LUVOCOM®

High-performance compounds

High-performance components at reduced system costs.

Thanks to application-optimized polymer compounds for structural applications and as metal substitutes.

LEHVOSS Group

We enable you to replace metals, reduce system costs and overcome supply chain bottlenecks.

With our polymer compounds tailored through application-specific modifications and our comprehensive technical application advice and -support. From design to series production. From material selection to material development to material production.

This is what we are committed to:

- Polymers enriched with reinforcing materials and additives.
- Our expertise in materials consulting, component/tool design and of processing support.
- Short material development times.
- Our expertise in plastics physics, plastics processing and component design.
- Our experience – gained as a business unit Customized Polymer Materials since 1984 as a partner to industry respectively from the development of more than 4,000 developed high-performance compounds.

All this makes us:

- A market leader for carbon fiber reinforced thermoplastics from PP to PEEK, compounds based on of polyaryletherketone (PAEK) with, for example, more than 400 different PEEK compounds, thermoplastics with tribological modification and for 3D printing materials for individualized series production.
- A recognized development partner of original equipment manufacturers, system suppliers and processors.
- A material developer who accompanies you in all projects or production processes, supports you and, above all, helps you move forward.

The expertise of the material developer.

Extensive material selection.
Expertise in materials development.
Comprehensive application technology consulting and support.

Product Highlights LEHVOSS Customized Polymer Materials

Good to know

What characterizes polymers?

The group of thermoplastics includes semi-crystalline and amorphous polymers.

Due to their specially arranged macromolecules, semi-crystalline polymers (compared to amorphous polymers) exhibit:

- a higher wear resistance,
- a lower coefficient of friction,
- a generally better chemical resistance and
- better creep and fatigue properties.

Amorphous polymers, on the other hand, exhibit (in contrast to semi-crystalline polymers) due to their disordered macromolecules:

- an isotropic shrinkage behavior (which ensures the production of particularly dimensionally accurate parts with lower tolerances) and
- have – as a rule – a higher impact strength.

Important to know:

1. Temperature resistance and temperature behavior are among the factors that determine whether plastic parts prove themselves in practice. A plastic is always considered to have sufficient temperature resistance if the mechanical properties do not change by more than a defined percentage under a defined temperature exposure and time period (test of the relative temperature index (RTI) and / or temperature index TI). This is exacerbated by the influence of chemicals / media and must be checked on a case-by-case basis.
2. When thermoplastics are heated, physical and chemical changes occur. The physical changes are generally reversible, the chemical changes irreversible.
3. When heated for a short time, the reversible physical changes cause a lowering of the mechanical strength values – irreversible chemical changes may also occur with longer exposure time of the heating process.

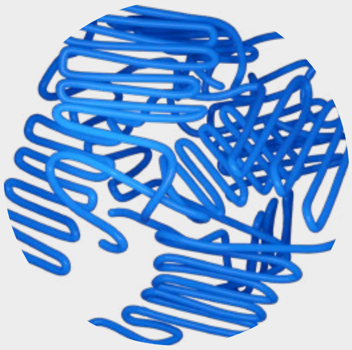
Thermoplast

Amorphous

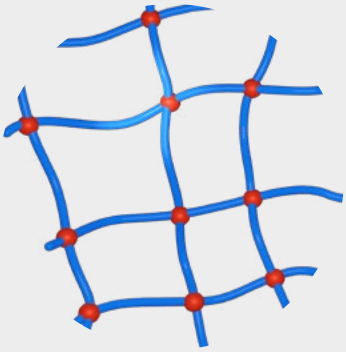
Tangle Structure

Semi-crystalline

Lamella Structure

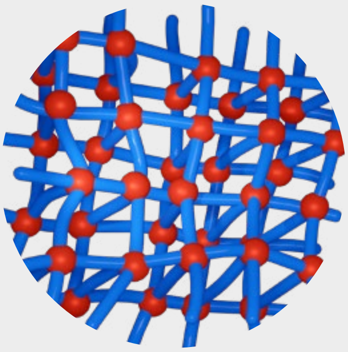


Elastomer



wide-meshed

Thermoset



close-meshed

Which polymers are suitable the most for structural applications and as metal substitutes?

Polyamides (PA)

Polyamides – especially PA 6 and PA 66 – are the most commonly used semi-crystalline thermoplastics for demanding technical components.

You have:

- excellent mechanical properties,
- a temperature resistance sufficient for numerous applications as well as
- excellent tribological properties.

They also exhibit good chemical resistance – for example to organic solvents, oils and fats – on. Their properties are influenced, among other things, by the degree of crystallization and the water content. Polyamides react to the moisture content of the environment with reversible water absorption or release. Before they are processed, they must be dried.

	PA 6	PA 66
Tg (glass transition temperature)	50 – 60 °C	60 – 70 °C
Melting temperature	220 °C	260 °C
max. moisture absorption at 50 % rh (%)	3.0	2.8
max. moisture absorption in water (%)	9.5	8.5

Polyphthalamides (PPA)

PPA comprises a group of partially aromatic, partially crystalline polymers having a high melting point, a high glass transition temperature (of up to over 150 °C) as well as a high heat resistance.

PPA have:

- a low moisture absorption of only 0.1 to 0.3 percent,
- better chemical resistance (also to aggressive chemicals) compared to standard polymers,
- good resistance to fuels, brake fluids, synthetic engine, gear and transformer oils as well as glycol, sulfuric acid and road salt,
- good tensile strength, stiffness and impact strength, and
- a low coefficient of friction and low degree of wear.

The resulting constant mechanical properties – such as their dimensional stability or also their high creep resistance – enable PPA to be used in a wide range of applications. These often include tribological applications.

	PA 6T/6I
max. moisture absorption at 50 % rh (%)	1.8
max. moisture absorption in water (%)	7.0

Polyphenylene sulfide (PPS)

PPS comes in two variants: with linear or branched polymer chains – which are mainly noticeable in the mechanical properties: Linear PPS has higher toughness and elongation at break than branched PPS.

Both PPS:

- are semi-crystalline high-performance polymers consisting of aromatic molecules linked by sulfides,
- have a continuous service temperature of 220 °C and a glass transition temperature (Tg) of around 90 °C,
- In addition to low water absorption, they also exhibit good dimensional stability and has an inherent flame retardancy,
- have good electrical properties,
- are highly impermeable to most liquids and gases,
- tend to creep only slightly even at high temperatures,
- are also suitable for long, narrow molded parts and complex mold geometries due to their good flow properties, and
- have excellent chemical resistance to almost all solvents, numerous acids and alkalis.

Polyetherimide (PEI)

PEI is a high performance amorphous polymer with high dielectric strength. It is inherently flame retardant (with low smoke generation and smoke density) and has a service temperature of 170 °C (long-term) and over 200 °C (short-term), respectively, and a glass transition temperature (Tg) of 220 °C.

PEI is further characterized by:

- resistance to alcohol, acids and hydrocarbon solvents,
- good hydrolytic stability and
- stable electrical properties over a wide frequency range.

Polyaryletherketones (PAEK)

The PAEK family includes a range of semi-crystalline high-performance polymers. The three most important of these are PEEK, PEKK and PEK.

Characteristic of PAEK in total is:

- the molecular structure based on alternating ketone (R-CO-R) and ether (R-O-R) groups,
- the high temperature stability,
- the high mechanical strength,
- the excellent chemical resistance,
- the very good fire behavior and not least
- the high tribological performance and
- the continuous operating temperature in the range of 260 °C.

PEEK is particularly: resistant to many organic/inorganic chemicals, high-energy electromagnetic waves (e.g. gamma/X-rays) and hydrolysis (up to about 280 °C).

	PEEK	PEKK	PEK
Tg (glass transition temperature)	143 °C	160 – 165 °C	152 °C
Melting temperature	343 °C	305 – 358 °C	373 °C

What fillers/additives are there and what effects do they have?

It is important when using fibers as fillers or additives,
a) select the fiber type that suits your needs,
b) to ensure that it is ideally linked into the polymer during compounding, and
c) also pay attention to the optimum alignment of the fibers when designing the component, as this is a decisive factor for both the mechanical and tribological properties.

Aramid fibers (AF)

The aramid fibers, which are based on aromatic polyamide, have a low specific weight, increased composite strength and good mechanical and favorable tribological properties – especially in combination with soft partner materials such as aluminum or bronze. Their strength, on the other hand, is relatively low – perpendicular to the longitudinal axis – and also the possibilities of combining them with polymers are not optimal (fiber breakage occurs during processing, so the mechanical level of joints reinforced with aramid fibers is not particularly high).

Glass fibers (GF)

Glass fibers have an amorphous structure with isotropic properties. They impress with their high tensile and compressive strength and the possibility of increasing the mechanical properties of polymers, especially at high temperatures. Special glass fibers with, for example, borosilicate glass or flat, oval fibers thereby improve the resistance and the mechanics respectively optimize the filling especially in thin sections.

Glass fiber reinforced thermoplastics ensure higher mechanical strength even at high temperatures and provide a supporting effect in the friction surface. The reinforced materials are characterized by improved creep behavior, a lower coefficient of thermal expansion and somewhat improved thermal conductivity.

Carbon fibers (CF)

Carbon fibers, which are mainly based on pyrolyzed polyacrylonitrile (PAN), are characterized by:

- their high tensile strength,
- their thermal and electrical conductivity,
- their low specific weight and
- their negative coefficient of thermal expansion.

It should be emphasized that CF-reinforced thermoplastics:

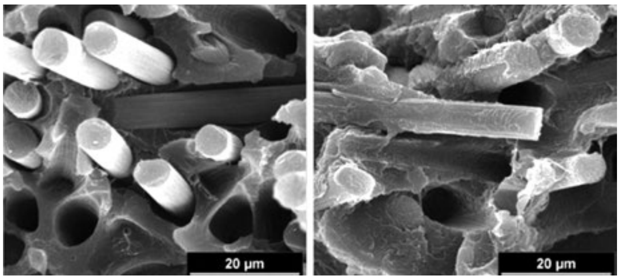
- provide the highest level of mechanical strength,
- have good wear properties, increased thermal conductivity and higher pv values,
- are usually also electrically conductive and
- when pitch fibers are used, for example, also ensure exceptional elasticity.

Compared to glass fibers, carbon fibers exhibit better wear behavior.

The reason for this is their graphite-like layered lattice structure on the surface, which glides in a defined manner and thus wears less.

Compounds with carbon fibers – such as LUVOCOM XCF (**see page 25**) – exhibit low thermal expansion and increased thermal conductivity and have:

- high strengths,
- very good tribological properties,
- electrical conductivity,
- dimensional stability and long-term dimensional stability as well as
- a low weight.



Scanning electron micrographs of PEEK with CF.

Mineral fibers (MF)

With the MF typically sorted from mined minerals and usually slightly contaminated with by-products, very good isotropic properties can be achieved in particular, which greatly improve any compressive strengths that may be required. Regardless of the size, the resulting L/D ratio is important, with a basically low to medium L/D ratio already available.

Ceramic fibers

Characteristic for ceramic fibers are the abrasiveness during processing as well as the high tensile strength (comparable to that of glass fibers) and elasticity (higher than that of glass fibers), respectively.

Thin mica flakes

Thin, electrically insulating mica flakes are often used as a synergist to further reinforcements, for example to achieve a better L/D ratio. Mica flakes themselves have an L/D ratio in the X and Y directions, which – when properly shaped – enables high isotropy. Their mechanics are comparable to ground glass fibers, while at the same time – due to their non-abrasive behavior towards metals – they are also a good substitute for glass fibers.

Basalt fibers (BF)

Basalt fibers have a very high thermal and electrical resistance, a high sound absorption coefficient and are non-flammable. Their increased stiffness makes them mechanically comparable with glass fibers. Characteristic is also their good chemical resistance to acids and organic solvents.

Steel fibers

Steel fibers are based on drawn stainless steel filaments. They are characterized by their low tensile strength and low modulus of elasticity. As a rule, they are used mainly for high-efficiency EMI compounds. Since the filaments are not stiff enough, they usually bend permanently several times during processing, resulting in a beautiful, highly conductive mesh even at low loads. The deformation as well as the poor adhesion of polymers to steel cause but a very low reinforcing effect. On the other hand, highly conductive, but still flexible films can be produced.

What are the reasons for using polymers instead of metals?

There are a number of good reasons for using a plastic component instead of a metal component. The main drivers here are:

- Targeted necessary cost reductions
- Product performance enhancements through lightweight construction
- Reduction of the Carbon Footprint due to lower energy requirements during production
- Shortage and increase in price of metals due to globally relevant influences (for example, in the form of conflicts, reduced transport capacities, or even lower scrap revenues).
- Energy constraints that are directly noticeable in the processing of light metals – especially aluminum and magnesium and their alloys

Particularly with regard to product performance enhancement, the focus is not only on structural components or mechanically stressed components, such as those encountered in tribological applications, but also on the integration or improvement of further properties. These include, for example, both:

- the electrical conductivity as well as the thermal conductivity,
- the shielding for the protection of electrical/electronic devices and
- the detectability/detection in food technology.

From the point of view of plastics physics in this context, the typical anisotropic properties of polymer compounds compared to metals should be mentioned. Through functionalization with reinforcing materials – for example in the form of particles, discs, flakes or fibers – these properties can be influenced in a targeted manner and thus disadvantages can be reduced or eliminated.

Application example: transmission shift forks

Transmission shift forks transmit shifting movements – which a driver exerts on the selector levers – to so-called sliding sleeves. As a rule, these gearshift forks consist of a large number of metal parts. The cooperation between the Dutch company Royal DSM, the German system supplier CarNaTrix (a company of the KOKI Group) and the LEHVOSS Group has developed a transmission shift fork based on a high-performance PPA reinforced with carbon fibers.

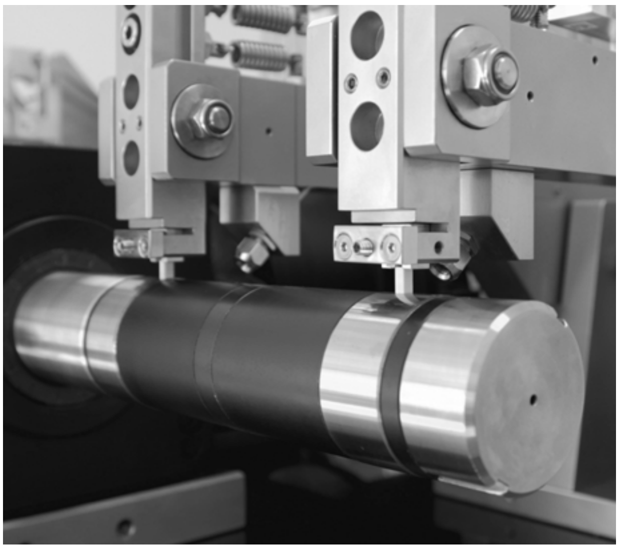
This fork version (see illustration) not only meets all the requirements placed on it in terms of strength, rigidity (even at high temperatures), oil resistance and tribology (due to contact with metal) – it also impresses above all with a reduced number of components, reduced costs and reduced weight.

With this development, the LUVOCOM 25 product line was created. Behind it are compounds that are all based on this special PPA.

Application-specific modifications. The use of polymer compounds in three different areas:

Polymers in tribological applications

With application-specific modified polymer compounds, you can realize low-maintenance or maintenance-free tribological systems without additional lubrication. In already lubricated assemblies, the excellent dry-running properties of polymer compounds also help to increase the planning reliability of designers and the application reliability of users alike.



Added to this are further economic and technological advantages such as:

- the cost-effective processability,
- the higher wear resistance in many cases compared to classic metal solutions,
- the low density and
- the high corrosion resistance.

The basis for this is the integration of lubricants and reinforcing materials, which improves the wear, friction and running-in properties of polymers – and thus of the entire tribological system. Tribological polymer compounds with integrated lubricants and reinforcing materials are mainly used in moving parts such as bushings, plain bearings, gears, rollers or even sliders. For further information, please request our compendium "**Guide to Tribology**".

LEHVOSS supports the development of components with extensive tribological testing options, such as the block-on-ring test bench (photo).

Polymers
in EMI shielding applications

With ready-made polymer compounds you can:

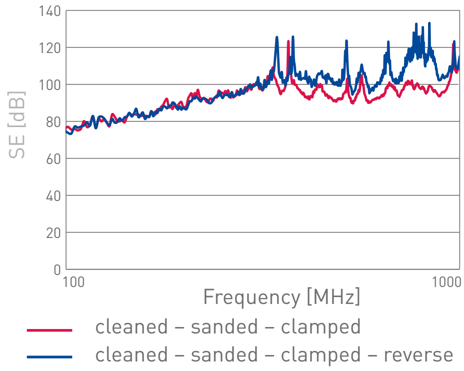
a) improve the shielding effect against electromagnetic radiation,

b) significantly reduce the risk of defects in molded parts,

c) replace conductive coatings or metal inserts and thus ultimately

d) reduce your system costs.

This is done on the basis of ready-to-use polymer compounds, modified with conductive fillers/additives and rheologically optimized for easy processing or for the realization of thin molded part walls.



Shielding effectiveness for 4 mm compression molded plate with LUVOCOM 1-8864/ES

Polymers
in food processing applications

The use of polymer compounds in place of metal in the design of for example containers, molds, machine parts or scrapers, as used in the food industry sets potential for savings in terms of weight and thus ultimately also in terms of energy consumption.

Conveyor bucket for food, made of LUVOCOM Detectable

Other advantages include:

- Detectability in case of food contamination due to damage to the equipment.
- Conformity with EU Regulation 10/2011 and compliance with migration limits according to EN 1186 for materials and articles used in the food sector.
- Pigmentation in numerous shades for visual differentiation from food.

LEHVOSS Customized Polymer Materials

Our product highlights:

The following statements and tables describe a selection of special product ranges and classic modifications of our LUVOCOM high-performance compounds. All of them are compounds that are optimized for different applications and offer specific, outstanding advantages in each case.

The descriptions also include the respective challenges for the fillers and reinforcing materials as well as the filling grades or material development/special compounding. Already since the 1980s, expertise in this field of high-performance materials has been one of the core competencies of the LEHVOSS Group. This expertise provides the basis for high-modulus plastics that

a) can close any performance gap with metals,

b) for example, exceed aluminum in specific modules and

c) are often leaders in their class.

The following also applies to all compounds and materials presented here: Application-specific material adaptations are possible at any time. Further information, also on other products and options from our company, you will of course receive on **request**.

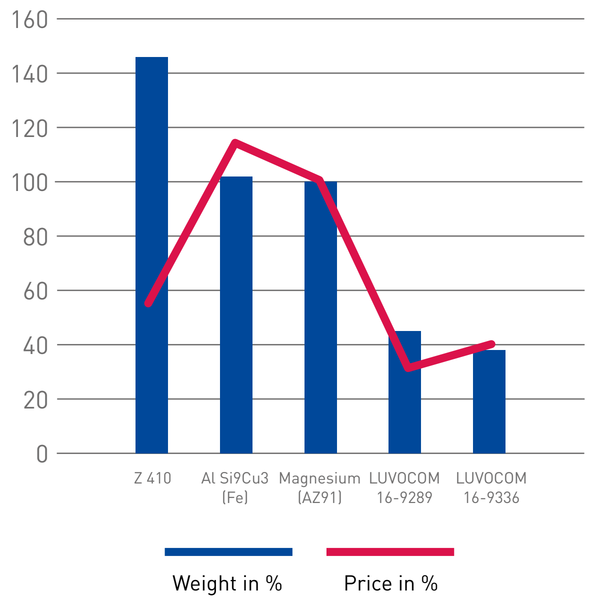
Benchmark on metal and composites/organosheets

LUVOCOM high-performance compounds with carbon fibers and glass fibers offer – compared to other reinforced thermoplastics:

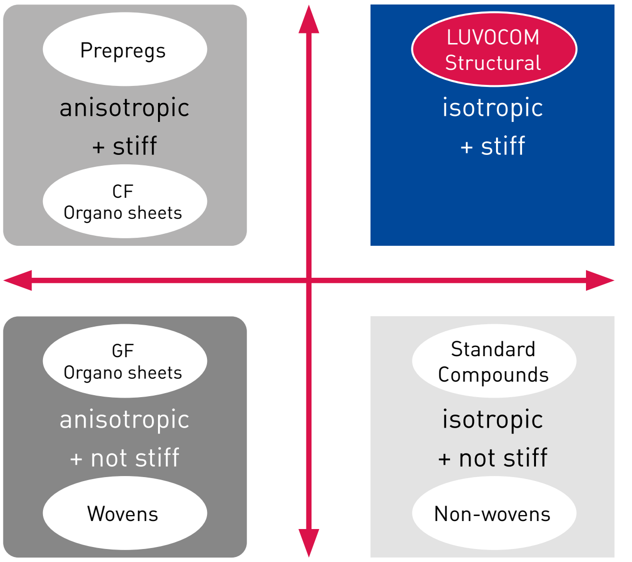
- a weight reduction of up to 62 percent,
- a modulus of elasticity of up to 52 GPa,
- a tensile strength of up to 425 MPa and
- a reduction in system costs of up to 70 percent.

They are also often optimized for use in the viewing area.

System costs of metal alloys and LUVOCOM compounds at the same strength level
Application: structural parts in automotive instrument panels



Properties of the different classes of materials
LUVOCOM Structural – Compounds in comparison



LUVOCOM PEEK CF

Highlight: Outstanding modulus of elasticity

"The embedding of carbon fibers (CF) makes this PEEK material an absolute high-performance material, capable of outperforming aluminum in terms of specific modulus at all times thanks to its extremely high-performance fillers and maximum filler content.

The particular challenges here are in the processing.

Challenge 1:
Since extremely stiff fibers are relatively easy to break, compounding must be highly controlled. Otherwise, you get milled fibers with a high modulus, which in turn lead to a lack of strength, as the valuable high-performance fibers through excessive crushing were strongly degraded.

Challenge 2:
The more filler is added, the more intrinsic shear is applied during compounding generated. This in turn leads to a shortening of the fibers. Too little shear, on the other hand in turn leads

a) to poorly embedded fibers,

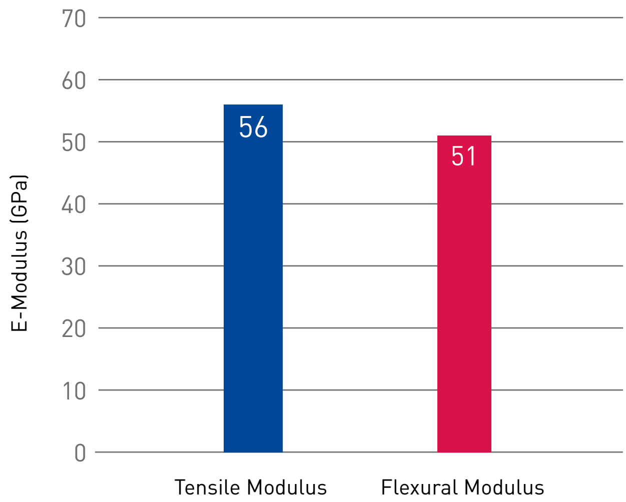
b) to poor granule quality and harbors

c) also the danger that the fibers not completely detach from the bundles.

The art of the material developer is now to achieve maximum modules with a high percentage of selected fibers while achieving tight tolerances in mechanics from batch to batch."

Dr. Jan Sumfleth, Product Developer LEHVOSS Customized Polymer Materials

E-Modulus



Property	Unit	LUVOCOM PEEK CF[1]
Density	g/cm^3	1.52
Tensile strength	MPa	294
Tensile modulus	GPa	56
Elongation	%	0.7
Flexural strength	MPa	474
Flexural modulus	GPa	51
Flexural elongation	%	1.1
Charpy 1eU	kJ/m^2	45

[1] LUVOCOM 1105-8048

LUVOCOM PPA CF

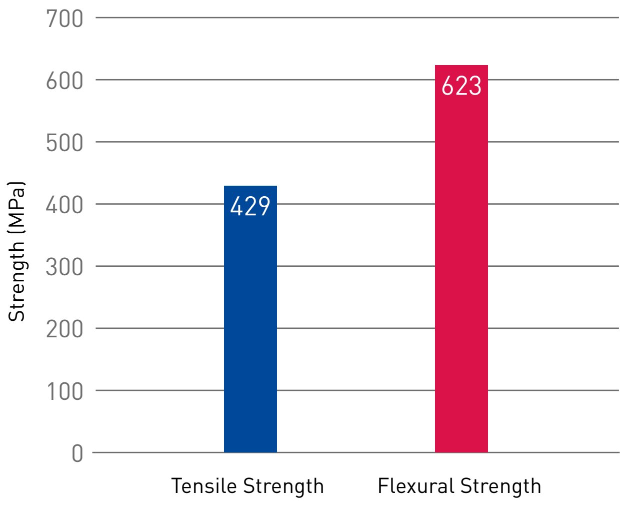
Highlight: Highest strength plus modulus plus impact strength

"This compound combines maximum strength with modulus and impact strength. The material developer is challenged to control both the raw materials and their processing in such a way that the optimum – maximum possible elongation in relation to the module – can be achieved.

The careful selection of materials and the precise control of the process allow to use the maximum strength without compromising on the other parameters. As a welcome side effect, this produces high impact strength."

Rene Warnick, Head of Product Development
LEHVOSS Customized Polymers Materials

Strength



Property	Unit	LUVOCOM PPA CF[1]
Density	g/cm^3	1.36
Tensile strength	MPa	429
Tensile modulus	GPa	50
Elongation	%	1.4
Flexural strength	MPa	623
Flexural modulus	GPa	39
Flexural elongation	%	2
Charpy 1eU	kJ/m^2	90

[1] LUVOCOM 20-9807/XCF

LUVOCOM PP CF

Highlight: Higher-performance polyolefin compounds compared to PA GF/PA CF

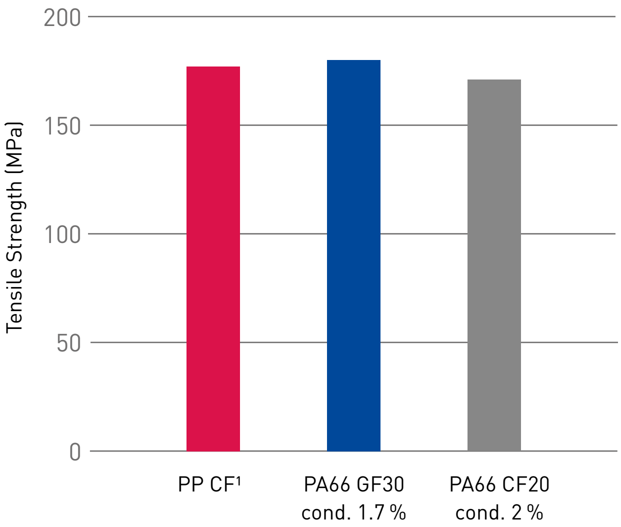
"To combine the mechanical performance of standard polyamides with lower water absorption and weight in reinforced plastics, commercially available compounds often offer a PA/PP compound as a possible solution. We at LEHVOSS think this is a half-hearted solution and have instead developed a material that has 100 percent the chemical strength of pure PP and better dimensional stability in terms of water absorption compared to PA/PP. The result is LUVOCOM PP CF.

A compound that – especially as a carbon fiber-filled PP blend in the conditioned state:

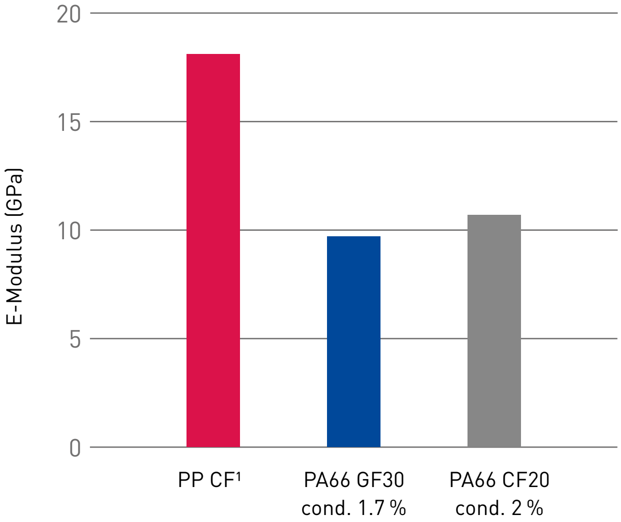
- is on a par with dried polyamides in terms of strength values,
- surpasses them in terms of E-modularity and
- due to its lightness, has a specific module practically twice as high as a standard solution."

Dr. Jan Sumfleth, Product Developer
LEHVOSS Customized Polymer Materials

Strength



E-Modulus



Property	Unit	LUVOCOM PP CF[1]
Density	g/cm^3	1.05
Tensile strength	MPa	170
Tensile modulus	GPa	18
Elongation	%	1.8
Flexural strength	MPa	240
Flexural modulus	GPa	18
Flexural elongation	%	2
Charpy 1eU	kJ/m^2	55

[1] LUVOCOM 60-50097

LUVOCOM PPA HT CF

Highlight: The PEEK-CF alternative for strong mechanical properties at elevated temperatures

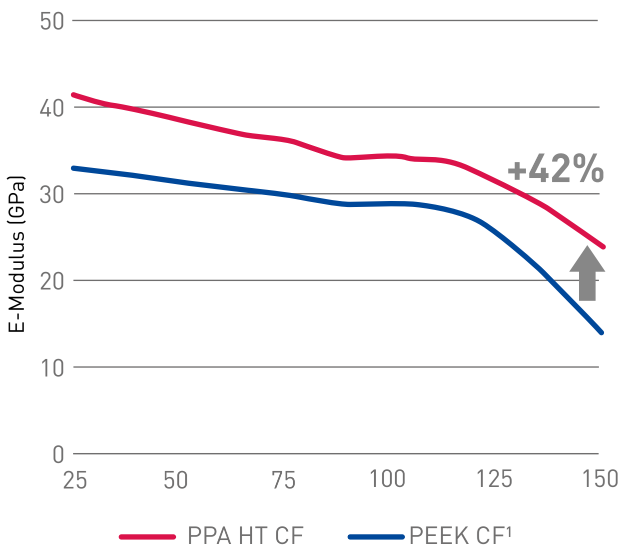
"For those who need dimensional stability at high temperatures but do not want to choose PEEK compounds for cost reasons, a material such as our LUVOCOM PPA HT CF with its high Tg offers an absolutely viable alternative.

Using the most suitable polymer type and combining our experience – both in the selection of carbon fibers and in the course of blending mineral fillers to reduce distortion and cost – this compound has already been approved as a complement to aluminum in manual transmissions for cars and trucks (**see example on page 13**). By comparison, a much more expensive PEEK with 40 percent carbon fibers at a maximum working temperature of 150 °C is by far inferior.

And yes – the compound has lower chemical strength and higher water absorption (which is largely compensated by the filler system). But those who want to invest in a top-quality product at a low price, there is no getting around the PEEK-alternative LUVOCOM PPA HT CF, with its smart compromises in detail."

Rene Warnick, Head of Product Development
LEHVOSS Customized Polymers Materials

E-Modulus over temperatures



Property	Unit	LUVOCOM PPA CF[2]
Density	g/cm³	1.61
Tensile strength	MPa	220
Tensile modulus	GPa	41
Tensile modulus @150°C	GPa	24
Elongation	%	0.6
Flexural strength	MPa	340
Flexural modulus	GPa	38
Flexural elongation	%	1
Charpy 1eU	kJ/m²	20

[1] PEEK CF 40
[2] LUVOCOM 25-9901

LUVOCOM PEEK with hollow glass spheres

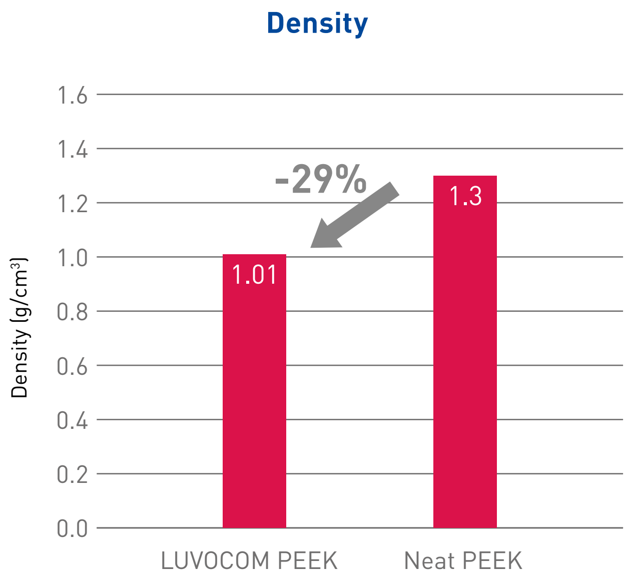
"If you want to further reduce the weight of plastic components, you need above all a compound with low density or low weight. To achieve such a weight reduction, the following two options are among those available: The use of blowing agents or the use of hollow glass spheres.

Blowing agents are known for their high efficiency, but they make subsequent reworking practically impossible, as there is always a risk when using them that the entire porosity collapses.

Hollow glass spheres, on the other hand, are compression-resistant and can therefore also be used for films, among other things, as thermoforming always continues to be possible. However, they require particularly careful handling or sensitive production settings, as they can be crushed despite their compression resistance. As collapsed spheres then gain so much weight (from originally far below 1g/cm³ to 2.5g/cm³), that the efforts can have a counterproductive effect on the desired weight reduction.

In addition, there are other advantages such as a shorter cooling time and a steeper heating curve, which can be used, for example, in thin-walled heat exchange systems as a radiator."

Holger Vandrich, Business Development
LEHVOSS Customized Polymer Materials



Property	Unit	LUVOCOM PEEK[1]	Unreinforced LUVOCOM PEEK[2]
Density	g/cm³	1.01	1.30
Tensile strength	MPa	75	100
Tensile modulus	GPa	4.4	3.6
Elongation	%	1.9	5
Flexural strength	MPa	95	145
Flexural modulus	GPa	4.3	3
Flexural elongation	%	2.2	6.5
Charpy 1eU	kJ/m²	20	60

[1] LUVOCOM 1105-50303 (with hollow glass spheres)
[2] LUVOCOM1105-7685

LUVOCOM PA GF

**Highlights: Black. GF-reinforced.
Antistatic. Laser weldable.**

"The use of antistatic plastics for enclosures is not uncommon and the use of fiber-reinforced plastics is also (almost) standard today. Things get tricky for most suppliers whenever the housing is to be assembled by means of laser welding.

The prerequisite for this is sufficient laser transparency. Only then can the beam pass through the upper cover and be absorbed by the lower part in the joining area. This is the only way to generate enough heat to fuse the parts to be joined and ensure the required weld seam quality. And this despite the loss in intensity that the beam experienced by both the distortion of the optical fiber and the shading of the antistatic.

If the entire assembly is then also to be black, this is usually not possible because the pigments of most dyes are not sufficiently transparent in the relevant wavelength range.

However, with a compound based on PA-GF, we have developed a coloring concept that not only enables high transparency from 700 nm, but also offers the possibility of varying the coloring as desired, or rather to design. This technology can also be applied to high-temperature plastics such as PPS and PEEK for injection molded articles."

Holger Vandrich, Business Development
LEHVOSS Customized Polymer Materials

Sample No.	Sample thickness [mm]	Surface resistivity [Ω]	Light transmittance* [%]
1	1.5	10^8	20.7
2	1.5	10^8	21

*Wavelength: 940 nm

Property	Unit	LUVOCOM PA GF[1]
Density	g/cm³	1.39
Tensile strength	MPa	163
Tensile modulus	GPa	9
Elongation	%	3.7
Flexural strength	MPa	240
Flexural modulus	GPa	7
Flexural elongation	%	4.8
Charpy 1eU	kJ/m²	80
Insulation resistance R25	Ω	10^{8-11}

[1] LUVOCOM 3-9814/BK

LEHVOSS Group

LUVOCOM PA LGF

Highlight: A compound from the LFT product line with maximum impact strength

"Due to the bigger fiber length in properly injection molded articles, the individual filaments are entangled within the molded part. In the event of an impact event, this prevents the crack propagation proceeds unhindered.

For standard short glass materials, the force finds their way between the individual filaments through and causes a clean break. Long fibers are difficult to break by force in a comparatively soft thermoplastic matrix, so that due to the interlacing they still provide reinforcement even if the matrix is already locally destroyed, resulting in very advantageous impact resistance at high speeds.

To optimize the puncture resistance to a maximum, we additionally modify the polymer matrix to allow higher shear forces between matrix and fibers before delamination. The impact or puncture energy is increased by dispersed within the polymer matrix. This allows for an overall longer elongation before a crack even forms."

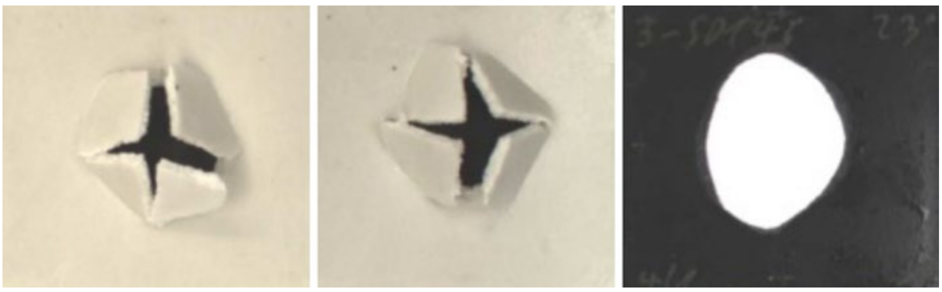
Eric Folz, Business Development LFT
LEHVOSS Customized Polymer Materials

n=10	V-Impact m/s	V-Mean m/s	Ve m/s	Fm N	EM J	Im mm	Ep J	Ip mm
x	4.54	4.47	4.42	1478.7	6.8	7.2	8.1	8.3

- Maximum force Fm [N]
- Deformation at maximum force Im [mm]
- Energy to maximum force Em [J]
- Puncture deflection Ip [mm]
- Puncture energy Ep [J]

Property	Unit	LUVOCOM PA LGF[1]
Density	g/cm^3	1.31
Tensile strength	MPa	185
Tensile modulus	GPa	10
Elongation	%	3
Flexural strength	MPa	255
Flexural modulus	GPa	9
Flexural elongation	%	4
Charpy 1eU	kJ/m^2	100
Charpy 1eA	kJ/m^2	40

[1]LUVOCOM 1-8867/LGF/HI



Penetration test according to ISO 6603 with plates (60x60x2 mm).
The pictures on the left show test plates made of LUVOCOM 1-8867/LGF/HI, with broken parts still connected to the main body, indicating ductile material behavior. The picture on the right shows a black test plate made of a standard PA LGF with penetration and no connected parts. A typical result for a brittle material.

LUVOCOM XCF

Highlight: Unique extra performance

"With this product line, we offer the world's leading thermoplastic carbon fiber compounds. The extra carbon fiber technology (XCF) offers tensile strengths of up to 425 MPa, tensile modulus of elasticity of up to 52 GPa (with simultaneously high impact strength), weight savings of up to 30 percent and greater design freedom thanks to lower filler contents.

The materials also exhibit low thermal expansion, improved thermal conductivity and high dimensional stability. This opens up even more opportunities to replace metals and composites (CFRP and GFRP) in components that are subject to particularly high mechanical demands, thus reducing a) weight and b) costs.

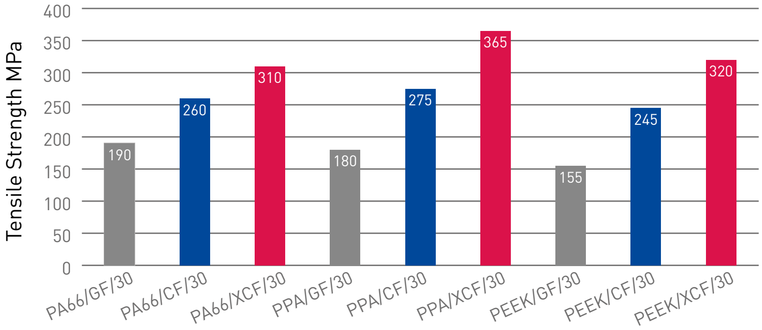
XCF compounds can be processed in conventional injection molding processes without the need for special machines or techniques.

Another approach is the substitution of plastics with short and long glass fiber reinforcement – especially in applications where additional weight saving is required. Good examples of such applications are lifting elements with high-performance motors or electric drive systems.

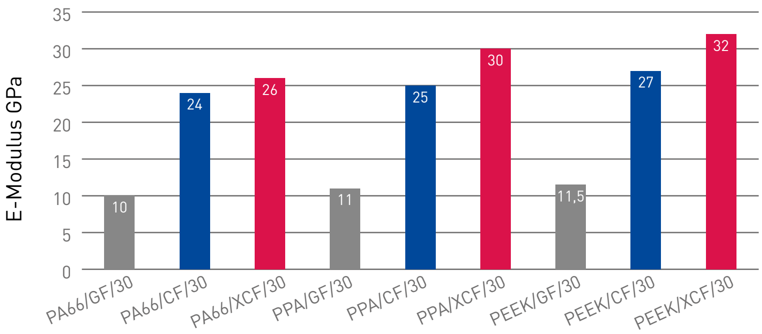
Typical applications for XCF compounds are:

- fast-moving components in mechanical and apparatus engineering (for example thread guides, pump impellers, gears, cams and connecting rods),
- air and exhaust management systems, vacuum pumps, steering systems and drive trains in automotive,
- luggage carriers and structural elements in aviation, and
- ski bindings and roller skis in the sports and leisure sector."

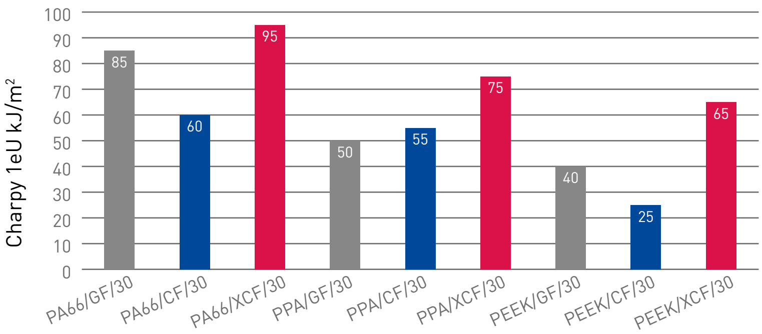
Dr. Jan Sumfleth, Product Developer LEHVOSS Customized Polymer Materials



Comparison of the tensile strength of glass and carbon fiber reinforced polymers: LUVOCOM XCF up to 100 percent stronger than GF compounds and 33 percent stronger than classic CF compounds.



E-modulus comparison of glass and carbon fiber reinforced polymers: LUVOCOM XCF up to 178 percent stiffer than GF compounds and 20 percent stiffer than classic CF compounds.



Comparison of the impact strength of glass- and carbon fiber-reinforced polymers: LUVOCOM XCF up to 60 percent tougher than GF compounds and 160 percent tougher than classic CF compounds.

LEHVOSS Group

LUVOCOM LFT

Highlight: customized long-fiber thermoplastics

"LFT differ from their 'siblings', the short fiber thermoplastics (sFT), in a number of parameters and performance characteristics:

- For example, when high relaxation resistance (creep resistance) is required, LFT can close the technical gap compared to sFT.
- LFT are less critical when components with thick walls or large wall thickness jumps are to be realized. The risk of
- shrinkage and sink marks is significantly lower compared to sFT. This can be an advantage, especially for large molded parts that are to directly follow the original metal design.
- The filling behavior of LFT is generally more favorable compared to sFT, since the filling pressure and the holding pressure are better conducted through the melt. Particularly with large wall thickness differences in the component and especially with thinner walls, significant fiber degradation is not to be expected.
- In general, LFT components exhibit lower anisotropy compared to sFT.
- In addition, LFT exhibit an impact strength that cannot be achieved with commercially available sFT (exception: LUVOCOM XCF).

If LUVOCOM LFT is compared with metal, the differences in terms of costs and Carbon Footprint and, not least, technical properties are particularly noticeable:

- The comparatively short service life of die casting molds, their relatively high costs for mold regeneration and the energy costs for high processing temperatures are offset on the part of LFT by the significantly longer tool life, the generally lower wear in the mold, the generally significantly lower processing temperatures and the resulting more favorable energy balance.
- Depending on the selected polymer, fiber type and fiber content in the LFT, the basic mechanical strengths are in some cases significantly higher than those of conventional die casting and many light metal forming alloys. In many cases, even special high-strength metal solutions can be replaced by plastics.
- Both in terms of corrosion resistance – for example to seawater, acids and alkalis – and in applications involving contact with chemicals – especially in combination with heat and high loads – even high-alloy stainless steels are often replaced to create durable and cost-effective solutions.

Of course, all this only applies if sufficiently long fibers are transported into the component by means of a suitable component and mold design, an optimized injection molding process and, of course, the right equipment of the injection molding machine. The first step is therefore always to select the LUVOCOM LFT tailored to the application with the right polymer, the suitable fibers and the right fiber content.

And as impressive as all this is, it must also be clearly stated that LFT materials also have their special features. They form weld lines differently than sFT and the weld line strengths are also lower with LFT – this must always be taken into account when designing a component.

The special features of LFT in a nutshell:

- More demanding in processing (for example mold preparation, partial screw design)
- Partially lower weld line strength
- More demanding in compounding

The strengths of LFT to the point:

- Less creep
- Better surface quality
- Good dyeability
- Less warpage and higher dimensional stability
- Isotropy
- Less shrinkage
- Better fatigue behavior
- Higher impact strength (especially at low temperatures)
- Better shielding (with CF or steel fibers)
- Less shrinkage
- Design freedom (variation of wall thickness)
- Better filling performance (holding pressure, thin walls)"

Eric Folz, Business Development LFT
LEHVOSS Customized Polymer Materials

Ashing of LFT components

Due to the correct design of the sprue and the component, as well as careful processing, the component is equipped with a very well-developed fiber network. The basic geometry of the article can still be recognized as a fiber structure.

Component with insufficient fiber length distribution (tendency to very short fibers, caused by massive fiber damage. In the present case, an additive caused a kind of skin formation).

No compound without comprehensive quality control

For quality inspection in incoming goods, for the development of products and for process monitoring, we have a wide range of testing and analysis methods at our disposal. This enables us to check the raw materials used in detail and to deliver each product batch with a test certificate in good conscience.

The consistently high premium quality of our materials over the long term is thereby ensured by our comprehensive quality management system. It covers all relevant services in the areas of:

- raw material testing and verification,
- raw material suppliers,
- batch testing and
- production.

Our certification according to ISO 9001: gives you investment security and always enables you to save costs: from incoming goods inspection to development and our own quality assurance.

Besides the

a) standardized mechanical tests by our calibrated universal testing machines (the basis for the factory certificates according to DIN EN 10204 3.1) and

b) chemical and physical test methods (such as Karl Fischer titration or density determination using a helium pycnometer), our own laboratory also has numerous other methods, procedures, options and test equipment. These include:

- Thermogravimetric Analyses (TGA),
- Differential Scanning Calorimetry (DSC),
- Thermomechanical Analyses (TMA),
- tribological tests (including "block on ring"),
- high pressure capillary rheometer,
- pVT measurements,
- MFR/MVR measurements,
- the determination of the yield point/viscosity number,
- the determination of particle size distribution by laser diffraction,
- the FT-IR spectrometer,
- hot disk thermal conductivity measurement,
- the determination of the electrical conductivity,
- the CIELAB system and
- the fire test chamber.

Data sheet values – important to know:

1. The fiber orientation

Data sheet properties for fiber-reinforced compounds – measured via a campus test bar – always show a superposition of longitudinally oriented fibers in the outer regions of a specimen, while the fibers in the core region are oriented transversely. This is unavoidable when using standard specimens such as Campus, as these are 4x10 mm^2 in cross-section, while a pronounced core area only forms from a thickness of >1.5 mm. Although this is altogether a quite realistic scenario, it should be realized that especially in the case of strongly reinforced materials, the aspect ratio of the power can be very significant.

2. The composite material

It is essential to consider the properties dependent on the composite material, such as creep and relaxation behavior.

3. The specimen

The manufacturing conditions of the specimen, its post-processing and conditioning also play an important role in the test:

- Partially crystalline specimens exhibit lower stiffness and slightly higher elongation if they are not fully crystallized – this can lead to deviating strength measurements.
- Even if the specimen is fully crystallized, curing may release residual internal stress introduced by the manufacturing process. Since this would override the stress from the test itself, this is worth investigating.
- The absorption of moisture can also lead to deviating results due to swelling and other interactions with the polymer.

4. Values are not a material specification

The values in data sheets do not represent a material specification – they are "only" intended as a guide value. It is therefore essential for a component designer to take into account a number of safety factors, as outlined in the following chapter.

5 facts every component designer should know:

Fact 1:

It is important to understand that a compound is just that: a material created by mixing different raw materials with specific properties. A composite of several materials. Therefore, a reduction to the singular term "material property" is already misleading in this context.

Fact 2:

Unlike metals, plastic solutions are typically anisotropic with respect to all properties. The reason for this is the functionalization of the thermoplastic polymers with fillers. If these filler particles were ideal spheres – from which all are practically far away -, the isotropy would be preserved. Particles come closest to the spherical shape – their expansions are similar in all three directions (x=y=z). Disks or flakes have at least two similar dimensions (x=y>z), while fibers (x>>y=z) are the most anisotropic. All these fillers thus – depending on their orientation – inherently promote the anisotropic effects produced in the part by the manufacturing process.

Fact 3:

Extrusion of semi-finished products leads to moderate anisotropy, injection molding produces the highest anisotropy by default, and compression molding leads to the most isotropic properties overall. Differences in processing thereby influence the result and affect all properties that make use of a percolation effect This also applies to isotropic filler systems.

Fact 4:

It is known that

a) shrinkage caused by the injection molding process through various parameters can be influenced,

b) that all the resulting measures vary the density of the polymer chains and solid fillers, which in turn

c) leads to a shift of the properties (at least if one changes the particle spacing in a given system). It follows from this: The data on a data sheet always refer specifically only to the sample (including the manufacturing process) on which they were tested.

Fact 5:

When plastics absorb moisture from the environment (and most do – even if it is only a little moisture), this can lead to a change in properties. As a rule, experts nowadays agree on aware of the typical shift caused by this, since it is a behavior that has been known for decades. What is not so well known, on the other hand, is the fact that thermal effects can also change properties other than "just" mechanical properties.

As a rule, this challenge is overcome by application specialists who are able to identify the main influence of the processing and design in order to determine an appropriate balance between the application requirements and the data sheet values.

The ability to tailor a standard composition to the specific requirements of the customer's process to enable optimum performance of the article is one of our core competencies.

Another core competence is the ability to perform a wide range of analytical tests. With the objective of finding out whether a part is broken due to lack of strength or lack of elongation (for example, because the modulus is too high); or whether the cause is purely a weld line or, for example, insufficient filling (for example, because the material is too viscous).

For this purpose, we use simulation software such as DIGIMAT. Based on a realistic material model, which overlays the data of the polymer with those of the filler, we thus gain optimal insight into the performance of different areas of an article.

In combination with another melt flow simulation software, we can predict the filling of the cavity – or the local fiber/filler orientation in the part design – and thus fully capture the effects of anisotropy in the final design.

For every application and every processing method, the appropriately matched product line:

In addition to our LUVOCOM product line, there are five other product lines – which we would like to briefly introduce here for the sake of completeness:

- LUVOCOM 3F: Compounds specifically for additive processes such as melt filament or melt pellet production.
- LUVOSINT: compounds specifically for additive manufacturing by powder bed fusion.
- LUVOCOM P: Thermoplastic compounds for powder coating in the field of tribology and corrosion protection.
- LUVOTECH: technical compounds for the processing technologies injection molding, extrusion and compression molding.
- LUVOTECH eco: Ready-to-use compounds with an improved life cycle assessment that can be used in injection molding as well as in extrusion and compression molding.

Our technical application consulting and support "takes hold" here as well. From design to series production. From material selection to material development to material production.

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