design and the versatile methods of plastic processing make it easy to integrate additional functions, to best use space and to achieve maximum weight savings. For components in the engine bay such as sensors, valves or switch and pump components, which are not in direct contact with the coolant, Ultramid® B3WG6 and Ultramid® A3WG6 are generally used. For components in continuous contact with cooling fluid, Ultramid® A3HG6 HR and Ultramid® A3WG6 HRX, which are particularly hydrolysis-resistant, show superior water and glycol resistance. In addition, many other components made from Ultramid® can be found under the hood ranging from cable ducts and air-flap systems to electrical steering systems.



Cable duct

For electric fans, fan shrouds and fan control units, products such as Ultramid® B3WG5, B3WG6 or A3WG6 are a popular choice because they are very well able to cope with the tough operating conditions in the engine compartment. Even large and complex fans are feasible. The many different design options help designers to optimize efficiency and noise emissions. Glass- or mineral-filled products such as Ultramid® B3WGM24 or Ultramid® B3WGM45 are used mainly for shrouds and enclosures.

Fan

For sensor applications, Ultramid® has established itself as a robust and versatile housing material. It is used, for example, for oil sensors or wheel speed sensors. Oil sensors measure the oil level and/or oil quality in the engine oil circuit. They function so reliably that they are gradually replacing the traditional oil dipstick. Typical sensor products are Ultramid® A3WG6, A3HG5, A3EG5 and B3WG6 for wheel sensors.

Modern automatic and dual-clutch transmissions are increasingly integrating the transmission control unit as a mechatronic assembly mounted directly into the transmission. Eliminating interfaces, cables and connectors makes the control units smaller and lighter. This also helps to reduce their susceptibility to faults and improves shifting comfort. In some cases, the control units are seated directly in the transmission oil.

They have to withstand oil temperatures of up to 140 °C and even higher peak temperatures as well as show good compatibility with modern transmission oils. Ultramid® A3WG6 and A3HG7 have proven to be very well suited for this extremely demanding application. These products allow the tight overmolding of what are known as punched tracks or grids. They are used for the electrical connection of the control unit. Another important aspect is good vibration resistance of the components fitted directly to the transmission.

For applications involving particularly sensitive electronic components, BASF has developed high-purity plastics in special electronic qualities. Products such as Ultramid® A3EG6 EQ or A3EG7 EQ help to further improve the service life and reliability of electronic systems (details see section 4.3). Our experts can provide valuable help in choosing the right product.

Oil sensor

In the automotive industry, the laser marking of components is used as a flexible, secure and permanent marking method, e. g. for the production control system or for traceability in case of failure. This replaces, for example, adhesive labels which are less durable. For laser marking and the modern joining technique of laser welding, BASF offers specially modified versions of Ultramid® such as Ultramid® A3WG6 LS or Ultramid® A3EG6 LT. “LS” is for laser-sensitive and “LS” for laser-transparent in laser welding applications. BASF has many years of experience and offers customers expert support in choosing the right material and optimizing the process used.

Section 4.2 describes the benefits and possibilities of laser welding, which is known, for example, from the fabrication of radio transmitter keys and sensor covers.

Ultramid® is frequently found in control elements inside the car, where its great toughness makes it ideal for steering column stalks and levers. These parts have to be extremely robust, but must not pose any risk of injury in case of a crash. A good and low-wearing surface is also required as well as printability or high-contrast laser marking of symbols. Besides, long-term resistance to hand sweat, grease, cosmetics or sunscreen is also of high importance. This is generally possible with partially crystalline materials such as Ultramid®.

Dashboard

Most Ultramid® grades meet the standard automotive requirements for fire safety in line with FMVSS 302 and DIN 75200 or ISO 3795. For additional requirements such as those in the commercial vehicle sector in line with ISO16750, a wide range of flame-retardant grades is available. It comprises predominantly halogen-free flame-retardant compounds, such as Ultramid® A3X2G5, A3X2G7, A3X2G10, A3XZG5, A3U40G5, A3U41G5 SI, A3U42G6 and Ultramid® T KR4365 G5. In case of fire, these products also show an extremely low smoke gas density and smoke gas toxicity. In their material class they achieve the best flame-retardant stability and thus low deposit formation. They are easy and economical to process. Products such as Ultramid® A3UG5 even meet the requirements of Bosch Standard N 2580-1 for ingredients of components. They can be equipped to be laser-markable.

In addition to the flame-retardant polyamides described above, BASF also offers a wide selection of other flame-retardant products. Detailed information is compiled in the brochure “Engineering plastics for the E&E industry”.

Ultramid® T

In comparison to other polyamides, the partially aromatic Ultramid® T (PA 6T/6) offers a very good level of toughness and a high level of dimensional stability under heat. It also shows mechanical properties which remain mainly constant both in the dry and wet states. This favorable property range is complemented by good chemical resistance and dimensional stability. Ultramid® T is suitable, for example, for connectors or sensor components which come into direct contact with corrosive fuels such as bio-fuels.

In addition, Ultramid® T shows good resistance to calcium chloride ($CaCl_2$). It thus meets the more stringent requirements regarding the resistance to salt spray in regions such as the USA, Russia or Japan, where road salts containing calcium are mainly being used.

With a melting point of 295 °C, Ultramid® T is also ideal for use in SMD[7] components and lead-free soldering technologies. Details on this can be found in Section 4.4.

Generator cover

Brush holder

[7] SMD = Surface Mounted Device

The Ultramid® product range is continuously optimized and expanded for the ever-changing requirements of our customers. The following chapters describe a number of special products and new developments which make possible new solutions in automotive electrics and electronics.

Ultramid® Balance

Ultramid® Balance is a material family based on PA6.10 with an interesting property profile. It shows high resistance to fuels, hydrolytic media and salt solutions such as calcium chloride or zinc chloride. It is therefore an interesting alternative to other long-chain high-performance polyamides such as PA6.12 or PA12.

Thanks to its lower water absorption, Ultramid® Balance is more dimensionally stable than PA6 or PA66. Its mechanical properties are less susceptible to environmental conditions or moisture content. Compared to PA12, it is more solid and rigid. It also shows better dimensional stability under heat.

Products such as Ultramid® S3EG6 Balance or A3HG6 Balance are very well suited for wheel sensors or other components which are exposed directly to salt spray. They can also be used for housings and components which require a high level of dimensional stability in critical installation situations or under extreme climatic conditions.

	High performance polyamide			Standard-PA
	Ultramid® S Balance	PA 612	PA 12	PA 66 HR
$CaCl_2$ resistance	+	+	++	•
Hydrolysis resistance	+	+	++	•
Strength	+	+	•	++
Flexural stiffness	+	+	•	++
Δ Mechanics (dry/conditioned)	+	+	++	•
Dimensional stability	+	+	++	•
Heat deflection temperature	+	+	•	++

Table 1: Properties of Ultramid® Balance in comparison

Fuel pressure sensor

Ultramid® Endure

Ultramid® Endure is a new glass fiber-reinforced polyamide with outstanding heat aging resistance. It effortlessly withstands constant loading for over 3,000 hours at 220 °C and brief temperature peaks of up to 240 °C. It is thus suitable for housings or sensor applications in charged air and intercooler systems, exhaust gas recirculation or other temperature-critical installation locations.

Ultramid® Structure LFX

Ultramid® Structure is a high-performance plastic which is reinforced with long glass fibers. Where even optimized short glass fiber-reinforced plastics reach their limits, Ultramid® Structure offers new opportunities for the electrical equipment in vehicle manufacturing. This polyamide has a property range that is unique for plastics. It is a major step forward when it comes to replacing metal. The high-performance plastic is particularly suitable for use in components which are exposed to high levels of stress and where designers previously choose metal.

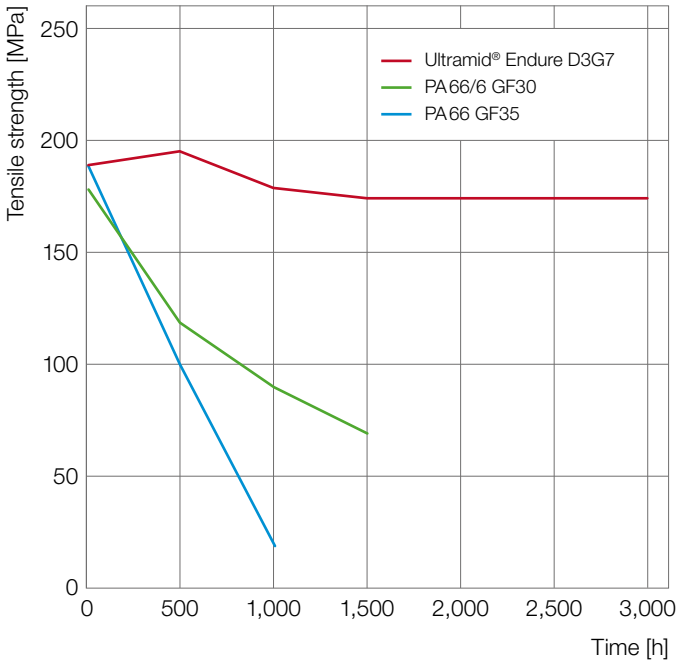


Fig. 1: Tensile strength (23 °C) of Ultramid® Endure after aging at 220 °C

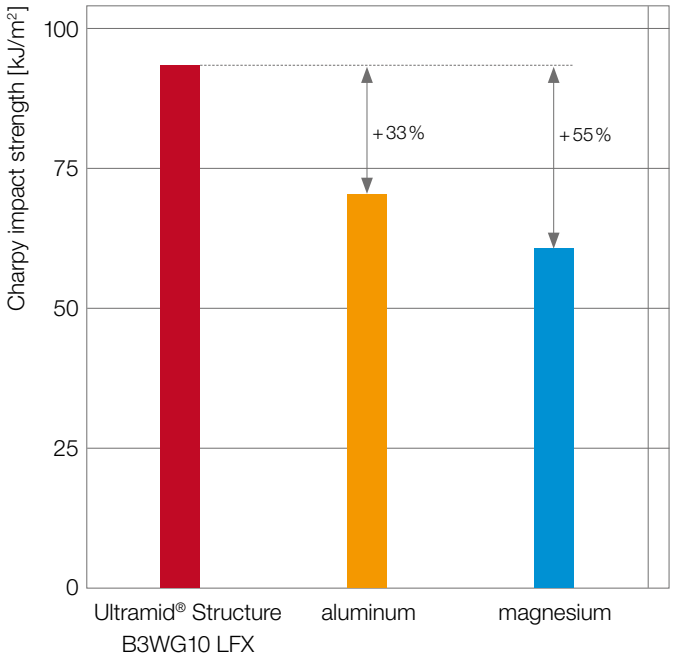


Fig. 2: Impact strenght of Ultramid® Structure compared to aluminum and magnesium

The range of possible applications extends from components and housings of generators, air-conditioning compressors, pump housings to steering boxes and housings of electric motors. The product range of Ultramid® Structure consists of PA6 and PA66 grades with long glass fiber reinforcement up to 60 percent such as Ultramid® Structure A3WG10 LFX, A3EG12 LFX, B3WG8 LFX and B3WG10 LFX.

Detailed information about Ultramid® and Ultramid® Structure can be found in the brochures “Ultramid®” and “Ultramid® Structure”.

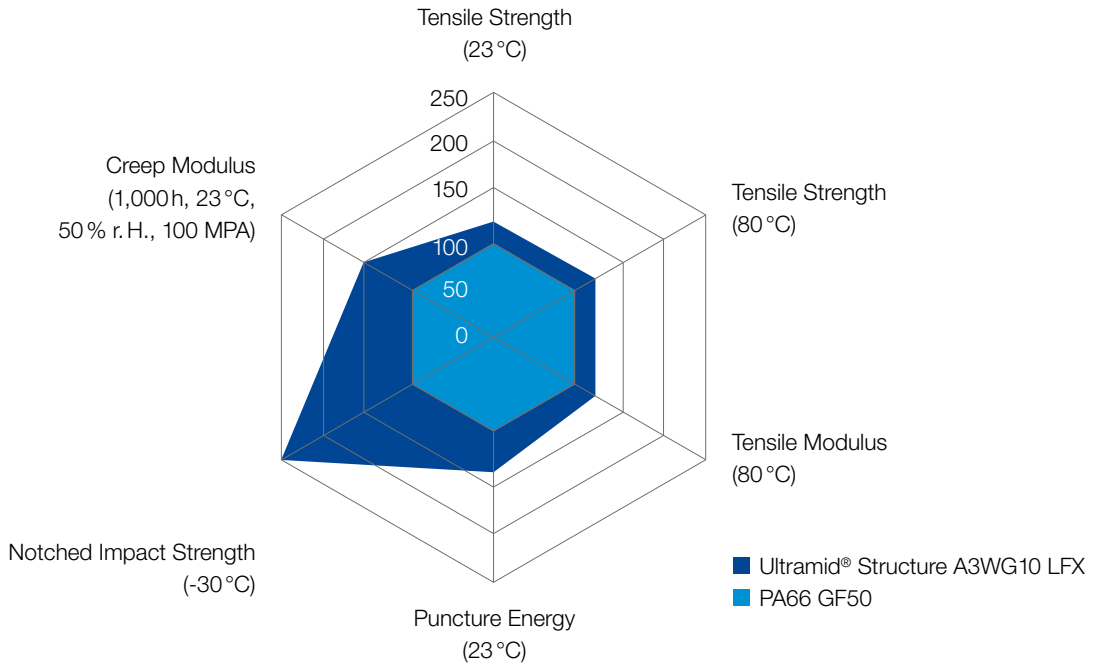


Fig. 3: The property profile of Ultramid® Structure compared to a standard PA with short-glass fiber reinforcement (50 % glass fibers)

3.2 Ultradur®

Because of its special combination of properties, Ultradur®, the polybutylene terephthalate (PBT) from BASF, is an ideal material for many applications in automotive electrics and electronics. As a result, it has long been established in all areas of automotive electronics systems. In addition to high rigidity and excellent heat resistance, it shows outstanding dimensional stability, good resistance to weathering and superior long-term electrical and thermal performance. Of particular significance for automotive electronics is the low water absorption and thus the fact that the mechanical and electrical properties are largely independent of moisture content or climatic conditions. Ultradur® is an indispensable material in particular for safety-critical components which have to work safely and reliably throughout the entire lifetime of a car.

Ultradur® is established as the first-choice material for ECU[8] housings by all the leading manufacturers and OEMs around the world. The range of applications covers the entire range of comfort control units, including seat and door modules, right through to safety-critical ABS[9]/ESP[10] systems, SRS or airbag control units or electrical steering and braking systems. Typical materials are Ultradur® B 4300 G4 and B 4300 G6. Metal inlays, contacts or punched tracks and grids can be overmolded more efficiently and the excellent dimensional stability guarantees that multi-pole connectors function steadily.

Ultradur® grades are available as laser-markable versions, which is particularly important for safety-critical components. This means that for example component data can be applied directly and permanently to the surface of the plastic via “Data Matrix Code”. So the data is easy to read and makes counterfeiting more difficult. Details on the laser welding of Ultradur® are summarized in Section 4.2.

ABS/ESP control unit

ECU housing for a camshaft control unit

[8] ECU = Electronic Control Unit
[9] ABS = Antilock Braking System
[10] ESP = Electronic Stability Program

Ultradur® is also used in some transmission control units of automatic transmissions which are fitted directly in the transmission. Without interfaces, cables and connectors, the functional integration makes these mechatronic control units smaller, lighter and reduces their susceptibility to faults. A typical grade for this extremely demanding application is Ultradur® B 4300 G6.

Ultradur® is indispensable as housing material. The range of applications extends from pressure or temperature sensors and mass air flow meters to acceleration and steering angle sensors. The sensor can be designed either as an independent unit or as an integrated component in more complex assemblies. Robust housings made from Ultradur® are also used to protect, among others, modern MEMS[11] sensors. They thus ensure the high reliability of these components in the long run. This is extremely important for safety-critical functions such as airbag or ESP systems. Ultradur® is also ideally suited for ultrasonic, radar, laser and video sensor technology. It thus helps to make modern driver assistance systems more reliable, comfortable and affordable.

Its suitability for dimensionally stable, thin-walled housings in combination with stable electrical properties make Ultradur® the ideal material for ignition coil modules which can be mounted directly in the cylinder head. The coils can be fixed and sealed in place with the standard casting compounds.

With the improved flowability of the Ultradur® High Speed grade delicate and thin-walled molded parts, which were previously barely conceivable, are now feasible. In addition to weight advantages, this also allows smaller installation spaces or improved productivity thanks to shorter cycle times.

Transmission control unit

Steering angle sensor

[11] MEMS = Micro-electromechanical systems

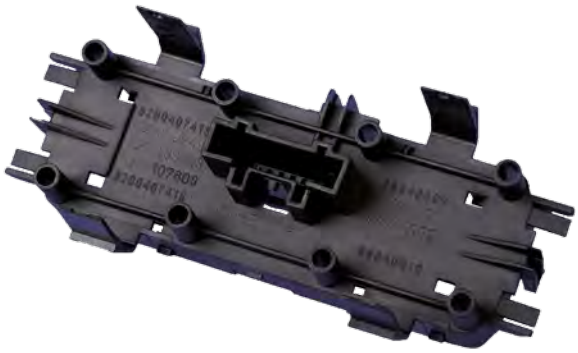
Airbag connectors

The balanced combination of the properties makes Ultradur® the obvious choice for many wire-to-wire and wire-to-board connectors which must have high dimensional stability and low warpage. Especially compared with polyamide, the very low moisture absorption ensures small dimensional changes and very constant properties in changing climatic conditions.

Apart from unreinforced products such as Ultradur® B 4520, the product range features a selection of glass fiber-reinforced grades such as Ultradur® B 4300 G2, B 4300 G4 and B 4300 G6.

All these products are also available in a High Speed version with even better flowability for connectors with extremely thin walls. The easy-flowing Ultradur® High Speed grades are the perfect choice because they are suitable for small grid dimensions and often allow shorter cycle times. In addition, an easy-flowing grade with 15 percent glass fiber reinforcement is available as Ultradur® B 4300 G3 High Speed. BASF offers the right material for almost any kind of connector type.

Plug-in connector

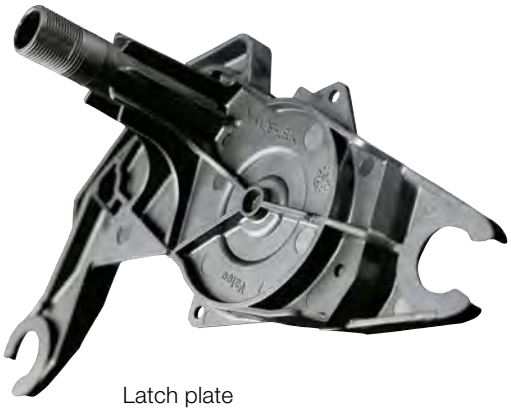


Plug-in connector made from Ultradur® High Speed

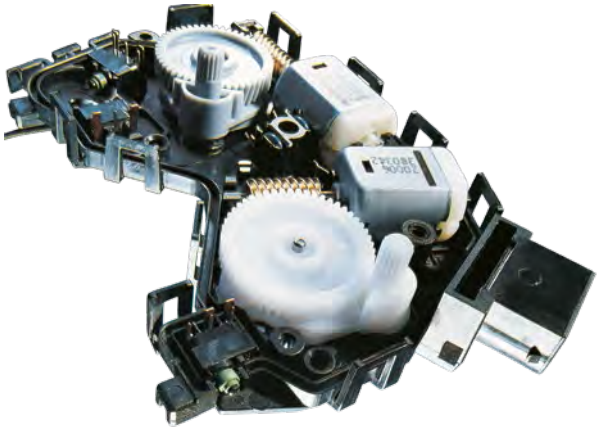
Ultradur® is furthermore used for housing applications which are subjected to high mechanical loads and where rigid, complicated geometries with good dimensional stability are required. Where multi-part modules have to be fitted or tolerance-sensitive assemblies such as gear transmissions or lever actuators have to be securely enclosed, the glass fiber-reinforced Ultradur® grades B 4300 G2, B 4300 G4, and B 4300 G6 are widely used.

Similar requirements apply for steering column modules as well as axial and radial fans used for interior ventilation and air-conditioning or for cooling fans of electrical devices. If necessary, flame-retardant grades are available.

Its excellent tribological properties and high wear resistance make Ultradur® suitable for components and sliding elements which are subject to friction. Typical applications are housings and functional parts of electric window winders, seat adjusters, sunroofs, mirror actuators or locking systems.



Latch plate



Locking system

Mirror actuator housing

Steering wheel module

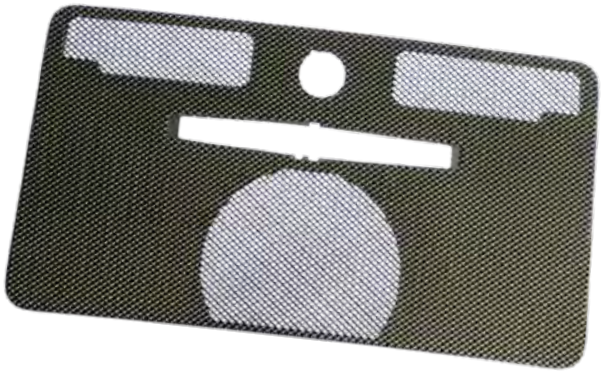
Ultradur® S

Ultradur® S (PBT/ASA) was specially developed for housing applications which require even better dimensional stability, a high level of complexity, low frictional wear or good surface quality together with high economic efficiency. Examples are door control units or the actuators housings for which Ultradur® S 4090 G4 or S 4090 G6 are used.

In order to make it easier for molders to create complex components, BASF offers optimized grades such as Ultradur® S 4090 GX, S 4090 G4X and S 4090 G6X. These materials have lower contents of anisotropic fillers, reinforcing materials and improved demolding properties. Thus, they are the best basis for the economic production of large and complex components. Ultradur® S is resistant to light exposure and elevated temperatures near the windshield. It is even suitable for components on the top of the dashboard. Examples are air-conditioning components such as diffuse fields, air distributors, ventilation grilles, air flaps and actuators as well as solar or temperature sensors.

Ultradur® S grades are also available as easy-flowing versions such as Ultradur® S 4090 G4 High Speed and S 4090 G6 High Speed. They combine design freedom and economic efficiency.

Ultradur® is generally suitable for exterior applications due to good resistance to UV light and weathering. Molded parts made from Ultradur® barely tend to yellowing and their surface hardly changes. The mechanical properties such as rigidity and tensile strength are rarely impaired. However, parts for exterior applications should be colored black. The most suitable products for parts which are heavily exposed are Ultradur® B 4040 G4 and B 4040 G6: They have an outstanding surface quality together with high UV stability. Examples of exterior applications are door handles and locking systems, wiper/washer systems, mirror mechanisms, sunroof components, air flap systems, exterior sensors or aerials. Parts made from Ultradur® can be easily coated.



Diffuse field

Door control unit

Especially for lamp frames and headlight bezels, Ultradur® B 4570 is a low-emission high-gloss product, which shows extremely low levels of degassing, even when used over a long period of time at temperatures of up to 160 °C. This reduces the risk of headlamp lenses becoming cloudy as a result of condensing ingredients. BASF's PBT portfolio for headlamps includes Ultradur® B 4520 for standard applications, Ultradur® B 4560 with optimized demolding properties, Ultradur® S 4090 with particularly good flowability and low warpage and Ultradur® B 4570.

Ultradur® is in general resistant to calcium chloride and zinc chloride. Thus, it meets the stringent requirements for resistance to salt spray in regions where road salt with calcium is used.

Most Ultradur® grades meet the standard requirements in vehicle manufacturing for fire safety in line with FMVSS 302 and DIN 75200 or ISO 3795. If products in line with ISO 16750 are required, BASF offers several flame-retardant grades.

Furthermore, BASF provides established flame-retardant products of the Ultradur® B 4406 range and halogen-free products, such as Ultradur® B 4441 G5 and Ultradur® B 4450 G5. Detailed information about these and other flame-retardant compounds can be found in the brochure "Engineering plastics for the E&E industry". The Ultradur® product range is continuously optimized and expanded in order to fulfill changing requirements of our customers. The following sections describe a number of special products and new developments for new solutions in automotive electrics and electronics.

Plug-in connectors

Headlamp bezel

Ultradur® HR

With the development of the hydrolysis-resistant Ultradur® HR grades, the ever-growing requirements of the automotive industry for climate testing and thermal aging have been taken into account.

The newly developed Ultradur® B 4330 G3 HR and B 4330 G6 HR are ideal for connectors which need to qualify for SAE USCAR-2 Component Class 5 for climate change testing at higher operating temperatures. The hydrolysis-resistant Ultradur® HR is already used as housing material for the latest generations of ABS/ESP control units. In long-term tests at 85 °C and with 85 % relative humidity, it does not show any notable signs of aging even after 5,000 hours. This grade helps to greatly improve reliability and failsafe quality of safety-relevant electronic components in the long run. With Ultradur® B 4330G3 HR HSP, BASF also offers a very free-flowing grade with 15 % glass fibers.

Ultradur® B4300 C3 LS

With Ultradur® B4300 C3 LS, a carbon-fiber reinforced Ultradur® is on the market for the first time. It features low electrostatic charge along with good conductivity. Due to the anti-static properties, less dust or dirt adheres to the component. The product absorbs hardly any water and is laser-markable. Furthermore, it can be easily combined with other PBT grades, e. g. by welding or bonding, and is also suitable for complex, thin-walled components.

Possible applications for this carbon fiber-reinforced PBT are parts with gases or fluids flowing through, elements that are subject to static charge due to friction and applications that require ESD (=electrostatic discharge) protection.

Moreover, components made of carbon-fiber reinforced Ultradur® are more reliable and more long-term resistant than plastics equipped with conventional anti-statics, as these additives are known to migrate to the surface and tend to lose their anti-static effect with time. The BASF material thus helps to fulfill the increasing demands on miniaturization, precision and security of parts in automotive electrics.

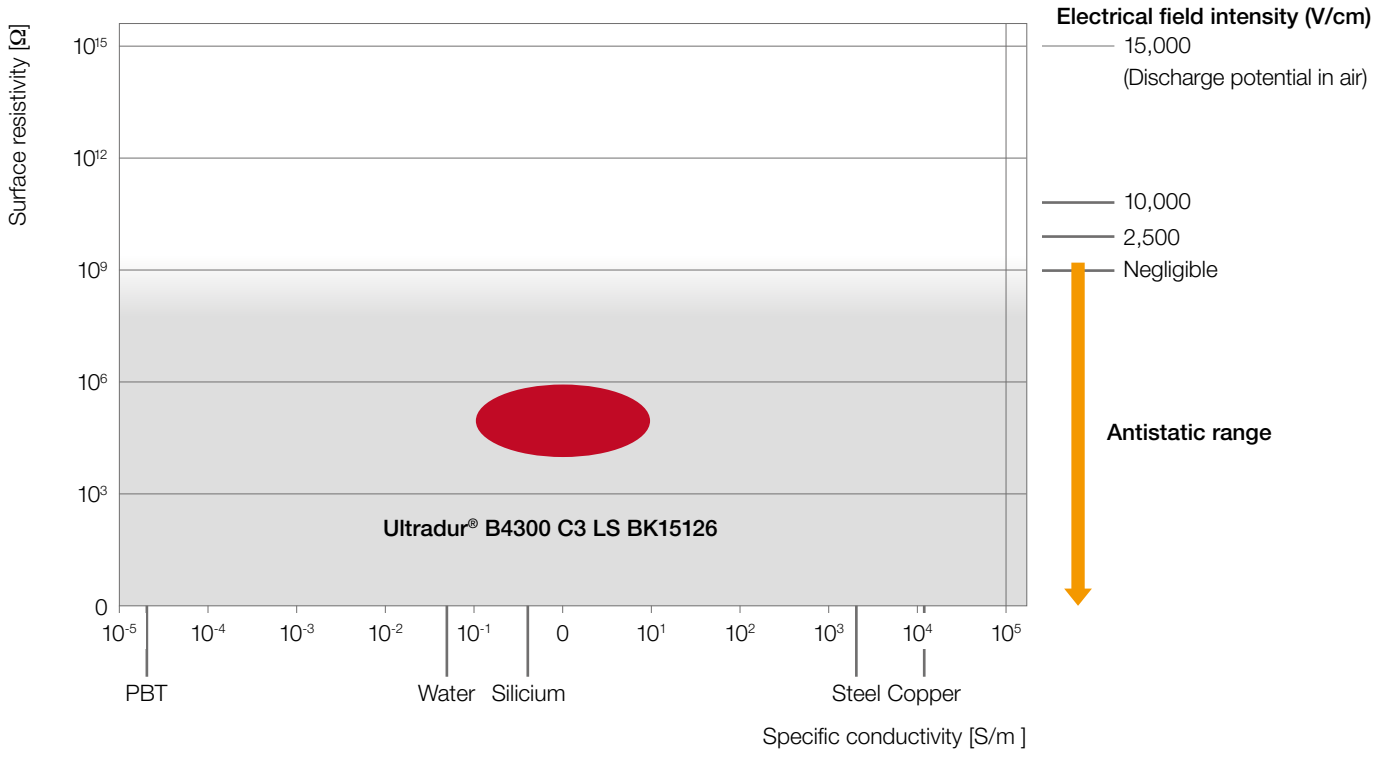


Fig. 4: Electric properties of carbon-fiber reinforced Ultradur® B4300 C3 LS

Ultradur® LUX

With Ultradur® LUX, BASF researchers have managed to raise the laser transparency up to a high and constant level which was previously unknown for PBT. Thanks to these improvements, much higher welding speeds are now possible.

In addition, the process window is becoming considerably wider at the same time. Details about laser welding are summarized in Section 4.2.

Detailed information about Ultradur® can be found in the brochure “Ultradur®”.

ABS/ESP control unit

Air flap control unit

3.3 Ultrason®

BASF's Ultrason® grades are amorphous thermoplastics which include polysulfone (PSU), polyethersulfone (PES) and polyphenylensulfone (PPSU). They are characterized by a very high heat resistance. Their special qualities are high dimensional stability as well as good, largely temperature-independent electrical and mechanical properties. Ultrason® is inherently flame-retardant. Many grades meet UL 94 V-0 without any additive. This property profile and its good electrical insulating capacity, high heat aging resistance and good resistance to hydrolysis, Ultrason® is particularly suitable for components which are subjected to high stresses over a wide temperature range from -50 °C to +180 °C. In the case of Ultrason® E, even temperature peaks of up to 220 °C are tolerable. BASF offers unreinforced products, which are transparent and thus quite unique for engineering plastics.

The main applications for polyethersulfones in automotive construction are headlamp reflectors and headlamp bezels. The high dimensional stability under heat and excellent surface quality are the perfect basis for manufacturing reflectors for headlamps as well as bezels, signal lamps and high-quality interior lighting. Even compact designs close to hot components or with unfavorable cooling conditions are feasible. The thermal expansion is consistently low over a wide temperature range. In addition to good processability, this helps to achieve an optimum design in reflector geometry. Hence, these compounds contribute to a high luminous efficiency, uniform illumination and a stable cut-off line for the headlamps.

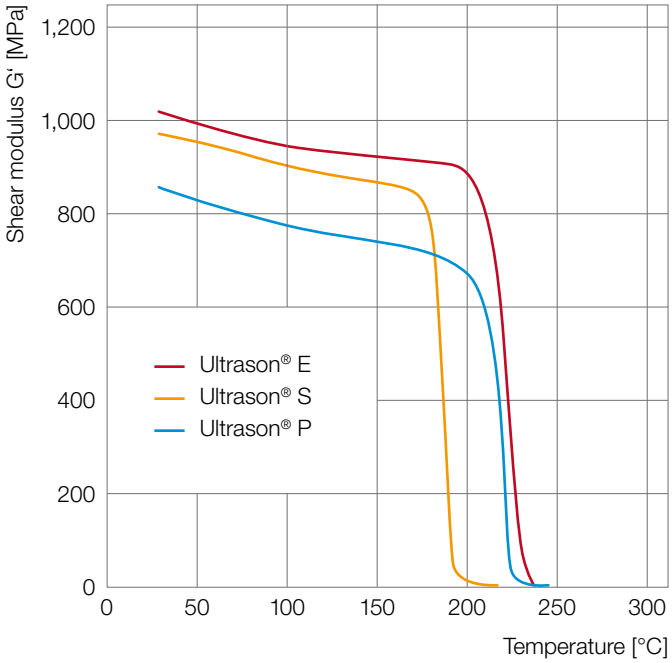
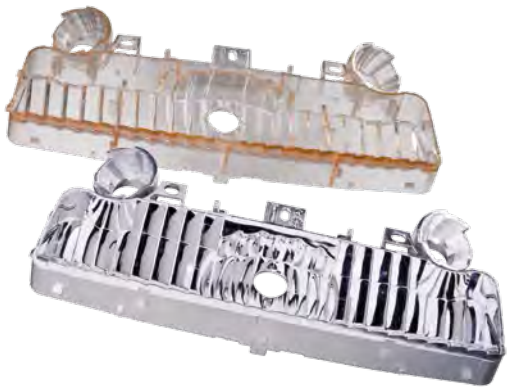


Fig. 5: Shear modulus curves according to ISO 6721



Interior lighting

Fog lamp housing

Special IR-transparent colors such as Ultrason® E 2010 MR black HM (Heat Management) reduce the level of heating caused by IR or thermal radiation. With Ultrason® as a reflector material, there is no limit to creativity for designers.

Direct metallization of surfaces is possible using typical methods such as PVD[12]. The good surface quality of molded parts leads to smooth and high-gloss reflector surfaces with good metal adhesion, e. g. of aluminum.

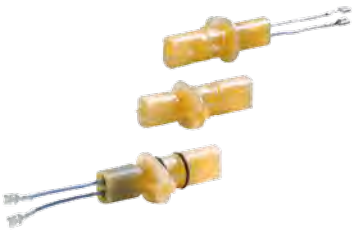
Where conventional thermoplastics reach their limits, Ultrason® is the ideal choice for components that have to withstand high thermal and mechanical loads, such as coil formers, sensors, plug-in connectors and functional parts of switches or relays. For example, Ultrason® is used for transmission connectors that have to be dimensionally stable at temperatures of up to 170 °C and show low swelling caused by the transmission oil.

On account of the good hydrolysis resistance, glass fiber-reinforced Ultrason® E 2010 G6 can be used for impellers of electrical coolant pumps. The high dimensional stability makes it easier to manufacture parts with narrow tolerances; thus enhancing the efficiency and effectiveness of the pumps.

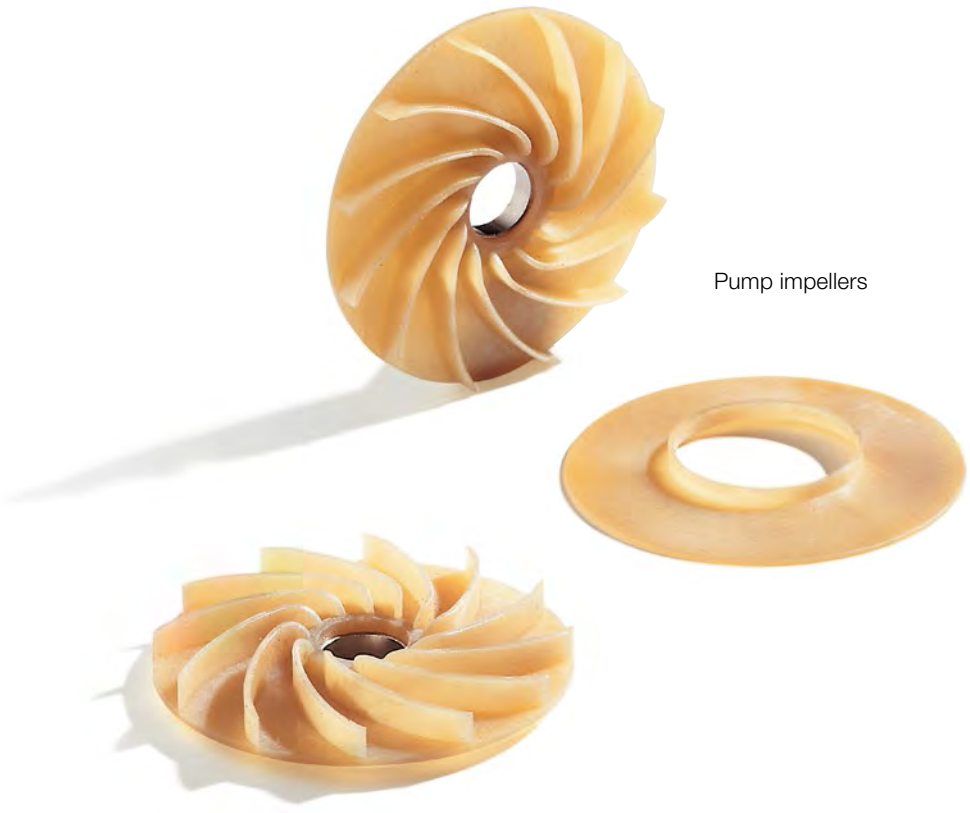
Independent of the temperature load, the exceptionally good creep resistance makes Ultrason® attractive for components which have to withstand mechanical loads over long periods of time. Ultrason® can be used as thermal insulator or heat shield for heat-sensitive components.

The transparency of the unreinforced Ultrason® grades allows solutions which are not possible with other engineering plastics. This transparency can be exploited especially for optical sensor components, displays or lamp covers.

Where high temperatures prevail and/or a high level of toughness or chemical resistance is required, this compound is the right choice. The good toughness can be used for shatter-proof transparent covers. It is an alternative to glass or transparent plastics which are more liable to fracture. The relatively high optical refractive index of up to 1.7 makes it easier to design optical lenses or optical systems.



Transmission plug connectors



Pump impellers

[12] PVD = Physical Vapor Deposition

Ultrason® is also used for the transparent enclosures of blade fuses in the conventional formats such as Maxi, ATO, Mini and Low-profile, which are characteristically colored transparent. When the fuse blows, Ultrason® is able to withstand the temperature peaks without any risk of ignition.

The good chemical resistance makes it possible to use Ultrason® for applications in the fuel system. Components made from Ultrason® are even suitable for installation in fluorinated fuel tanks, used for the purpose of reducing fuel permeation. In addition, Ultrason® E (PESU) and Ultrason® P (PPSU) show excellent resistance to the test gasoline FAM B, which is a real challenge for many other plastics.

Detailed information about Ultrason® can be found in the brochure “Ultrason® E, S, P”.

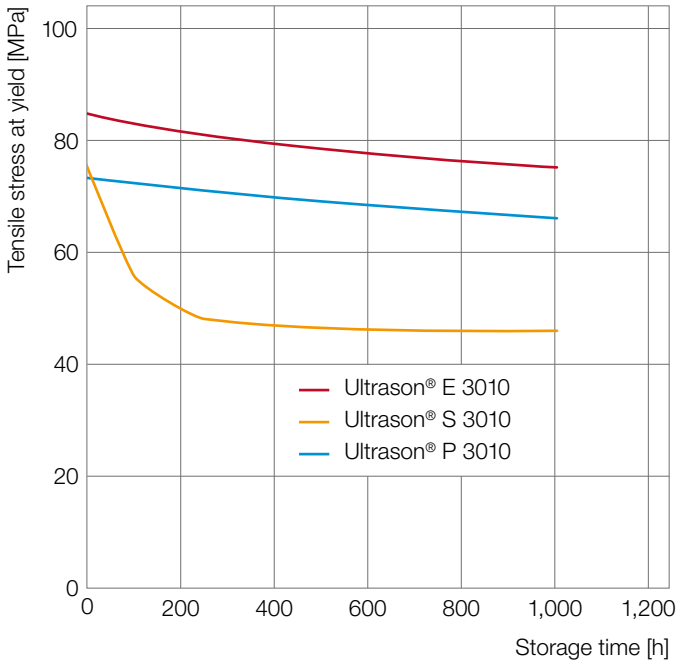


Fig. 6: Stability of Ultrason® in the presence of FAM B at 23 °C

Blade fuses

3.4 Ultraform®

Ultraform® is the brand name for BASF's range of thermoplastic co-polymeric polyoxymethylenes (POM). The special feature of Ultraform® is the ideal combination of strength, stiffness and toughness, which derive from its chemical structure. Owing to its high crystallinity, Ultraform® is stiffer and stronger than other engineering plastics, especially within the temperature range from 50 °C to 120 °C. This compound shows no transformation between the low glass-transition temperature of approximately -65 °C and the melting temperature of approximately 170 °C. This results in constant mechanical properties over a wide temperature range, which is interesting from a technical point of view.

At room temperature, Ultraform® has a distinct yield point at about 8 to 10 percent strain. Below this limit, Ultraform® shows good resilience, even under repeated loading. It is therefore especially suitable for elastic spring elements. In addition, it has a high creep strength and a low tendency to creep. This combination, together with high surface hardness as well as good frictional and wear properties, makes it suitable for many engineering applications.

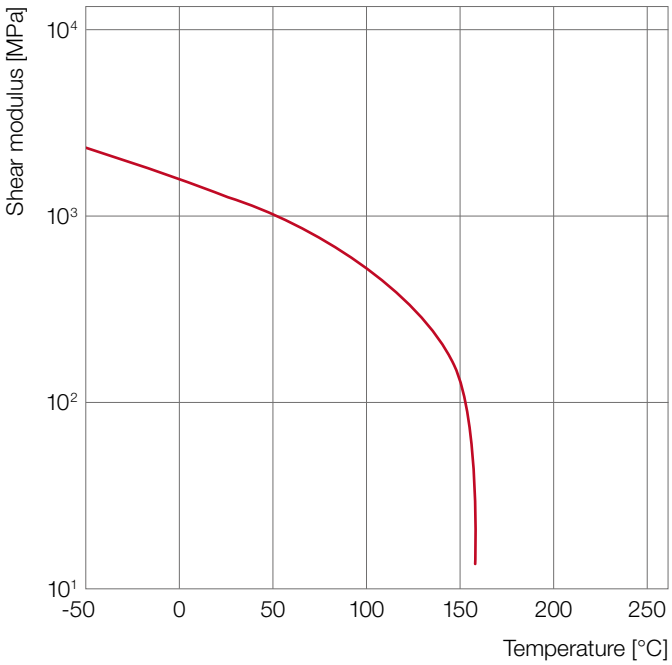
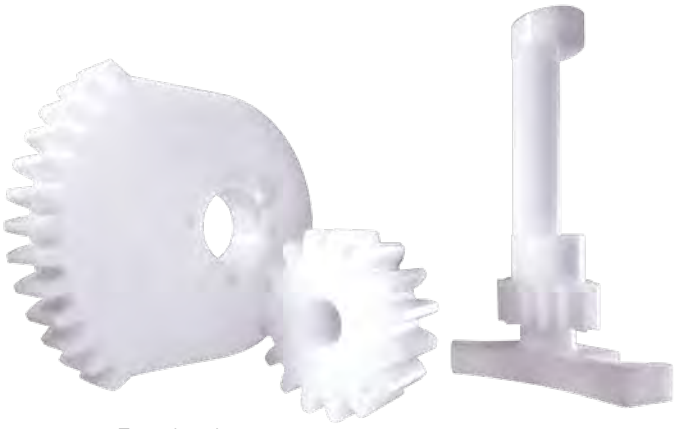


Fig. 7: Shear modulus of Ultraform® as a function of the temperature (measured according to ISO 6721)



Functional parts

Roll-over valve

Ultraform® is exceptionally resistant to many of the lubricants, fuels and chemicals used in automobiles, even at elevated media temperatures. An important field for Ultraform® is the entire area of fuel supply for both gasoline and diesel vehicles. Applications range from a complete fuel delivery module made from Ultraform® S2320 or N2200 G43, which is fitted right in the gas tank of the vehicle, to fuel meters, flow sensors or valves. Resistance to high alcohol admixtures and various bio-fuels is a matter of course.

In order to meet the requirements of SAE Standard J1645, Ultraform® N2320C has been developed. This is an electrically conductive material which prevents electrostatic charge and the risk of sparking in the fuel system. In test conditions in accordance with ISO 3915 (four-point method), this product achieves a value of just about 30 Ω · cm. It thus significantly exceeds the requirements of SAE J1645. Ultraform® is very resistant to urea solutions such as those used in AdBlue® technology for the selective catalytic reduction (SCR) of diesel exhaust gases. Ultraform® is suitable for many functional parts in direct contact with AdBlue®, for example fuel meters, pumps, connectors, valves or metering devices.

On account of its good tribological properties, Ultraform® is suitable for all applications where good sliding friction properties and low wear rates are important. Typical applications are gears, sliding elements of drives and actuators such as window winders, mirror adjusters or lock systems.

Fuel filter made from Ultraform® N2320C

Fuel delivery module

Loudspeaker grilles

Due to the excellent resilience of Ultraform®, spring functions can be integrated directly into a component and make additional metal springs redundant. This can simplify assembly and improve reliability. Examples are controls, buttons, switches and microswitches. The well-directed use of Ultraform® can have a positive influence on the touch, feel and sound of control buttons.

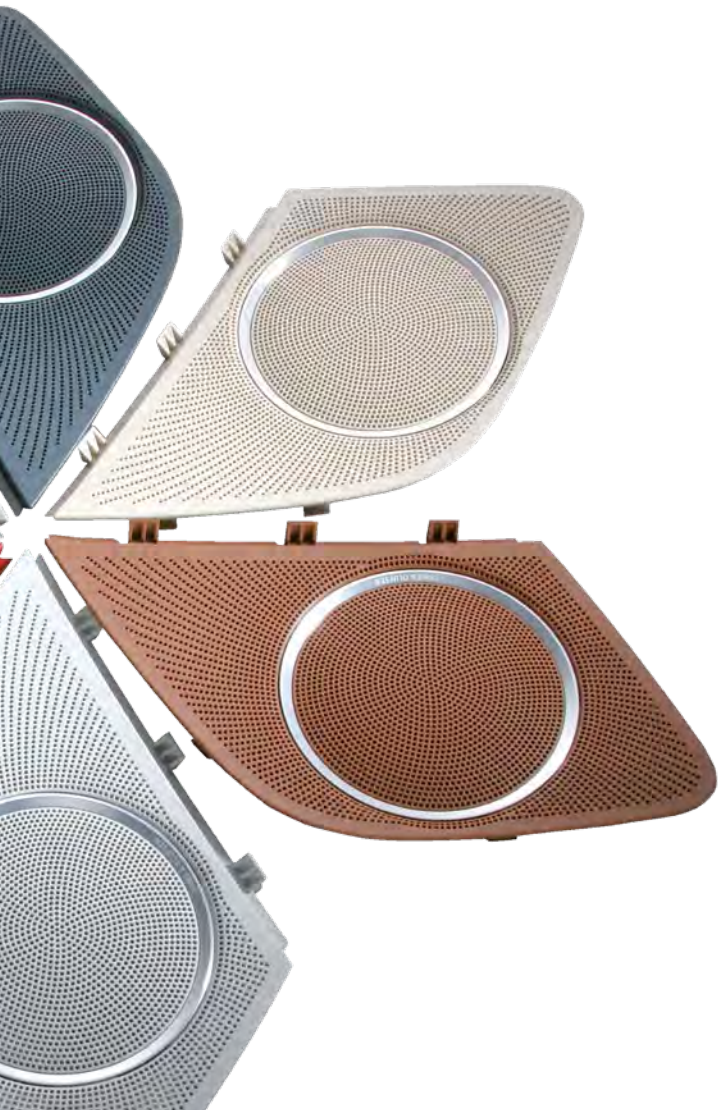
Components made from Ultraform®

Restrictions apply to the use of Ultraform® for exterior applications. It can be used for electric drives for mirrors, headlamp levelers, bend light actuators, for wiper/washer systems, clips and fastening elements and many more. However, direct exposure to sunlight should be avoided.

In the interior, Ultraform® is used for delicate loudspeaker covers. It replaces less robust plastics or expanded metal mesh. The high strength, toughness, scratch resistance and the good mechanical resilience protects grilles and loudspeakers when being kicked or bumped. Ultraform® helps to permanently prevent unpleasant rattles, squeaks or disruptive noises caused by distortions and vibrations during vehicle operation as well as buzzing and droning caused by loudspeaker excitation. The good processability of Ultraform® permits thin-walled and delicate structures. This in turn can have a positive impact on the quality of the sound of the speaker system.

For interior applications, low-odor products with optimized emission behavior are available (suffix: LEV).

Detailed information about Ultraform® can be found in the brochure “Ultraform®”.



Cable clip

3.5 Elastollan®

The high-performance material Elastollan® is BASF's thermoplastic polyurethane (TPU). These thermoplastic elastomers are available in a hardness range of approx. 35 Shore A to 83 Shore D.

The products are characterised by the following properties:

- high wear and abrasion resistance
- high tensile strength and excellent tear propagation resistance
- very good damping capacity
- very good low-temperature flexibility
- high resistance to oils, greases, oxygen, UV and ozone

Oil and grease resistance are the main characteristics of the polyester-based Elastollan® grades; the polyether-based Elastollan® grades offer good cut resistance, high tear strength and tear propagation resistance, as well as outstanding hydrolysis stability, low-temperature flexibility and microbial resistance.

This combination of properties has made Elastollan® very successful, even in very demanding applications in automotive electrical and electronic systems. The application scope ranges from simple grommets to complex housing seals and sheathing for high-voltage cables.

Elastollan® sheathings for cables and connectors meet the most demanding criteria for protecting valuable and sensitive wiring. The significantly contribute to operational reliability and safety. Elastollan®-sheathed cables provide a safe flow of energy and data, both for interior applications and for more extreme environments in the engine compartment or in the wheel well subject to stone impact, water and low temperatures.

High-quality cable sheathings and wiring components are essential, particularly in electromobility, to safely and durably meet the wide variety of technical demands for high-voltage, traction and charging cables.

Products in the Elastollan® 11 range, such as Elastollan® 1185 A 10, 1185 A 10 M and 1195 A 10, have proved successful for many years both for cables and for high-voltage cables with operating temperatures of -40 °C through to 125 °C (ISO 6722 Class C).

The "High Performance Material" Elastollan® 785 A HPM was developed for higher operating temperatures of up to approx. 150 °C (ISO 6722 Class D). It also meets the more stringent demands of temperature class D of German automotive manufacturer delivery specification LV 112; in some cases, the standard specifications are even exceeded.

As well as the "soft" Elastollan® 785 A 10 HPM with a hardness of 85 Shore A, BASF also offers the considerably harder Elastollan® 754 D 15 HPM (Shore D 53). In contrast to the softer material which is recommended for thicker walls that are found in sheathed cables and battery leads, Elastollan® 754 D 15 HPM is suitable for very thin core insulation. This product currently achieves the resistance required by ISO 6722 in humid heat over 1,000 hours.

Cable sheathings

Alternative plastics which exhibit a comparable performance in this respect are either considerably more expensive because they come from even higher temperature classes, or more complex and thus more cost-intensive in processing. This applies in particular to crosslinked materials that also have the disadvantage that they are not recyclable and cause problems with water tightness when connectors and bushes are injected.

With charging cables, Elastollan® can be used to produce thin, lightweight and, even at low temperatures, flexible cables and coiled cables. They make handling during charging easier for the car owner who also can store the cables more easily.

For special applications there are also halogen-free flame-retardant Elastollan® grades. Elastollan® 1185 A10 FHF, 1185 A10 HFFR, 1190 A10 FHF and 1192 A11 FHF have proved extremely suitable for extruded cables. Elastollan® 1192 A11 FHF also has improved flame retardance, making it ideal as cable sheathing for thin-walled UL-approved leads. Elastollan® 1185 A10 HFFR has a particularly low smoke gas formation and toxicity, for example for coach and rail applications.

The increasingly more complex wiring technology in modern cars often face restrictions regarding installation space. In certain situations, flat conductors with Elastollan® sheathing can offer a solution: they are light, easy to assemble, require little space and give greater performance and safety.

Flat conductors

Cable

Apart from cable sheaths, plug-in connectors, grommets, kink-resistant sleeves are made from Elastollan®. Direct over-molding allows for watertight, heavy-duty assemblies, comprised of cable sheath, contact carrier and sleeve, even when combining different grades of Elastollan®. Every single element also has high wear and abrasion resistance. For example, Elastollan® 1175 A10 W has established itself as a reliable material for kink-resistant sleeves in ABS and ESP wire harnesses.

Contact carriers and plug-in connectors that demand excellent impact strength with high rigidity and at the same time good elongation, low coefficient of thermal expansion and low shrinkage can be manufactured efficiently with the glass fiber-reinforced polyester-based Elastollan® R3000. It also has outstanding electrical properties with a high tracking resistance (CTI=600).

Plug-in connector

grommet

Elastollan® is also ideal for high-quality seals to reliably seal, for example, electronic housings, tops or covers against environmental influences and a wide variety of media. The seals are normally injected in a two-component injection molding process onto the housing materials ready for assembly.

Elastollan® shows predominantly good adhesion to the housing materials widely used in automotive electrics such as Ultramid® (PA) and Ultradur® (PBT).

Cable sheathing

Sealing

3.6 Elastofoam®

Elastofoam® is BASF's tradename for its polyurethane flexible integral foam systems. They can be found in the automotive industry wherever the highest level of design freedom and a very high degree of comfort are required as well as optics and haptics and complex physical demands. Flexible integral systems are widely used in vehicle electrics, predominantly in the production of cable sets and wiring harnesses, and also as a material for encapsulating connectors, for embedding entire wiring harnesses in foam and as a material for grommets and sleeves.

Where high dimensional stability is required due to restricted space available for installation or where wiring harnesses have to be protected from mechanical damage, specially customized polyurethane systems such as Elastofoam® I 4610/101 can fulfil these demands with minimum space requirement. The final assembly of the wiring harness is made easier by adapting the harness to the respective installation situation in the vehicle, and by foaming inserts and connectors in place in one process step. Foam encapsulation replaces and supplements other types of sheathing such as cable ducts, corrugated pipes and hoses.

The possibilities for three-dimensional design can also be applied to partial and complete harness foam encapsulation. In these so-called dimensionally stable harness sets which are increasingly being used not only for cars but also for commercial vehicles, up to several hundred single conductors can be combined and produced in virtually any form.

Angled pieces and multiple outlet points are nowadays indispensable for a modern harness. Connectors and fasterners for later assembly of the harness are foamed in a single process step. The demand of the automotive industry to wire ever more electronic components in ever smaller spaces is met by PU foam technology. Elastofoam® I 4610/101, for example, has proved useful also for very demanding solutions.

Polyurethane grommets made, for example, from Elastofoam® I 4610/111 are preferably used where reliable, one hundred-percent sealing of areas susceptible to moisture against creep water is required, for example at the inlet of electronic module boxes, control equipment, sensors or central electrics. Also in the grommet from the engine compartment to the car interior, the required longitudinal water tightness is more and more often guaranteed by polyurethane grommets or polyurethane sealing. The conventional fitting of cable sets with rubber sleeves, shrink tubing or cold-melt processes is very labour-intensive and often no longer meets today's requirements for sealing, process safety and productivity. A combination of materials such as a polyurethane grommet and a rubber sleeve is being used for certain applications.

Cable sheathings

Foam technology, however, offers a high level of process safety and productivity as well as the possibility to combine several functions. One single procedure replaces a whole chain of process steps. During foaming, the low-viscosity reaction mixture flows into the areas between the wires, encapsulates each individual wire, cures and thus reliably seals the harness. With the optimal coordination of foam system, mold geometry, mold and foaming process, foamed grommets can be accurately positioned on the harness with a closed foam surface. Because of the adapted hardness and flexibility of the foam the grommets can be fitted accurately and sealed reliably.

In general all products and processes must meet the usual test standards in the automotive industry or special internal specifications by the harness manufacturers. The test catalogue may call for the following tests or evidence (excerpt):

- Water pressure test
- Climate change test
- Ageing resistance
- Vibration strength
- Media resistance to:
  - Fuel mixtures
  - Diesel fuel
  - Engine oil
  - Radiator antifreeze
  - Windscreen wash fluid
  - Brake fluid
  - Battery acid
  - Automatic transmission oil
  - Power steering oil
  - Manual transmission oil

Polyurethane is a versatile material for the manufacture of wiring harnesses. BASF has accordingly developed a series of systems designed to meet the different purposes. The following table gives an overview of the key values.

Test	Measured values	Specification
Shore Hardness A	25 - 80	DIN ISO 7619-1
Density, total	250 - 1050 kg/m³	DIN EN ISO 845
Tensile strength	... - 8000 kPa	DIN EN ISO 1798
Elongation at break	... - 300 %	DIN EN ISO 1798
Tear propagation resistance	... - 13 N/mm	DIN ISO 34-1, B(b)
Flammability	< 100 mm/min	FMVSS 302
Short-term temperature resistance	... - 145 °C	Customer specification
Long-term temperature resistance	90 - 130 °C	Customer specification
Media resistance (test catalogue)	complies	Customer specification

Table 2: Values of PU systems by BASF for wiring harnesses

The choice of material depends on the particular purpose. BASF's experts can support with comprehensive advice on material, mold design, part design and process control, working with the customer to find the optimum solution for technical requirements and productivity. Thus PU foam technology can comply with the automotive industry's demand to wire ever more electronic components into ever smaller areas.

3.7 Cellasto®

The high-performance elastomer Cellasto® is a polyurethane-based microcellular foam. BASF uses Cellasto® to produce vibration control components and semi-finished products. The most well-known applications are spring aids, top mounts and spring isolators. Their properties make them particularly suitable for vehicles with alternative drive concepts.

Cellasto® is particularly well suited to meet the vibration demands of electromobility. It is

- compact and efficient – high level of deformation in restricted installation spaces
- flexible and durable – good dynamic decoupling with optimum durability
- lightweight with good damping properties – up to 30 % weight reduction with optimum damping and insulation properties

The amplitude-selective damping of Cellasto® leads to safe damping of component and system resonances with low dynamic stiffening and thus optimum vibration decoupling.

With spring aids made of Cellasto® it is possible to use lighter and more cost-effective steel springs with linear identification by progressively increasing the force, safely setting the final position and relieving the load on the surrounding structure due to its energy absorption and reduction of force peaks.

Elastic mounts made of Cellasto® are light, cost-optimised and efficient. They improve comfort and travel safety due to the particular static and dynamic properties of Cellasto®.

Spring isolators made of Cellasto® insulate roughness and damp spring resonances effectively, so that there is a significant NVH advantage (NVH = noise, vibration, harshness), particularly in vehicles where lightweight construction is a major consideration.

Shock absorber

The particular properties of Cellasto® are a major advantage over conventional elastic mounts, particularly in engine and powertrain mounts for electric vehicles. High-frequency noise is effectively decoupled. This is a particularly important consideration because the vibration behaviour of electric engines differs greatly from that of combustion engines. High forces act here due to high-torque engines with high-frequency vibrations on the bearing positions. At the same time, weight savings of approximately 30 % can be achieved by Cellasto® itself, as well as by optimization on the interfaces.

Cellasto® offers amplitude-selective damping and the possibility of achieving enormous deformations in compact installation spaces. Thus even heavy batteries for electric vehicles can be mounted effectively. In certain cases, it is even possible to use the weight of the battery as a weight-neutral dynamic vibration absorber.

Spring isolators

4 Problem solvers

4.1 Electromobility

Electromobility is an interesting field where experts anticipate a high growth potential in the coming years. Energy-efficient electromobility is a key technology in transforming individual mobility as well as to make it more environmentally friendly. BASF focuses on research and development activities ranging from battery technology and lightweight construction to intelligent heat management and innovative materials.

Many e-mobility solutions can only be implemented reliably and efficiently by using highly versatile plastics.

BASF's wide product range helps our customers to find the best material for many of these new and demanding applications. Our experts assist in developing new solutions and concepts as well as putting them into practice.

One focus is placed on battery systems of hybrid or electric vehicles. The key to the success of electromobility will be how quickly the performance, capacity, weight, safety, reliability and above all these, the manufacturing costs and economic efficiency of the battery systems can be improved further. Engineering plastics can make a vital contribution to optimizing the system as a whole and enabling mass production that is economically viable.

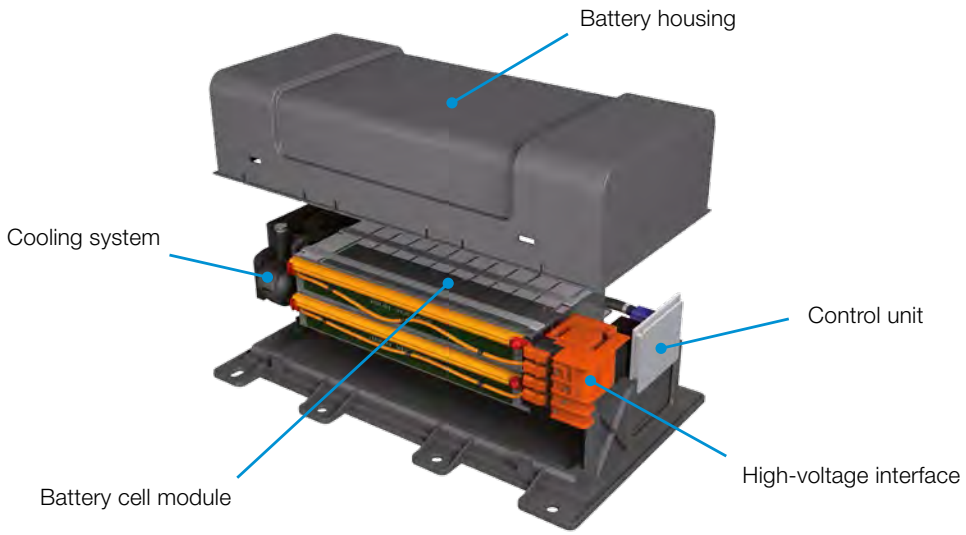


Fig. 8: Plastics in battery systems

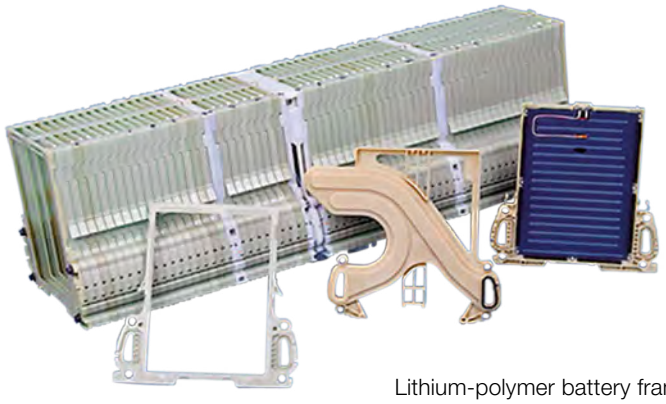
Depending on the specific requirements Ultradur®, Ultradur® S, Ultramid® and possibly Ultrason® are suitable for the battery or cell frames of lithium-polymer batteries. Our specialists are glad to assist in selecting the most suitable material.

For instance, Ultramid® grades with optimized hydrolysis resistance such as Ultramid® A3WG6 HRX or A3WG7 HRX are already used for liquid-cooled batteries. These grades are able to withstand hot coolants at peak temperatures of up to 130 °C.

The particular properties of the high-performance elastomer Cellasto® are a major advantage over conventional elastic mounts, particularly in engine and powertrain mounts for electric vehicles. High-frequency noise is effectively decoupled. This is a particularly important consideration because the vibration behaviour of electric engines differs very greatly from that of combustion engines. High forces act here due to high-torque engines with high-frequency vibrations on the bearing positions. Cellasto® offers amplitude-selective damping and the possibility of achieving major deformations in compact installation spaces. Thus batteries for electric vehicles can be stored effectively. In certain cases, it is even possible to use the weight of the battery as a weight-neutral dynamic vibration isolator.

For battery casings themselves – which today are still frequently made of metal – the use of both short glass fiber-reinforced Ultramid®, long glass fiber-reinforced Ultramid® Structure as well as composite solutions with Ultracom® is possible, depending on the size and weight of the battery. Using plastics makes it possible to optimize the weight and space as well as to integrate many functions easily. Modern fabrication methods which can be implemented on an industrial scale make a crucial contribution to the economic viability of the system as a whole.

BASF cooperates closely with partners and customers to come up with practical solutions. Beside obvious topics such as mechanical, thermal and electrical properties, issues relating to electromagnetic shielding, flame retardance and crash safety are also discussed. Especially in the event of accidents, plastics can offer crucial advantages. For instance, Ultramid® Structure is noted for its high energy absorption and good crash performance. Not least the electrical insulating capacity of plastics can be a crucial safety factor in the event of a crash.



Lithium-polymer battery frame

In the high-voltage system of hybrid and electric vehicles, voltages of up to 400 V and currents of over 100 A are achieved nowadays. Plastics are essential in guaranteeing the function and safety of components over the entire service life of the vehicle. Depending on the specific requirement, special Ultramid® or Ultradur® grades can be used; also flame-retardant types are available where required. What should not be ignored are the possible high temperatures generated under high currents and mechanical loads as well as the exposure to vibrations caused by the relatively heavy high-voltage cables. With many high-voltage components, the color orange is also mandatory as a safety and identifying feature. The color has to be stable across the entire service life of the component, which might require special solutions particularly at high operating temperatures. Many requirements are now specified in standards and industry instructions such as VDA[13] LV214 and LV215.

Elastollan® is used for high-quality cable sheathings and cable components. It is indispensable for fulfilling the diverse technical demands on high voltage, traction and charging cables safely and permanently.

The wide range of products and the wide experience of our experts can help our customers to find the best solutions for their particular application.

The charging technology for electric vehicles and plug-in hybrids constitutes an interface between the electrical system of the vehicle and the building installation. The single-phase or three-phase connection of the vehicles to the low-voltage grid via control cabinets or metering units is regulated, among others, by VDE[14] Application Rule VDE-AR-N 4102.

The charging station is normally connected to the electric vehicle via a type 2 plug-in connector in accordance with IEC 62196-2 or what is known as the “Combined Charging System”. This was defined by SAE and ACEA as a standard charging interface and should be a standard feature in all European vehicles from 2017. In this area, there is an increasing demand for flame-retardant plastics, which have been rarely used in the automotive industry until now.

High-voltage connector

[13] VDA=German Automotive Industry Association
[14] VDE = German Electrical Engineering Association

With charging cables made of Elastollan®, safe, lightweight and flexible cables and spiral cables (also at low temperatures) are possible. They make handling during charging easier for the car owner and he can store the cables more easily.

In addition to the plastics which are already established in automotive electrical systems, BASF – as one of the leading manufacturers of engineering plastics in the area of electrical installation – is able to offer a wide range of flame-retardant products. Detailed information regarding flame-retardant grades used in installation technology can be found in the brochure “Engineering plastics for the E&E industry”.

Engineering plastics are suitable for many electromobility applications which are not in public focus but are nevertheless no less important. Examples include housings and components for power electronics, controllers or battery management systems. Since the number of units produced so far is still limited, they are frequently made from metal.

As manufacturing volumes rise, plastic solutions will become an increasingly attractive option. Highly filled or long glass fiber-reinforced thermoplastics can replace even metal alloy castings in electric coolant pumps or air-conditioning compressors. They are even conceivable for the housings of electric motors or transmissions. When it comes to climate control and heating in electric cars, plastics can be used for auxiliary heaters, heat exchangers, fans and blowers.

In order to jointly overcome the many challenges, a close and trustworthy relationship with vehicle manufacturers and the entire supply chain is particularly vital and sensible, especially in such a new application area. BASF experts from the different specialist fields are ready to help our customers to successfully implement projects.

High-voltage connector

4.2 Laser welding

A joining technique which has quickly become established in automotive electronics is laser welding. It joins together plastic components quickly, contactless, dust-free and without any mechanical loading. This makes it not only cleaner than adhesive bonding; it also prevents possible damage to sensitive components caused by vibrations, as can occur with other welding methods. In addition, components can be joined together using laser welding in a particularly secure and reproducible way.

Laser welding involves a laser-transparent component being joined to a laser-absorbing component. The absorbing component absorbs the laser energy and melts at the focal point. The conduction in the contact region also causes the laser-transparent component to be heated at the same time until ultimately both components fuse together.

Whereas all black standard materials more or less absorb laser light, the challenge is to develop laser-transparent materials.

The process of laser welding requires special materials which have good and above all consistent laser transparency. BASF offers different proven Ultramid® combinations such as Ultramid® A3HG5 in black and uncolored, or special laser-transparent products such as the black Ultramid® A3EG6 LT.

With the new Ultradur® LUX, BASF researchers have been able to in-crease the laser transparency to a high and constant level that has not previously been achieved for PBT. Products such as Ultradur® LUX B 4300 G4 and Ultradur® LUX B 4300 G6 are available in black and uncolored. These materials allow good process reliability and high welding speeds. But it is not just the laser transparency per se that is better; the quality of the laser beam which is allowed through has also been improved considerably. It can be shown that Ultradur® LUX allows approximately two and a half times more light to pass through within the relevant wavelength than a conventional PBT GF 30, and this at the same time with a much lower widening of the laser beam.

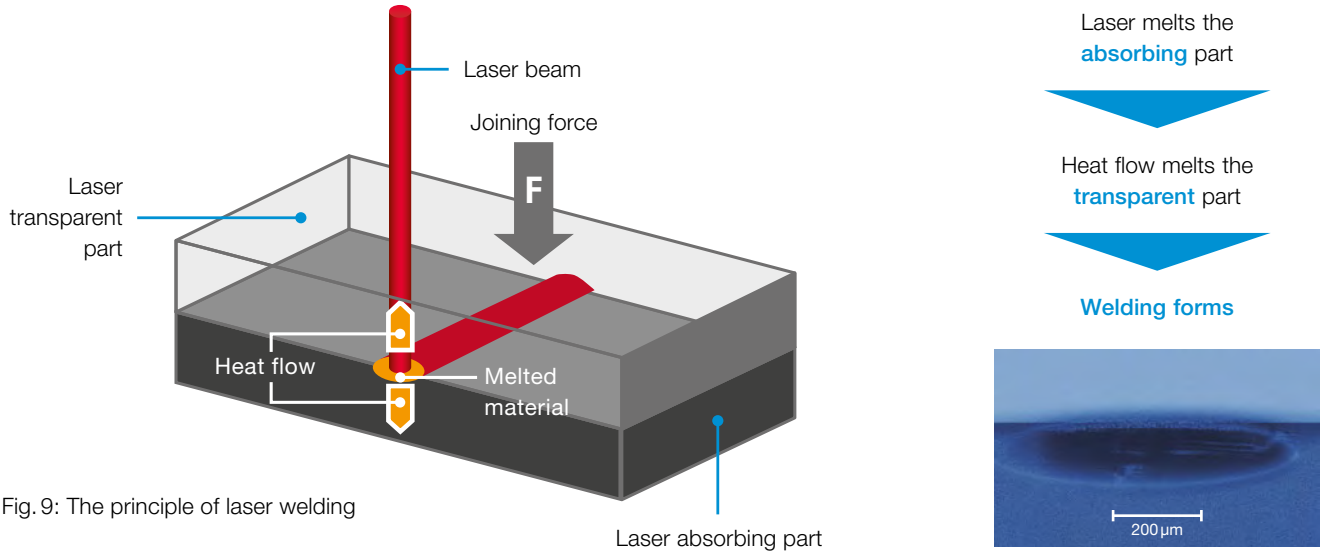


Fig. 9: The principle of laser welding

Laser welding and the laser-transparent Ultramid® and Ultradur® grades offer the user and processor numerous advantages:

- great freedom of design
- hugely expanded process window
- shorter cycle times
- high process consistency
- high quality consistency
- greater flexibility
- no storage of other materials (e. g. adhesive and primer)
- no particle abrasion
- no mechanical loading of the molded parts
- low, locally restricted input of heat
- virtually wear-free method
- materials with different viscosities can be welded
- repair welding possible
- no vibrations caused by the welding process

The welding of pre-mounted assemblies even with sensitive electronic or mechatronic components is possible. The reasons: the components are not subjected to any mechanical loading when they are joined together and there is only a low, locally restricted input of heat into the material. The weld line can be monitored very precisely. The polymer melt is expelled without lint or fuzz. This means that the flow behavior of air or liquids in laser beam-welded components is less prone to errors, which can be very important especially for sensors. In addition, the method works very flexibly, with almost no wear and no contact. With different versions such as contour, simultaneous, quasi-simultane-ous or mask welding, the method can be adapted perfectly for specific requirements.

In this special field our experts are glad to offer advice on the optimum choice of material and process technology.

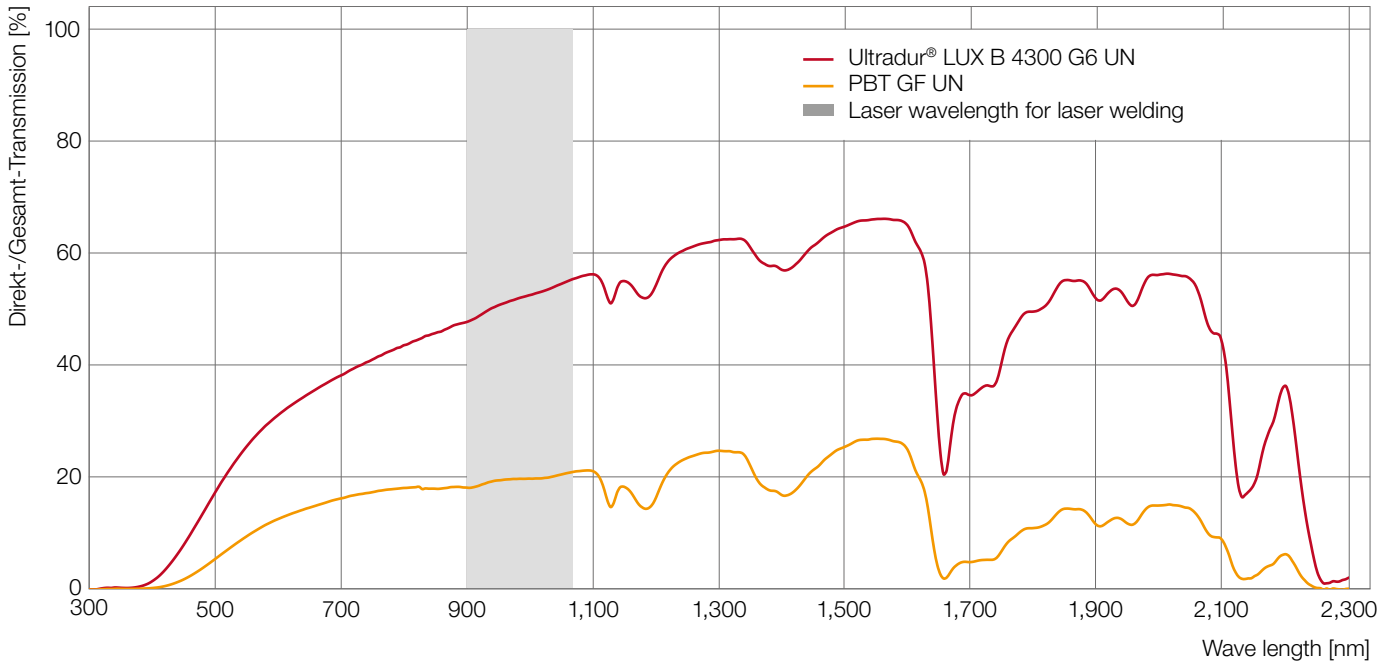


Fig. 10: Spectrally resolved transmission (total transmission) of Ultradur® LUX compared to a standard PBT: transmission curves for materials that are reinforced with 30 % glass fibers (2 mm test plates)

4.3 Ultramid® EQ for sensitive automotive electrics

For reliable micro-electronics in sensitive automotive applications such as control units and sensors, BASF has now developed a portfolio of various polyamide 6 and 66 grades that help prevent damage to circuits by electric corrosion.

The different Ultramid® EQ grades (EQ = electronic quality) are extremely pure, which means they have hardly any electrically active or corrosive contents, yet still offer good resistance to heat aging. They are subject to special quality tests that cover raw material selection, the production process, and the analysis of the halogen content. Available globally, the portfolio consists of uncolored and black grades with glass fiber contents of 30 and 35 percent, which are also laser-markable.

Portfolio (excerpt):
- Ultramid® A3EG6 EQ (PA66 GF30)
- Ultramid® A3EG7 EQ (PA66 GF35)
- Ultramid® B3EG6 EQ (PA6 GF30)

Ultramid® EQ has already proven itself in a range of applications under harsh conditions.

Electronic assemblies in modern transmission control units or safety-related applications such as airbag and anti-lock systems are becoming ever more compact and complex. They are also often exposed to high ambient temperatures and aggressive media such as oil. The delicate circuits are often connected to semi-conductors via thin wires which is known as wire bonding. In such surroundings, disruptive effects such as corrosion, ion migration, electrolyte formation, and creep currents can arise and in extreme cases cause entire assemblies to fail.

Transmission control unit

Plastics for housings and components have to be equipped in such a way that they do not react with the metals involved and thus prevent electronic failure.

All Ultramid® EQ grades have an organic heat stabilizer with a very low halogen content of less than 1 ppm. This prevents halogens like iodine or bromine from damaging metal wiring, ions from reacting with the metals, and undesired electric currents from arising.

In addition to the specified formula and complex production process, all Ultramid® EQ charges are checked carefully. This ensures that the manufacturing process does not introduce any halogen contamination to the material. The relevant certificate is provided to customers if desired. The new Ultramid® EQ portfolio is also well-suited for use in electric and hybrid vehicles with elevated AC and DC voltages.

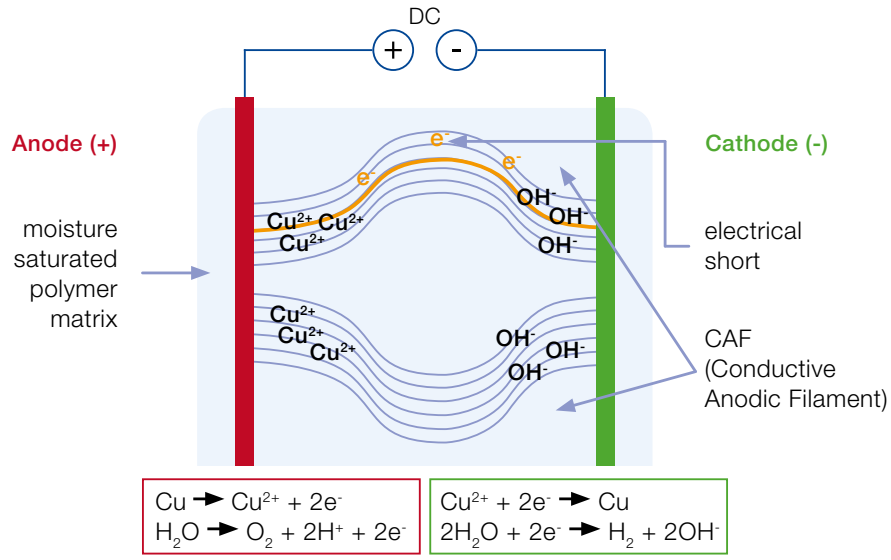


Fig. 11: Electrolytic corrosion (schematized)

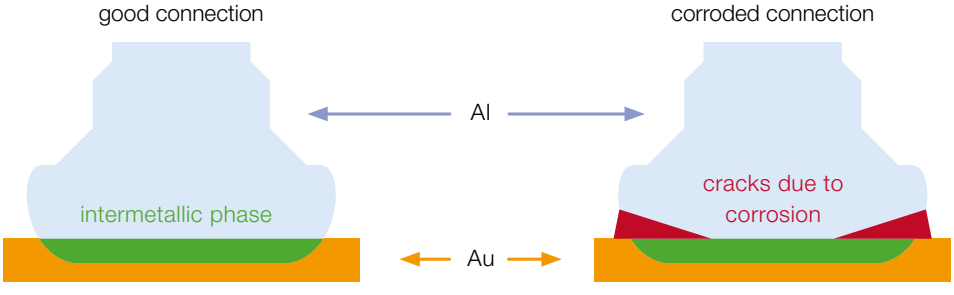


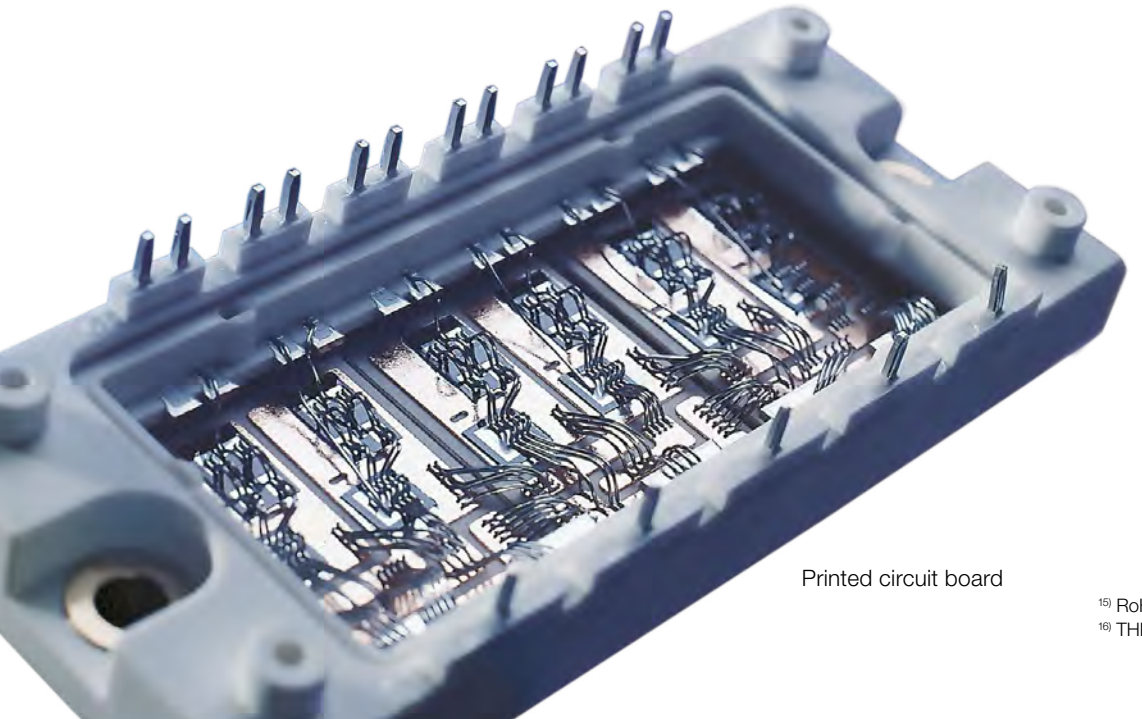
Fig. 12: Wire-bond corrosion (schematized)

4.4 Lead-free soldering

Soldering with lead-free solder or solder that complies with RoHS[15] has found its way into automotive electrics and electronics, as a result of voluntary commitment by the industry and the increasing global restrictions on the use of lead and lead alloys.

Lead-free solders require higher soldering temperatures and are thus more demanding with respect to the dimensional stability under heat of the plastics used. In accordance with DIN EN 61760-1 or J-STD-020C, the temperatures of the different soldering methods such as reflow, THR[16] or wave soldering reach peaks of up to 265 °C for up to 40 seconds. In the case of manual rework/repair soldering, even higher peak temperatures may occur in individual cases.

These high temperatures can no longer be handled safely with many plastics. They may result, for example, in permanent deformations if unsuitable plastic parts are inserted before the actual soldering process. Another problem can be caused by what is known as blistering as a result of evaporating moisture. What should also not be underestimated are differences in the thermal expansion between the printed circuit board and the components to be soldered. This can lead to tension and stress during cooling after the soldering process. As well, this can place a heavy load on the solder joints or even result in the failure of solder joints or components.



Printed circuit board

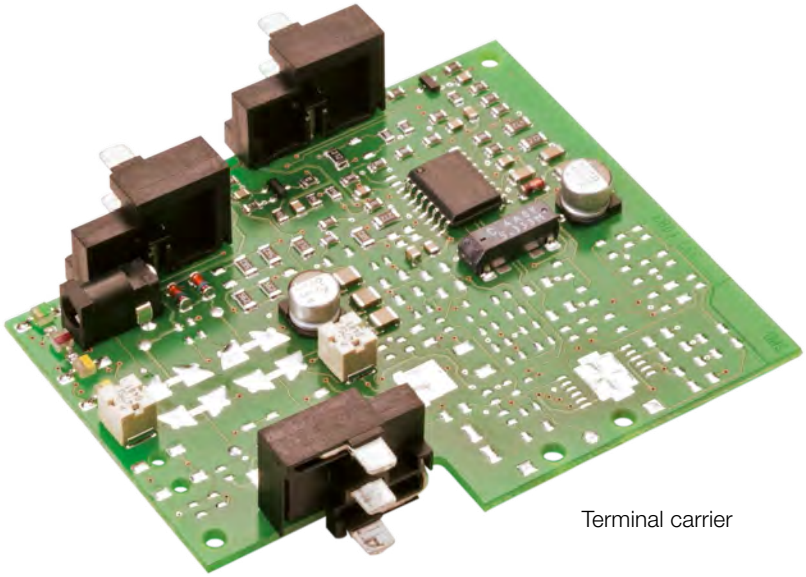
[15] RoHS = Restriction of Hazardous Substances
[16] THR = Through Hole Reflow

With a melting point of 295 °C, Ultramid® T is a high-performance thermoplastic which is suitable for lead-free soldering methods. At the same time it can meet further important requirements for automotive electrics such as good mechanics and good processing properties.

Ultramid® T can be used with all conventional soldering methods. It is suitable for SMD[17] and THR fitting.

The lower thermal expansion of the glass fiber-reinforced grades reduces the differences in thermal expansion, e. g. when soldering wire-to-board joints. Ultramid® T has a lower moisture absorption than e. g. PA66, which reduces the risk of blistering.

However, if components are stored for a longer time prior to soldering, moisture-proof packaging or pre-drying before the soldering process may be helpful in order to further reduce the risk of blistering.



Terminal carrier

[17] SMD = Surface Mounted Device

4.5 Ultrasim®

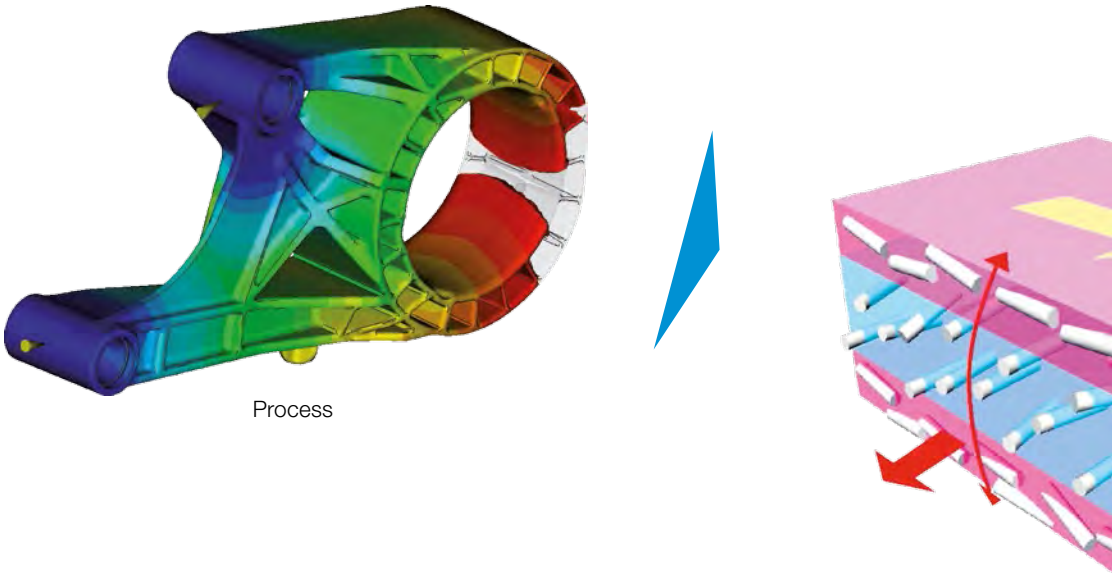
Ultrasim® is BASF's comprehensive and flexible CAE[18] expertise with innovative BASF plastics. The calculation of component concepts on a virtual basis extends from choosing the appropriate BASF materials and corresponding material models, the virtual prototype and the ideal manufacturing process through to the finished component. With Ultrasim®, components can be tailored to meet specific requirements – for efficient, lightweight components subject to high levels of stress and thus for long-term market success.

Building blocks of Ultrasim®:

- integrative simulation
- injection molding process
- anisotropy
- mathematical part optimization
- failure modeling
- high speed tensile tests
- material modeling

The modern calculation of thermoplastic components is very demanding for the developer. When it comes to the interaction between manufacturing process, component geometry and material, only an integrated approach can lead to an ideal component. Plastics reinforced with short glass fibers in particular have anisotropic properties depending on how the fibers perform in injection molding. Modern optimization methods support the component design and can improve it in every phase of its development.

BASF's Integrative Simulation incorporates the manufacturing process of the plastic component into the calculation of its mechanical performance. Using the numerical FE filling simulation as the basis for the calculation of the fiber orientation, each point of the component is assigned corresponding anisotropic material characteristics.



Process

[18] CAE = Computer Aided Engineering

This is provided by a completely new numerical description of the material which takes the properties typical of the plastic into account in the mechanical analysis. These properties include

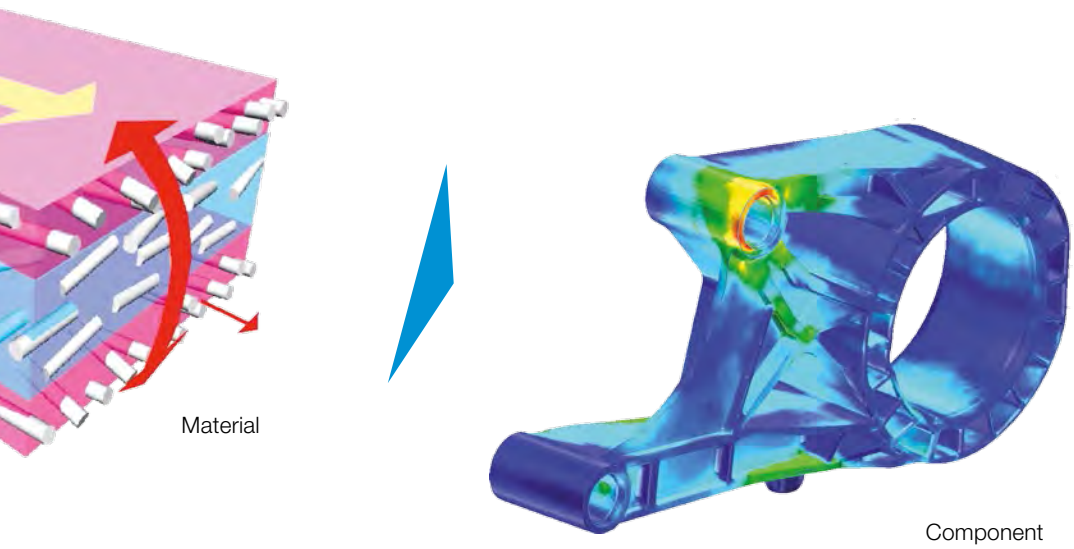
- anisotropy
- non-linearity
- dependence on strain rate
- tension-compression asymmetry
- failure performance
- dependence on temperature

BASF now offers an additional service for polyurethane systems. The internal simulation tool Ultrasim® has been extended so that the behavior of PU systems during foaming can be predicted in closed as well as open molds.

With the aid of Ultrasim®, BASF's CAE experts support our customers in designing sophisticated plastic components, among others with the following services:

- filling studies
- gate and weld line optimization
- shrinkage
- warpage
- long-term consistency of the component under sealing, assembly and operating loads
- creep behavior
- metal inserts
- mechanics
- crash
- simulation of foam processes
- integrative simulation of conductive plastics

So, BASF is more than a raw material manufacturer supplying innovative plastics that meet delivery time and quality requirements. Ultrasim® adapts flexibly to meet individual customer requirements. Weight and cost savings are just as important aims in the automotive industry as in the electrical/electronics sector and many other industries – with Ultrasim®, they can be achieved quickly and reliably.



Material

Component

4.6 Materials testing, parts testing and processing service

Our accredited laboratory for molding compound or materials testing can advise and support customers on all aspects of materials science and plastics-specific tests (accreditation certificate D-PL-14121-04-00 in accordance with DIN EN ISO/IEC 17025:2005). The range of testing services available covers the full spectrum of mechanical, thermal and electrical properties, but also topics such as weathering or fire performance.

Another vital service is offered by our laboratory for parts testing and joining technology which supports customers' project work. The extensive test capabilities include:

- temperature and climate storage tests
- temperature shock tests
- tensile, compression, bending, pull-out tests
- impact tests (crash, drop, head impact, stone impact)
- cyclic internal pressure tests with superimposed temperature and climate profiles
- flow tests, leak tests
- acoustic analyses, vibration analysis
- deformation and strain measurements by means of stereo photogrammetry
- non-destructive testing with computer tomography
- infrared thermography
- documentation of all transient processes with high-speed cameras
- testing, evaluation and optimization of all relevant joining technologies
- laser transparency and laser markability analyses

If necessary, specific tests from the field of automotive electronics or customer-specific tests can also be carried out, for example temperature shock tests followed by a leak tightness test, temperature-controlled oil storage tests on assemblies with simultaneous functional testing or shaker tests to demonstrate endurance strength.

An experienced team of processing experts is available to answer questions about processing, processing technology as well as special processing techniques. A well-equipped technical processing center can be used for project work.

Air mass sensor

5 | Range chart

The following range chart shows a small overview of BASF's extensive portfolio of engineering plastics and polyurethanes.

Information on all available products can be found at www.plasticsportal.eu or at the infopoints:

- PU-Infopoint: pu-infopoint@basf.com
- Ultra-Infopoint: ultraplaste.infopoint@basf.com
- Elastollan®-Infopoint: elastollan-infopoint@basf.com

Double-clutch transmission

Ultramid®

Reinforced grades

Typical values at 23°C[20]	Unit	Test method	Condition	A3WG6
Features				
Symbol	–	ISO 1043	–	PA66-GF30
Density	g/cm³	ISO 1183	–	1.36
Viscosity number (solution 0.005 g sulfuric acid/ml)	ml/g	ISO 307	–	145
Water absorption, saturation in water at 23 °C	%	ISO 62	–	5.2-5.8
Moisture absorption, saturation in standard cond. atmo. 23°C/50 % r. h.	%	ISO 62	–	1.5-1.9
Processing				
Melting point, DSC	°C	DIN 53 765	–	260
Melt volume rate MVR 275/5	cm³/10 min	ISO 1133	–	40
Melt temperature range, injection-molding/extrusion	°C	–	–	280-300
Mold temperature range, injection-molding	°C	–	–	80-90
Molding shrinkage, restricted[21]	%	–	–	0.55
Flammability				
Test according to UL-Standard at d = 1.6 mm thickness	class	UL 94	–	HB
Motor Vehicle Safety Standard Test: thickness ≥ 1 mm	–	FMVSS 302[24]	–	+
Mechanical Properties				
Tensile modulus of elasticity	MPa	ISO 527-1/-2	dry/cond.	10,000/7,200
Stress at yield (v = 50 mm/min), at break* (v = 5 mm/min)	MPa	ISO 527-1/-2	dry/cond.	190*/130*
Elongation at yield (v = 50 mm/min), at break* (v = 5 mm/min)	%	ISO 527-1/-2	dry/cond.	3*/5*
Tensile creep modulus, 1,000 h, elongation ≤ 0.5 %, +23 °C	MPa	ISO 899-1	cond.	5,300
Flexural modulus	MPa	ISO 178	dry/cond.	8,600/6,500
Flexural stress at max. force	MPa	ISO 178	dry/cond.	280/210
Charpy impact strength (23 °C)[22]	kJ/m²	ISO 179/1eU	dry/cond.	85/100
Charpy impact strength (-30 °C)	kJ/m²	ISO 179/1eU	dry	70
Charpy notched impact strength (23 °C)[22]	kJ/m²	ISO 179/1eU	dry/cond.	13/22
Charpy notched impact strength (-30 °C)	kJ/m²	ISO 179/1eA	dry	10
Izod notched impact strength A (23 °C)[22]	kJ/m²	ISO 180/A	dry/cond.	11.5/15.5
Izod notched impact strength A (-30 °C)	kJ/m²	ISO 180/A	dry	–
Thermal properties				
Heat distortion temperature under 1.8 MPa load (HDT/A)	°C	ISO 75-1/-2	–	250
Heat distortion temperature under 0.45 MPa load (HDT/B)	°C	ISO 75-1/-2	–	250
Max. service temperature, up to a few hours[23]	°C	–	–	240
Temperature index for 50 % loss of tensile strength after 20,000 h/5,000 h	°C	IEC 60216	–	145/175
Coefficient of linear expansion, longit./transv. (23-80 °C)	10^{-4}/K	ISO 11359-1/-2	–	0.2-0.3/0.6-0.7
Thermal conductivity	W/(m·K)	DIN 52 612-1	–	0.35
Specific heat capacity	J/(kg·K)	–	–	1,500
Electrical properties				
Dielectric constant at 1 MHz	–	IEC 60250	dry/cond.	3.5/5.6
Dissipation factor at 1 MHz	10^{-4}	IEC 60250	dry/cond.	140/3,000
Volume resistivity	Ω·m	IEC 60093	dry/cond.	10^{13}/10^{10}
Surface resistivity	Ω	IEC 60093	cond.	10^{10}
Comparative tracking index CTI, test solution A	–	IEC 60112	–	450
Core Products				UN
				SW00564

[20] For undyed product, unless otherwise indicated in the product designation.

[21] Test box with central gating, base dimensions (107 · 47 · 1.5) mm, processing conditions: $T_{M\,PA6}$ = 260 °C, $T_{M\,PA66}$ = 290 °C, T_W = 60 °C for unreinforced and T_W = 80 °C for reinforced grades

[22] N = not broken

[23] Empirical values for parts repeatedly exposed to this temperature for several hours at a time over a period of years, provided that shaping and processing were in accord with the material.

[24] + = passed

A3WG7	A3EG5	A3HG5	A3HG7	B3EG6	B3WG6	B3GK24
PA66-GF35	PA66-GF25	PA66-GF25	PA66-GF35	PA6-GF30	PA6-GF30	PA6-(GF10+GB20)
1.41	1.32	1.32	1.41	1.36	1.36	1.34
145	145	145	145	140	140	140
4.7-5.3	5.7-6.3	5.7-6.3	4.7-5.3	6.3-6.9	6.3-6.9	6.3-6.9
1.4-1.8	1.7-2.1	1.7-2.1	1.4-1.8	1.9-2.3	1.9-2.3	1.9-2.3
260	260	260	260	220	220	220
35	50	50	40	50	50	70
280-300	280-300	280-300	280-300	270-290	270-290	270-290
80-90	80-90	80-90	80-90	80-90	80-90	80-90
0.5	0.55	0.55	0.5	0.35	0.35	0.5
HB	HB	HB	HB	HB	HB	HB
+	+	+	+	+	+	+
11,500/8,500	8,600/6,500	8,600/6,500	11,200/8,500	9,500/6,200	9,500/6,200	6,000/3,000
210*/150*	175*/120*	170*/120*	200*/150*	185*/115*	185*/115*	110*/60*
3*/5*	3*/6*	3*/6*	3*/5*	3.5*/8*	3.5*/8*	3.5*/15*
6,600	4,300	4,300	6,600	–	–	2,000
10,000/8,000	7,600/6,000	7,600/6,000	10,000/8,500	8,600/5,000	8,600/5,000	5,000/3,000
300/240	260/200	260/200	300/240	270/180	270/180	130/70
95/105	65/90	65/90	95/100	95/110	95/110	40/90
75	55	55	75	80	80	39
14/22	12/18	12/18	13/22	15/30	15/30	5/11
12	9	9	12	11	11	4.5
14/18	9.5/15	9.5/15	14/18	15/20	15/20	5/8.5
–	–	–	–	–	–	–
250	245	245	250	210	210	150
250	250	250	250	220	220	200
240	240	240	240	200	200	200
145/175	135/165	140/170	140/170	135/165	145/175	–
0.15-0.2/0.6-0.7	0.25-0.35/0.6-0.7	0.25-0.35/0.6-0.7	0.15-0.2/0.6-0.7	0.2-0.25/0.6-0.7	0.2-0.25/0.6-0.7	0.35-0.4/–
0.35	0.34	0.34	0.35	0.36	0.36	0.34
1,500	1,600	1,600	1,500	1,500	1,500	1,400
3.5/5.7	3.5/5.5	3.5/5.5	3.5/5.7	3.8/6.8	3.8/6.8	3.9/4.6
200/3,000	140/1,600	140/1,600	200/1,500	230/2,200	230/2,200	200/700
$10^{13}/10^{10}$	$10^{13}/10^{10}$	$10^{13}/10^{10}$	$10^{13}/10^{10}$	$10^{13}/10^{10}$	$10^{13}/10^{10}$	$10^{13}/10^{10}$
10^{10}	10^{10}	10^{10}	10^{10}	10^{10}	10^{10}	10^{10}
450	550	550	550	575	450	425
UN	UN	UN	UN	UN	UN	UN
SW20560	–	SW00564	SW00564	SW00564	SW00564	SW00564

Ultramid®

Reinforced grades, reinforced grades with good hydrolysis resistance, impact-modified grades, Ultramid® S Balance

Typical values at 23°C[20]	Unit	Test method	Condition	TKR 4355 G5
Features				
Symbol	–	ISO 1043	–	PA6T/6 GF25
Density	g/cm³	ISO 1183	–	1.35
Viscosity number (solution 0.005 g sulfuric acid/ml)	ml/g	ISO 307	–	130
Water absorption, saturation in water at 23 °C	%	ISO 62	–	5-6
Moisture absorption, saturation in standard cond. atmo. 23°C/50 % r.h.	%	ISO 62	–	1.1-1.5
Processing				
Melting point, DSC	°C	DIN 53 765	–	295
Melt volume rate MVR 275/5	cm³/10 min	ISO 1133	–	–
Melt temperature range, injection-molding/extrusion	°C	–	–	310-330
Mold temperature range, injection-molding	°C	–	–	80-120
Molding shrinkage, restricted[21]	%	–	–	0.4
Flammability				
Test according to UL-Standard at d = 1.6 mm thickness	class	UL 94	–	HB
Motor Vehicle Safety Standard Test: thickness ≥ 1 mm	–	FMVSS 302[24]	–	–
Mechanical Properties				
Tensile modulus of elasticity	MPa	ISO 527-1/-2	dry/cond.	9,000/9,000
Stress at yield (v = 50 mm/min), at break* (v = 5 mm/min)	MPa	ISO 527-1/-2	dry/cond.	185/170
Elongation at yield (v = 50 mm/min), at break* (v = 5 mm/min)	%	ISO 527-1/-2	dry/cond.	3/3
Tensile creep modulus, 1,000 h, elongation ≤ 0.5 %, +23 °C	MPa	ISO 899-1	cond.	6,500
Flexural modulus	MPa	ISO 178	dry/cond.	7,300
Flexural stress at max. force	MPa	ISO 178	dry/cond.	–
Charpy impact strength (23 °C)[22]	kJ/m²	ISO 179/1eU	dry/cond.	80
Charpy impact strength (-30 °C)	kJ/m²	ISO 179/1eU	dry	–
Charpy notched impact strength (23 °C)[22]	kJ/m²	ISO 179/1eU	dry/cond.	11
Charpy notched impact strength (-30 °C)	kJ/m²	ISO 179/1eA	dry	–
Izod notched impact strength A (23 °C)[22]	kJ/m²	ISO 180/A	dry/cond.	8.5
Izod notched impact strength A (-30 °C)	kJ/m²	ISO 180/A	dry	–
Thermal properties				
Heat distortion temperature under 1.8 MPa load (HDT/A)	°C	ISO 75-1/-2	–	245
Heat distortion temperature under 0.45 MPa load (HDT/B)	°C	ISO 75-1/-2	–	–
Max. service temperature, up to a few hours[23]	°C	–	–	270
Temperature index for 50 % loss of tensile strength after 20,000 h/5,000 h	°C	IEC 60216	–	135/160
Coefficient of linear expansion, longit./transv. (23-80 °C)	10^{-4}/K	ISO 11359-1/-2	–	0.25/0.5-0.6
Thermal conductivity	W/(m·K)	DIN 52 612-1	–	0.25
Specific heat capacity	J/(kg·K)	–	–	1,400
Electrical properties				
Dielectric constant at 1 MHz	–	IEC 60250	dry/cond.	4.3/4.5
Dissipation factor at 1 MHz	10^{-4}	IEC 60250	dry/cond.	300/400
Volume resistivity	Ω·m	IEC 60093	dry/cond.	10^{13}/10^{12}
Surface resistivity	Ω	IEC 60093	cond.	10^{13}
Comparative tracking index CTI, test solution A	–	IEC 60112	–	600
Core Products				UN
				SW00564

[20] For undyed product, unless otherwise indicated in the product designation.

[21] Test box with central gating, base dimensions (107 · 47 · 1.5) mm, processing conditions: $T_{M\,PA6}$ = 260 °C, $T_{M\,PA66}$ = 290 °C, T_W = 60 °C for unreinforced and T_W = 80 °C for reinforced grades

[22] N = not broken

[23] Empirical values for parts repeatedly exposed to this temperature for several hours at a time over a period of years, provided that shaping and processing were in accord with the material.

[24] + = passed

TKR 4355 G7	A3HG6 HR	B3ZG3	S3WG6
PA6T/6 GF35	PA66-GF30	PA6-I GF15	PA610-GF30
1.43	1.37	1.22	1.31
130	145	160	150
4.3-5.3	5.2-5.8	7.2-7.8	2.0-2.6
0.8-1.2	1.5-1.9	2.1-2.7	0.8-1.2
295	260	220	220
–	25	35	30
310-330	280-300	270-290	270-290
80-120	80-90	80-90	80-90
0.35	0.55	0.5	0.4
HB	–	HB	–
+	–	+	–
12,000/12,000	10,000/6,800	5,500/2,900	8,600/6,800
210/200	190*/120*	110*/ 60*	150/110
3/3	3.2*/5.4*	4*/18*	4/6
8,700	5,300	–	–
10,600	8,700/5,800	4,500/2,500	7,700/6,300
290	275/200	150/80	225/180
100	80/90	75/110	85/85
–	65	55	80
14.5	11/16	16/30	13/13
–	9	7	8
–	12/20	15/29	–
–	9	5	–
245	250	180	200
–	250	200	220
270	240	180	–
135/160	–	–	–
0.15/0.5-0.6	0.2-0.3/0.6-0.7	0.3-0.35/0.7-0.8	0.3/0.9-1.5
0.28	0.34	0.34	0.31
1,300	1,500	–	1,300
4.2/4.4	3.5/5.6	3.7/6.2	3.8/4.3
200/300	– /3,000	250/2,000	176/567
$10^{13}/10^{12}$	$10^{13}/10^{10}$	$10^{13}/10^{10}$	$7^{10}/8^{9}$
10^{13}	10^{10}	10^{10}	2^{14}
600	450	550	550
UN	–	–	–
SW00564	SW23591	SW30564	SW00564

Nomenclature

Structure

The name of Ultramid® commercial products generally follows the scheme below:

Ultramid®	Subname	Technical ID	Suffixes	Color

Subnames

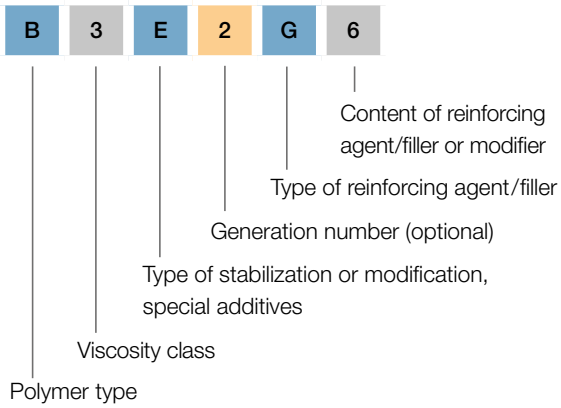
Subnames are optionally used in order to particularly emphasize a product feature that is characteristic of part of a range.

Examples of subnames:

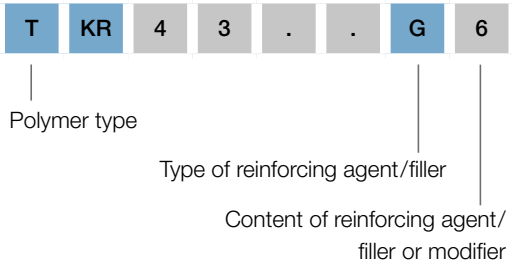
Endure	Particularly good long-term stabilization against hot air
Structure	Particularly good notched impact strength at low temperatures, and without any disadvantages for the stiffness and strength

Technical ID

The technical ID is made up of a series of letters and numbers which give hints about the polymer type, the melt viscosity, the stabilization, modification or special additives and the content of reinforcing agents, fillers or modifiers. The following classification scheme is found with most products:



Ultramid® T generally has the following classification scheme:



Letters for identifying polymer types

A	Polyamide 66
B	Polyamide 6
C	Copolyamide 66/6
D	Special polymer
S	Polyamide 610
T	Polyamide 6T/6

Numbers for identifying viscosity classes

3	Free-flowing, low melt viscosity, mainly for injection molding
35	Low to medium viscosity
4	Medium viscosity

Letters for identifying stabilization

E, K	Stabilized, light natural color, enhanced resistance to heat aging, weather and hot water, electrical properties remain unaffected
H	Stabilized, enhanced resistance to heat aging, hot water and weather, only for engineering parts, electrical properties remain unaffected, depending on the grade light-beige to brown natural color
W	Stabilized, high resistance to heat aging, can only be supplied uncolored and in black, less suitable if high demands are made on the electrical properties of the parts

Letters for identifying special additives

F	Functional additive
L	Impact-modified and stabilized, impact resistant when dry, easy flowing, for rapid processing
S	For rapid processing, very fine crystalline structure, for injection molding
U	With flame-retardant finish without red phosphorus
X	With red phosphorus as the flame-retardant finish
Z	Impact-modified and stabilized with very high low-temperature impact strength (unreinforced grades) or enhanced impact strength (reinforced grades)

Letters for identifying reinforcing agents/fillers

C	Carbon fibers
G	Glass fibers
K	Glass beads
M	Minerals
GM	Glass fibers in combination with minerals
GK	Glass fibers in combination with glass beads

Key numbers for describing the content of reinforcing agents/fillers or modifiers

2	approx. 10 % by mass
3	approx. 15 % by mass
4	approx. 20 % by mass
5	approx. 25 % by mass
6	approx. 30 % by mass
7	approx. 35 % by mass
8	approx. 40 % by mass
10	approx. 50 % by mass

In the case of combinations of glass fibers with minerals or glass beads, the respective contents are indicated by two numbers, e. g.

GM53	approx. 25 % by mass of glass fibers and approx. 15 % by mass of minerals
GK24	approx. 10 % by mass of glass fibers and approx. 20 % by mass of glass beads

M602 represents approx. 30 % by mass of a special silicate (increased stiffness).

Suffixes

Suffixes are optionally used in order to indicate specific processing or application-related properties. They are frequently acronyms whose letters are derived from the English term.

Examples of suffixes:

Aqua®	Meets specific regulatory requirements for drinking water applications
Balance	Based at least partly on renewable raw materials
CR	Crash Resistant
EQ	Electronic Quality
FC	Food Contact; meets specific regulatory requirements for applications in contact with food
GIT	Gas Injection Technology
GP	General Purpose
High Speed	High flowability of the melt
HP	High Productivity
HR	Hydrolysis Resistant, increased hydrolysis resistance
HRX	New generation of HR products
LDS	Laser Direct Structuring, for preparing the electroplating of electrical conductor tracks
LF	Long Fiber Reinforced
LS	Laser Sensitive, can be marked with Nd:YAG laser
LT	Laser Transparent, can be penetrated well with Nd:YAG lasers and lasers of a similar wavelength
SF	Structural Foaming
SI	Surface Improved, for parts with improved surface quality
ST	Super Tough
WIT	Water Injection Technology

Color

The color is generally made up of a color name and a color number.

Examples of color names:
Uncolored
Black 00464
Black 00564
Black 20560

Ultradur®

Unreinforced grades, reinforced grades, reinforced grades with improved flowability

Typical values at 23 °C for uncolored products	Unit	Test method	B 4520	B 4300 G2
Product Features				
Symbol	–	ISO 1043	PBT	PBT-GF10
Colors: uncolored (UN), black (BK)	–	–	UN, SW	UN, SW
Density	kg/m³	ISO 1183	1,300	1,370
Viscosity number, solution 0.005 g/ml phenol/1.2-dicholoro benzene (1:1)	cm³/g	ISO 1628	130	115
Water absorption, saturation in water at 23 °C	%	similar to ISO 62	0.5	0.4
Moisture absorption, saturation in standard atmosphere 23 °C/50 % r. h.	%	similar to ISO 62	0.25	0.2
Processing methods				
Melting temperature, DSC	°C	ISO 11357-1/-3	223	223
Melt volume rate MVR 250° / 2.16 kg	cm³/10 min	ISO 1133	21	16
Melt volume rate MVR 275° / 2.16 kg	cm³/10 min	ISO 1133		
Melt temperature range, injection-molding	°C	–	250-275	250-275
Mold temperature range, injection-molding	°C	–	40-70	60-100
Melt temperature range, extrusion	°C	–		
Molding shrinkage, free, longitudinal/transversal	%	ISO 2577, 294-4	1.5/1.7	1.22/1.38
Fire behavior				
Flammability according to UL94 (thickness)[25]	class (mm)	UL94	HB (≥ 0.75)	HB (≥ 0.75)
Flammability (thickness)	class (mm)	IEC 60695-11-10		
Flammability of materials in cars at d ≥ 1 mm thickness[26]	–	FMVSS 302	+	+
Mechanical properties				
Tensile modulus of elasticity	MPa	ISO 527-1/-2	2,500	4,400
Tensile stress at yield (v = 50 mm/min), stress at break* (v = 5 mm/min)	MPa	ISO 527-1/-2	55	80*
Strain at yield (v = 50 mm/min)	%	ISO 527-1/-2	3.7	
Nominal strain at break (v = 50 mm/min), strain at break* (v = 5 mm/min)	%	ISO 527-1/-2	>50	4.5*
Tensile creep modulus, 1,000 h, elongation ≤ 0.5 %, +23 °C	MPa	ISO 899-1	1,200	
Flexural modulus	MPa	ISO 178	2,400	4,100
Flexural strength	MPa	ISO 178	85	140
Charpy impact strength (23 °C)[27]	kJ/m²	ISO 179/1eU	N	37
Charpy impact strength (-30 °C)[27]	kJ/m²	ISO 179/1eU	180	38
Charpy notched impact strength (23 °C)[27]	kJ/m²	ISO 179/1eA	5	4
Charpy notched impact strength (-30 °C)[27]	kJ/m²	ISO 179/1eA	3	3.5
Ball intendation hardness H 358 N/30 sec, H 961 N/30 sec*	MPa	ISO 2039-1	130	160*
Thermal properties				
Heat deflection temperature under 1.8 MPa (HDT/A)	°C	ISO 75-1/-2	55	175
Heat deflection temperature under 0.45 MPa (HDT/B)	°C	ISO 75-1/-2	165	210
Max. service temperature (short cycle operation)[28]	°C	–	200	210
Temperature index, at 50 % loss of tensile strength after 20,000 h/5,000 h	°C	IEC 60216-1	120/140	
Thermal coefficient of linear expansion, longitudinal (23-80 °C)	10^{-6}/K	ISO 11359-1/-2	130-160	50-60
Thermal conductivity (23 °C)	W/(m·K)	DIN 52 612-1	0.27	0.23
Specific heat capacity (23 °C)	J/(kg·K)		1,250	1,200
Electrical properties				
Dielectric constant at 100 Hz/1 MHz	–	IEC 60250	3.4/3.3	3.6/3.6
Dissipation factor at 100 Hz/1 MHz	10^{-4}	IEC 60250	20/200	12/150
Volume resistivity	Ω·m	IEC 60093	10^{14}	10^{14}
Surface resistivity	Ω	IEC 60093	10^{13}	10^{13}
Comparative tracking index CTI, test solution A	–	IEC 60112	550	300
Available versions				
Laser-markable (LS)/Laser-transparent (LT)	–	–		

[25] Yellow card available
[26] + = passed
[27] N = not broken
[28] Typical values for parts required to withstand repeated exposure to this temperature for several hours over years of use, assuming appropriate shaping and processing for the material.

B 4300 G4	B 4300 G6	B 4040 G4	B 4040 G6	B 4520 High Speed	B 4300 G2 High Speed	B 4300 G3 High Speed
PBT-GF20	PBT-GF30	PBT-PET-GF20	PBT-PET-GF30	PBT	PBT-GF10	PBT-GF15
UN, SW	UN, SW	SW	SW	UN	UN, SW	UN, SW
1,450	1,530	1,470	1,550	1,300	1,374	1,410
107	105	105	105	115	105	100
0.4	0.4	0.4	0.4	0.5	0.4	0.4
0.2	0.2	0.2	0.2	0.25	0.2	0.2
223	223	223	223	223	223	223
15	11			50	28	24
		22	15			
250-275	250-275	250-280	250-280	250-275	230-275	230-275
60-100	60-100	60-100	60-100	40-70	60-100	60-100
0.43/1.16	0.34/1.07	0.4/0.9	0.3/0.9		0.9/1.1	0.7/1.1
HB (≥ 0.75)	HB (≥ 0.75)			HB (≥ 0.75)	HB (≥ 1.5)	HB (≥ 0.75)
		HB (≥ 0.75)	HB (≥ 0.75)			
+	+	+	+			
7,000	9,800	7,500	10,500	2,200	4,400	5,600
115*	137*	120*	145*	53	85*	100*
				3.5		
3.5*	3*	2.8*	2.6*	>50	3.9*	3.7*
	7,500					
6,570	9,460	7,010				
170	210	190				
54	70	40	60	190	25	30
50	68	40	55		26	30
6.5	9	5.5	8	4	3.5	5
6	8.5					
180*	190*	190				
205	215	180	200	55	165	185
220	220	215	220	130	210	215
210	210	210	210	200	210	210
135/150	140/160		140/160			
30-40	20-30	20-30	20-30			
0.25	0.27					
1,150	1,050	1,100	1,050			
3.7/3.7	4/3.8	3.7/3.5	4/3.8		3.6/3.6	3.7/3.7
12/150	25/170	14/180	16/170		12/150	12/150
10^{14}	10^{14}	10^{14}	10^{14}		10^{14}	10^{14}
10^{13}	10^{13}	10^{13}	10^{13}		10^{13}	10^{13}
300	375	300	250		300	300
	LS, LT				LS	LS

Ultradur®

Reinforced grades with improved flowability, reinforced grades with good hydrolysis resistance, reinforced grades, reinforced grades with improved flowability

Typical values at 23 °C for uncolored products	Unit	Test method	B 4300 G4 High Speed	B 4300 G6 High Speed
Product Features				
Symbol	–	ISO 1043	PBT-GF20	PBT-GF30
Colors: uncolored (UN), black (BK)	–	–	UN, SW	UN, SW
Density	kg/m³	ISO 1183	1,450	1,530
Viscosity number, solution 0.005 g/ml phenol/1.2-dicholoro benzene (1:1)	cm³/g	ISO 1628	100	90
Water absorption, saturation in water at 23 °C	%	similar to ISO 62	0.4	0.4
Moisture absorption, saturation in standard atmosphere 23 °C/50 % r. h.	%	similar to ISO 62	0.2	0.2
Processing methods				
Melting temperature, DSC	°C	ISO 11357-1/-3	223	223
Melt volume rate MVR 250°/2.16 kg	cm³/10 min	ISO 1133	22	23
Melt volume rate MVR 275°/2.16 kg	cm³/10 min	ISO 1133		
Melt temperature range, injection-molding	°C	–	230-275	230-275
Mold temperature range, injection-molding	°C	–	60-100	60-100
Melt temperature range, extrusion	°C	–		
Molding shrinkage, free, longitudinal/transversal	%	ISO 2577, 294-4	0.47/1.1	0.35/1.1
Fire behavior				
Flammability according to UL94 (thickness)[25]	class (mm)	UL94	HB (≥ 0.75)	HB (≥ 1.5)
Flammability (thickness)	class (mm)	IEC 60695-11-10		
Flammability of materials in cars at d ≥ 1 mm thickness[26]	–	FMVSS 302		
Mechanical properties				
Tensile modulus of elasticity	MPa	ISO 527-1/-2	7,000	9,700
Tensile stress at yield (v = 50 mm/min), stress at break* (v = 5 mm/min)	MPa	ISO 527-1/-2	115*	140*
Strain at yield (v = 50 mm/min)	%	ISO 527-1/-2		
Nominal strain at break (v = 50 mm/min), strain at break* (v = 5 mm/min)	%	ISO 527-1/-2	3.3*	2.7*
Tensile creep modulus, 1,000 h, elongation ≤ 0.5 %, +23 °C	MPa	ISO 899-1		
Flexural modulus	MPa	ISO 178		10,000
Flexural strength	MPa	ISO 178		210
Charpy impact strength (23 °C)[27]	kJ/m²	ISO 179/1eU	45	60
Charpy impact strength (-30 °C)[27]	kJ/m²	ISO 179/1eU	40	50
Charpy notched impact strength (23 °C)[27]	kJ/m²	ISO 179/1eA	6	7.5
Charpy notched impact strength (-30 °C)[27]	kJ/m²	ISO 179/1eA		
Ball intendation hardness H 358 N/30 sec, H 961 N/30 sec*	MPa	ISO 2039-1		
Thermal properties				
Heat deflection temperature under 1.8 MPa (HDT/A)	°C	ISO 75-1/-2	195	200
Heat deflection temperature under 0.45 MPa (HDT/B)	°C	ISO 75-1/-2	220	220
Max. service temperature (short cycle operation)[28]	°C	–	210	210
Temperature index, at 50 % loss of tensile strength after 20,000 h/5,000 h	°C	IEC 60216-1		
Thermal coefficient of linear expansion, longitudinal (23-80 °C)	10^{-6}/K	ISO 11359-1/-2	30-40	20-30
Thermal conductivity (23 °C)	W/(m·K)	DIN 52 612-1		
Specific heat capacity (23 °C)	J/(kg·K)			
Electrical properties				
Dielectric constant at 100 Hz/1 MHz	–	IEC 60250	3.7/3.7	4/3.8
Dissipation factor at 100 Hz/1 MHz	10^{-4}	IEC 60250	12/150	25/170
Volume resistivity	Ω·m	IEC 60093	10^{14}	10^{14}
Surface resistivity	Ω	IEC 60093	10^{13}	10^{13}
Comparative tracking index CTI, test solution A	–	IEC 60112	300	350
Available versions				
Laser-markable (LS)/Laser-transparent (LT)	–	–	LS	LS

[25] Yellow card available
[26] + = passed
[27] N = not broken
[28] Typical values for parts required to withstand repeated exposure to this temperature for several hours over years of use, assuming appropriate shaping and processing for the material.

B 4330 G3 HR	B 4330 G6 HR	S 4090 G2	S 4090 G4	S 4090 G6	S 4090 G4 High Speed	S 4090 G6 High Speed
PBT-I-GF15	PBT-I-GF30	PBT-ASA-GF10	PBT-ASA-GF20	PBT-ASA-GF30	PBT-ASA-GF20	PBT-ASA-GF30
UN, SW	UN, SW	SW	UN, BK	UN, SW	SW	UN, SW
1,390	1,490	1,310	1,390	1,470	1,390	1,480
106	108	105	105	105	105	100
0.4	0.4	0.4	0.4	0.4	0.4	0.4
0.2	0.2	0.2	0.2	0.2	0.2	0.2
223	223	223	223	223	223	223
23	7	20	20	20	35	25
250-275	250-280	250-275	250-275	250-275	250-275	250-275
60-100	60-100	60-100	60-100	60-100	60-100	60-100
0.9/1.15	0.5/1.1		0.43/0.74	0.29/0.75	0.4/0.8	0.27/0.8
	HB (≥ 0.75)	HB (≥ 0.75)	HB (≥ 0.75)	HB (≥ 0.75)		
HB (≥ 0.75)					HB (≥ 1.5)	HB (≥ 1.5)
		+	+	+		
5,300	8,500	4,500	6,900	9,700	6,900	9,600
100*	120*	75*	105*	125*	100*	120*
3.5*	3.4*	2.9*	2.4*	2.2*	2.4*	2.1*
		3,300	4,700	6,700		
4,900	7,860	4,100	6,400	8,700	6,800	
160	190	119	151	183	155	
62	74	37	50	58	43	50
35	65	24	40	50	30	44
10	14	4	5.5	7	5.5	7
6	8	3.2	5.3	6.5		
		140*	153*	164*		
200	205	105	160	175	180	187
220	220	190	205	210	210	215
210	210	170	170	170	170	170
		110/140	110/140	110/140		
30-60	20-40		40-50	20-30	25-35	20-30
		0.27	0.28	0.29		
	1,250	1,200	1,150	1,100		
		3.6/3.4	3.7/3.6	3.8/3.7	3.7/3.6	3.8/3.7
		31/205	30/190	30/180	30/190	30/180
10^{14}	10^{14}	10^{14}	10^{14}	10^{14}	10^{14}	10^{14}
10^{15}	10^{15}	10^{14}	10^{14}	10^{14}	10^{14}	10^{14}
500	400	375	450	500	325	325
LS	LS		LS	LS	LS	LS

Nomenclature

Structure
The name of Ultradur® commercial products generally follows the scheme below:

Ultradur®	Subname	Technical ID	Suffixes	Color

Subnames

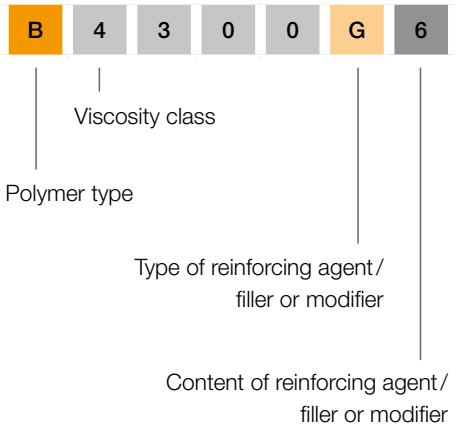
Subnames are optionally used in order to particularly emphasize a product feature that is characteristic of part of a range.

Example of subnames:

LUX Particularly high transparency to the radiation from Nd:YAG lasers and lasers of a similar wavelength, e. g. diode lasers

Technical ID

The technical ID is made up of a series of letters and numbers which give hints about the polymer type, the melt viscosity and the finish with reinforcing agents, fillers or modifiers. The following classification scheme is found with most products:



Letters for identifying polymer types

B Polybutylene terephthalate (PBT) or polybutylene terephthalate + polyethylene terephthalate (PET)
S Polybutylene terephthalate + acrylonitrile styrene acrylate polymer (ASA)

Numbers for identifying viscosity classes

1 Very low viscosity
2 Low viscosity
4 Medium viscosity
6 High viscosity

Letters for identifying reinforcing agents, fillers, and modifiers

G Glass fibers
C Carbon fibers
K Glass beads
M Minerals
Z Impact modifiers
GM Glass fibers in combination with minerals

Key numbers for describing the content of reinforcing agents and fillers

2 approx. 10 % by mass
3 approx. 15 % by mass
4 approx. 20 % by mass
6 approx. 30 % by mass
10 approx. 50 % by mass
12 approx. 60 % by mass

In the case of combinations of glass fibers with minerals, the respective contents are indicated by two numbers, e. g.

GM13 approx. 5 % by mass of glass fibers and approx. 15 % by mass of minerals

Suffixes

Suffixes are optionally used in order to indicate specific processing or application-related properties. They are frequently acronyms whose letters are derived from the English term.

Examples of suffixes:

Aqua®	Suitable for drinking water applications
FC	Food Contact; meets specific regulatory requirements for applications in contact with food
High Speed	High flowability of the melt
HR	Hydrolysis Resistant, increased hydrolysis resistance
LS	Laser Sensitive, can be marked with Nd:YAG laser
LT	Laser Transparent, can be penetrated well with Nd:YAG lasers and lasers of a similar wavelength
PRO	Profile Covered Raw Materials Only; fulfill specific regulatory requirements and demands for medical device applications

Color

The color is generally made up of a color name and a color number.

Examples of colors:
Uncolored
Black 00110
Black 05110

Ultraform®

Unreinforced grades, reinforced grades, impact-modified grades

Typical values for uncolored products at 23 °C	Unit	Test method	N2320 003	W2320 003
Product Features				
Abbreviation	–	ISO 1043	POM	POM
Density	g/cm³	ISO 1183	1.4	1.4
Water absorption, saturation in water at 23 °C	%	similar to ISO 62	0.8	0.8
Moisture absorption, saturation under standard climatic cond. 23 °C / 50 % r.h.	%	similar to ISO 62	0.2	0.2
Processing				
Injection molding (M), extrusion (E), blow molding (B)	–	–	M	M
Melting point, DSC	°C	DIN 53 765	167	167
Melt volume rate MVR 190/2.16	cm³/10 min	ISO 1133	7.5	25
Melt flow rate MFR 190/2.16	g/10 min	ISO 1133	8.8	29.4
Melt temperature range, injection molding	°C	–	190-230	190-230
Mold temperature range	°C	–	60-120	60-120
Mechanical properties				
Modulus of elasticity in tension	MPa	ISO 527-2	2,700	2,800
Tensile stress at yield (v = 50 mm/min)	MPa	ISO 527-2	65	65
Tensile stress at break (v = 5 mm/min)	MPa	ISO 527-2	–	–
Elongation at yield	%	ISO 527-2	9.4	7.5
Nominal elongation at break/elongation at break*	%	ISO 527-2	27	24
Tensile creep modulus, 1,000 h	MPa	ISO 899-1	1,400	1,350
Charpy impact strength (+23 °C)[29]	kJ/m²	ISO 179/1eU	210 C	150 C
Charpy impact strength (-30 °C)[29]	kJ/m²	ISO 179/1eU	190 C	150 C
Charpy notched impact strength (+23 °C)	kJ/m²	ISO 179/1eA	6	5
Charpy notched impact strength (-30 °C)	kJ/m²	ISO 179/1eA	5.5	4
Izod notched impact strength (+23 °C)	kJ/m²	ISO 180/A	6	5
Izod notched impact strength (-30 °C)	kJ/m²	ISO 180/A	5.5	5
Ball indentation hardness H 358/30	MPa	ISO 2039-1	145	145
Ball indentation hardness H 961/30	MPa	ISO 2039-1	–	–
Thermal properties				
Heat deflection temperature under 1.8 MPa load (HDT/A)	°C	ISO 75-2	100	100
Vicat softening temperature VST/B/50	°C	ISO 306	150	150
Max. service temperature, up to a few hours[30]	°C	–	100	100
Coefficient of linear thermal expansion, long. (23-55 °C)	10^{-5}/K	DIN 53752	11	11
Electrical properties				
Dielectric constant at 100 Hz/1 MHz	–	IEC 60250	3.8/3.8	3.8/3.8
Dissipation factor at 100 Hz/1 MHz	10^{-4}	IEC 60250	10/50	10/50
Volume resistivity	Ω · cm	IEC 60093	10^{13}	10^{13}
Surface resistivity	Ω	IEC 60093	10^{13}	10^{13}
Dielectric strength K20/K20	kV/mm	IEC 60243-1[31]	40	40
Comparative tracking index CTI, test solution A	–	IEC 60112	600	600
Comparative tracking index CTI, test solution B	–	IEC 60112	600	600

[29] N = not broken

[30] Known values for parts that have to withstand this temperature repeatedly for several hours over the course of years of use, presupposing proper shaping and processing of the material.

[31] In transformer oil

N2200 G53	N2720 M210	N2650 Z2 LEV	N2650 Z4 LEV
POM-GF25	POM-M10	(POM + PUR)	(POM + PUR)
1.58	1.48	1.37	1.35
0.9	0.8	0.8	0.8
0.15	0.2	0.2	0.2
M	M	M	M
168	166	167	167
4	7	7.5	7
5.5	8.8	8.5	8.1
190-230	190-230	190-215	190-215
60-120	60-120	60-80	60-80
8,800	4,000	1,900	1,500
–	63	52	45
130	–	–	–
–	6.5	13	16
3*	18	48	40
5,800	–	700	500
55 C	85 C	N	N
60 C	80 C	290 C	270 C
9	3.5	12	15
8.5	3.5	7	8
9	–	10	12
9	–	7	7
–	145	105	80
190	–	–	–
163	115	80	80
160	150	140	130
110	100	100	100
4	8	13	13
4/4	3.9/3.8	4.1/3.9	4.3/4.2
40/70	50/60	80/120	120/170
10^{12}	10^{12}	10^{12}	10^{11}
10^{14}	10^{14}	10^{14}	10^{14}
43	40	34	32
600	600	600	600
600	600	600	600

Nomenclature

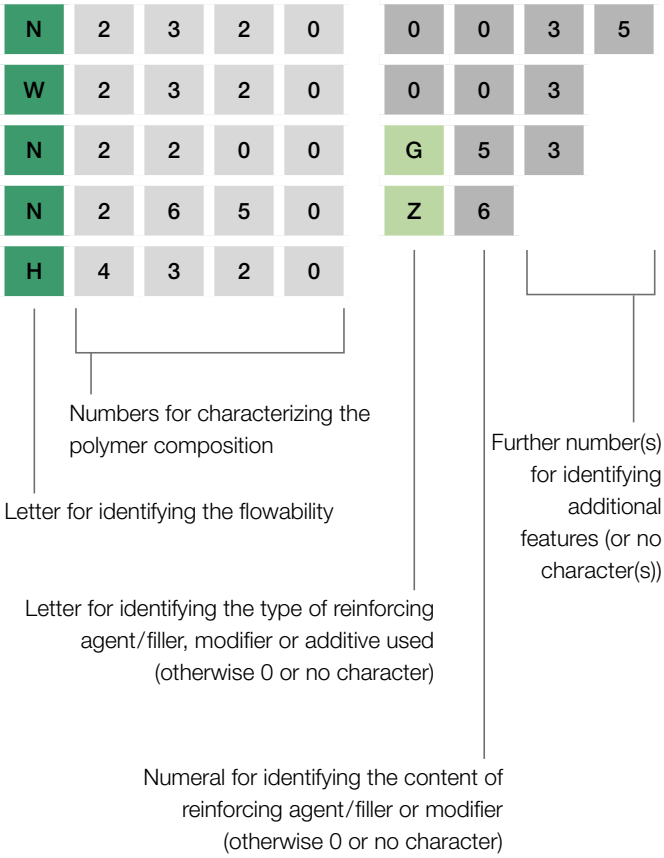
Structure

The name of Ultraform® commercial products generally follows the scheme below:

Ultraform®	Technical ID	Suffixes	Color

Technical ID

The technical ID is made up of a series of letters and numbers which give hints about the melt flow rate, the type of reinforcing agents, fillers, modifiers or additives used, their content in the material and special features if applicable. The following classification scheme is found with most products:



Letters for identifying the melt flow rate

The melt flow rate corresponds to the position of the letters in the alphabet: The later the letter appears in the alphabet, the higher the melt flow rate. Usually one of the letters E, H, N, S, W or Z is used. The following rule applies:

E Lowest flow rate, lowest MVR value
Z Highest flow rate, highest MVR value

Letters for identifying the type of reinforcing agent, filler, modifier or additive used

E Impact-modified with rubber
G Glass fibers
K Chalk
L Conductive carbon black
M Mineral
P Special lubricant
U UV-stabilized
Z Impact-modified with thermoplastic polyurethane

Characteristic numbers for describing the content of reinforcing agents, fillers or modifiers

The numbers 2, 4, 5, 6 and 9 are usually found. The greater the number, the higher the content. The following rule applies:

2 approx. 10 % by mass
4 approx. 20 % by mass
5 approx. 25 % by mass
6 approx. 30 % by mass
9 approx. 45 % by mass

Suffixes

Suffixes are optionally used in order to indicate specific processing or application-related properties. They are frequently acronyms whose letters are derived from the English term.

Examples of suffixes:

Aqua® Meets specific regulatory requirements for drinking water applications
FC Food Contact; meets specific regulatory requirements for applications in contact with food
LEV Low Emission Version; low in odors
PRO Profile Covered Raw Materials Only; meets specific regulatory requirements and needs for medical applications

Color

The color is generally made up of a color name and a color number.

Examples of colors:

Uncolored
Black 00120
Black 00140 (in the case of products that are modified with thermoplastic polyurethane)
Black 00160 (in the case of products that are modified with rubber)

Ultrason®

Unreinforced grades, reinforced grades

Typical values at 23 °C for uncolored products	Unit	Test method	E 2010	E 3010
Features				
Symbol	–	ISO 1043	PESU	PESU
Density, apparent density*	g/cm³	ISO 1183	1.37	1.37
Viscosity number [32]	cm³/g	ISO 1628	56	66
Water absorption, equilibrium in water at 23 °C	%	similar ISO 62	2.2	2.2
Moisture absorption, equilibrium 23 °C/50% r.H.	%	similar ISO 62	0.8	0.8
Processing				
Injection Molding (M), Extrusion (E), Blow Molding (B)	–	–	M, E, B	M, E, B
Glass transition temperature, DSC (10 °C/min)	°C	ISO 11357-1/-2	225	228
Melt volume rate MVR 360 °C/10 kg	cm³/10 min	ISO 1133	70	35
Melt temperature, injection molding	°C	–	340-390	350-390
Mold temperature, injection molding	°C	–	140-180	140-180
Molding shrinkage, in direction of flow	%	ISO 294	0.82	0.85
Molding shrinkage, perpendicular to flow	%	ISO 294	0.86	0.90
Fire behavior				
Burning behavior at 1.6 mm thickness	class	UL 94	V-0	V-0
Burning behavior at 3.2 mm thickness	class	UL 94	V-0	V-0
Mechanical properties				
Tensile modulus	MPa	ISO 527-2	2,650	2,650
Tensile stress at yield (v = 50 mm/min), stress at break* (v = 5 mm/min)	MPa	ISO 527-2	85	85
Elongation at yield (v = 50 mm/min), elongation at break* (v = 5 mm/min)	%	ISO 527-2	6.9	6.9
Charpy impact strength (+23 °C) [33]	kJ/m²	ISO 179/1eU	N	N
Charpy impact strength (-30 °C) [33]	kJ/m²	ISO 179/1eU	N	N
Charpy notched impact strength (+23 °C)	kJ/m²	ISO 179/1eA	7	8
Charpy notched impact strength (-30 °C)	kJ/m²	ISO 179/1eA	7.5	8
Izod notched impact strength (+23 °C)	kJ/m²	ISO 180/A	7	8
Izod notched impact strength (-30 °C)	kJ/m²	ISO 180/A	7.5	8
Ball intendation hardness H 358/30	MPa	ISO 2039-1	154	154
Ball intendation hardness H 961/30	MPa	ISO 2039-1	–	–
Thermal properties				
Heat deflection temperature 1.8 MPa (HDT/A)	°C	ISO 75-2	205	207
Temperature index (short cycle operations) [34]	°C	–	220	220
Relative temperature index related to 50% decrease of tensile strength after 20,000 h	°C	UL 746B	190	190
Coefficient of linear thermal expansion, longitudinal (23-80 °C)	10^{-4}/K	ISO 11359-1/-2	0.52	0.52
Coefficient of linear thermal expansion, longitudinal (140/180 °C)	10^{-4}/K	ISO 11359-1/-2	-/0.59	-/0.59
Electrical properties				
Relative permittivity (100 Hz/1 MHz)	–	IEC 60250	3.9/3.8	3.9/3.8
Dissipation factor (100 Hz/1 MHz)	10^{-4}	IEC 60250	17/140	17/140
Volume resistivity	Ω·cm	IEC 60093	> 10^{13}	> 10^{13}
Surface resistivity	Ω	IEC 60093	> 10^{14}	> 10^{14}
Dielectric strength K20/K20	kV/mm	IEC 60243-1 3	37	34
Comparative tracking index, CTI, test liquid A	–	IEC 60112	125	125
Comparative tracking index, CTI, test liquid B	–	IEC 60112	125	125
Optical properties				
Refractive index (specimen thickness = 1 mm)	–	–	1.65	1.65
Light transmission (specimen thickness = 2 mm)	%	ASTM D 1003	88	88

[32] Viscosity number, solution 0.01 g/ml phenol/1,2-dichloro benzene (1:1)

[33] N = not broken

[34] Empirical values determined on articles repeatedly subjected to the temperature concerned for several hours at a time over a period of several years on condition that the articles were properly designed and processed according to BASF recommendations.

S 2010	E 2010 G4	E 2010 G6	S 2010 G4	S 2010 G6
PSU	PESU-GF20	PESU-GF30	PSU-GF20	PSU-GF30
1.23	1.50	1.59	1.38	1.46
63	56	56	63	63
0.8	1.6	1.6	0.7	0.6
0.3	0.6	0.6	0.2	0.2
M, E, B	M, E	M, E	M, E	M, E
187	225	225	187	187
90	29	25	40	30
330-390	350-390	350-390	350-390	350-390
120-160	150-190	150-190	130-180	130-180
0.68	0.36	0.28	0.31	0.29
0.72	0.61	0.58	0.52	0.46
HB	V-0	V-0	V-1	V-1
V-2	V-0	V-0	V-0	V-0
2,550	6,900	9,800	6,600	8,900
75	130*	150*	115*	125*
6	3.2*	2.3*	2.9*	2.2*
N	60	55	50	40
N	65	60	55	45
5.5	8	10	8	8.5
6	8	9.5	8	8.5
5.5	8	10	8	8.5
6	8	9.5	8	8.5
135	–	–	–	–
–	205	224	170	193
176	222	223	184	185
180	220	220	180	180
155	180	190	160	160
0.53	0.20	0.15	0.26	0.20
0.6/-	-/0.23	-/0.17	0.28/-	0.25/-
3.1/3.1	4.2/4.2	4.3/4.3	3.5/3.5	3.7/3.7
8/64	20/100	20/100	10/60	10/60
$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$	$> 10^{13}$
$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$	$> 10^{14}$
40	37	37	46	45
125	125	125	125	125
125	125	125	125	125
1.63	–	–	–	–
89	–	–	–	–

Nomenclature

Structure
The nomenclature adopted for the products consists of an alphanumeric code, the key to which is given below. An appended “P” signifies that the product concerned is a specialty intended for the preparation of solutions.

1st digit (letter):
type of polymer
E Polyethersulfone (PESU)
S Polysulfone (PSU)
P Polyphenylensulfone (PPSU)

2nd digit (number):
viscosity class
1 … low viscosity
6 … high viscosity

6th digit (letter):
reinforcements
G glass fibers
C carbon fibers

7th digit (number):
proportion of additives
2 mass fraction of 10%
4 mass fraction of 20%
6 mass fraction of 30%

Example

E	2	0	1	0	G	6
1st digit	2nd digit	3rd digit	4th digit	5th digit	6th digit	7th digit

e. g. Ultrason® E 2010 G6

E Polyethersulfon (PESU)
2 of medium viscosity
standard injection-molding grade)
G6 30% by weight of glass fibers

Elastollan®

Product ranges 11, HPM, R

Properties	Unit	Test method	1175 A W	1185 A
Features				
Hardness	Shore A	ISO 7619-1 (3s)	75	87
Hardness	Shore D	ISO 7619-1 (3s)	–	36
Density	g/cm³	EN ISO 1183-1-A	1.14	1.12
Glass fiber content	%	–	–	–
Fire behavior				
Burning behaviour (depends on wall thickness)	–	UL 94	V0/V2	HB
Mechanical properties				
Tensile strength	MPa	DIN 53504-S2	40	45
Tensile strength (test specimen type 1A) test speed 50 mm/min	MPa	EN ISO 527	–	–
Tensile strength after storage in water at 80 °C for 21 days	MPa	DIN 53504-S2	–	–
Tensile strength after storage in water at 80 °C for 42 days	MPa	DIN 53504-S2	28	32
Elongation at break	%	DIN 53504-S2	700	600
Elongation at break (test specimen type 1A) test speed 50 mm/min	%	EN ISO 527	–	–
Elongation at break after storage in water at 80 °C for 21 days	%	DIN 53504-S2	–	–
Elongation at break after storage in water at 80 °C for 42 days	%	DIN 53504-S2	750	600
Stress at 20 % elongation	MPa	DIN 53504-S2	2	2.5
Stress at 100 % elongation	MPa	DIN 53504-S2	4	6
Stress at 300 % elongation	MPa	DIN 53504-S2	8	10
E-modulus by tensile test	MPa	EN ISO 527	–	–
Tear strength	N/mm	ISO 34-1Bb	40	70
Abrasion loss	mm³	ISO 4649-A	45	25
Compression set 23 °C / 72 hours	%	ISO 815	20	25
Compression set 70 °C / 24 hours	%	ISO 815	40	45
Compression set 100°C / 24 hours	%	ISO 815	–	–
Charpy impact strength (23 °C)	kJ/m²	EN ISO 179-1	–	–
Charpy impact strength (-30 °C)	kJ/m²	EN ISO 179-1	–	–
Charpy notched impact strength (+23 °C)	kJ/m²	EN ISO 179-1	kB	kB
Charpy notched impact strength (-30 °C)	kJ/m²	EN ISO 179-1	kB	kB
Thermal properties				
HDT determined at 1.8 MPa	°C	EN ISO 75-2/A	–	–
HDT determined at 0.45 MPa	°C	EN ISO 75-2/B	–	–
Average linear coefficient of thermal expansion between 23 °C and 80 °C	$10^{-6} \cdot K^{-1}$	DIN 53752-A	–	–
Vicat-softening temperature at 10 N a. 120 °C/h (procedure VST/A 120)	°C	EN ISO 306	–	–
Optical properties				
Color	–	–	–	–

1195 A	785 A HPM	754 D HPM	R 3000
96	85	–	–
48	–	55	73
1.15	1.18	1.24	1.38
–	–	–	20
HB	–	–	HB
55	45	35	–
–	–	–	80
–	40	30	–
37	–	–	–
500	700	450	–
–	–	–	10
–	750	550	–
500	–	–	–
6	3.5	15	–
10	6	20	–
18	11	40	–
–	–	–	2,800
100	70	160	–
25	40	20	–
30	20	25	–
45	30	35	–
–	50	45	–
–	–	–	120
–	–	–	70
kB	kB	kB	30
kB	kB	kB	10
–	–	–	125
–	–	–	160
–	–	–	20
–	120	155	–
–	–	–	uncolored

For your notes

Engineering plastics for the E&E industry – Literature:

- Engineering plastics for the E&E industry – Standards and ratings
- Engineering plastics for the E&E industry – Products, applications, typical values
- Engineering plastics for the E&E industry – Poster (not available as PDF)
- Engineering plastics for automotive electrics – Products, applications, typical values

PMET 1602 BE

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. (August 2016)

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