

In this hand Espresso machine, the property combination of polyarylsulfones, such as transparency, pressure and heat resistance, are combined with the necessary food approval

(photos and sources: BASF)

# Polyarylsulfones (PSU, PESU, PPSU)

**Portfolio Optimization.** Polyarylsulfones are amorphous high-temperature (HT) thermoplastics, comprising polysulfone (PSU), polyethersulfone (PESU) and polyphenylsulfone (PPSU). They feature principally – but not only – glass transition temperatures up to 225 °C (PESU), transparency and inherent flame resistance. With their exceptional stiffness, high strength, good hydrolysis resistance and outstanding chemical resistance, they offer a profile that – in comparison to other engineering plastics – predestines this material class for a very broad applications spectrum that is still growing. For these reasons, a continuous process of portfolio refinement is taking place in the market.

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**W**ith continuous service temperatures up to 180°C, the members of this family of materials represent the amorphous counterpart to semicrystalline high-temperature plastics, such as LCP (liquid crystal

polymer), PPS (polyphenylene sulfide) and PEEK (polyether ether ketone). In addition, they offer very good dimensional stability, which is combined with a low creep tendency, and can be increased further by fiber reinforcement. Moreover, compared with the even more heat-resistant PEEK products, PSU, the more thermally resistant PESU and the tougher PPSU offer a more constant range of properties under changing temperatures.

## Manufacturers, Capacities, Production

After the takeover of Gharda by Solvay in 2006, and the subsequent portfolio optimization, with substitution of

the Gafone brands with Veradel brands, there are still three large producers of polyarylsulfones in the world: BASF SE, Ludwigshafen, Germany, Solvay, Brussels, Belgium, and Sumitomo, Sendai,

Manufacturer	Products	Capacities [t/a]
BASF	PSU, PESU, PPSU	12,000
Sabic	PEI	15,000
Solvay	PSU, PESU, PPSU	30,000
Sumitomo	PESU	3,000

**Table 1. The most important polyarylsulfone and polyetherimide manufacturers (date: 2010)**

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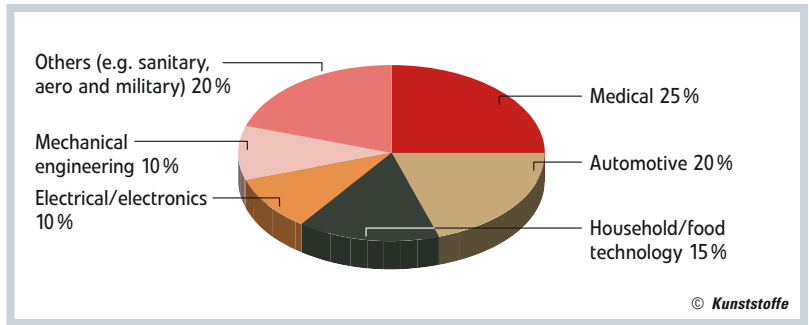
Japan. The associated production capacity increased by more than 30 % in the past five years to about 45,000 t/a. Counting PEI (polyetherimide) from Sabic Innovative Plastics, Pittsfield, MA, USA, which competes with polyarylsulfones in many applications, the market has a production capacity of about 60,000 t/a in total (Table 1).

The very wide range of applications comprises, besides automotive and electrical/electronics, many highly specialized innovative applications, for example in metrology, fuel cells or the production of high-performance membranes. The high-temperature plastics often fulfill a technical pioneering role and perform functions that are too demanding for other plastics (Title photo). The market for amorphous high-temperature plastics is therefore still highly fragmented (Fig. 1).

**Special Products and Applications**

A representative example of current product innovations is Ultrason Dimension from BASF, unveiled in 2010. In this modified glass fiber-reinforced PESU, it was possible to combine good dimensional stability with high service temperatures, impressive mechanical performance and easy processability by injection molding.

**Fig. 1. Worldwide consumption of amorphous HT thermoplastics, subdivided according to fields of application (date: 2010)**



Until now, these demands in the field of high-temperature materials had been mutually exclusive. With the new material, the flow properties could be increased without impacting the customary high dimensional stability of the amorphous matrix. The coefficient of thermal expansion of the new Ultrason is about as high as that of aluminum, which opens up interesting applications under the engine hood and in hot oil, for example for pistons and gear wheels (Fig. 2).

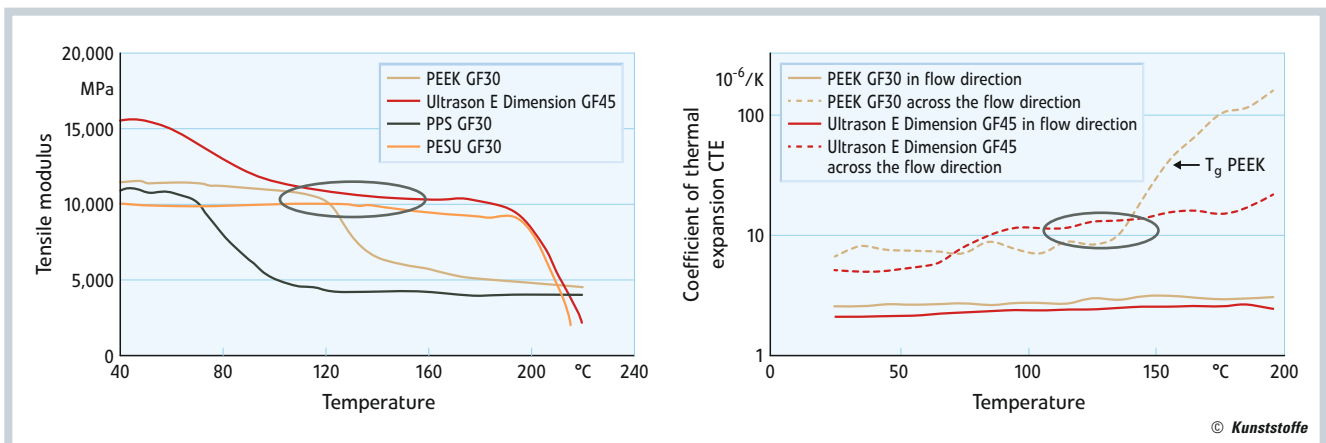
Moreover, BASF's range has also included PPSU for three years, marketed as Ultrason P. This high-performance plastic is mainly characterized by the combination of high melt temperature of a PESU, the low water absorption of a PSU and a Charpy notch impact resistance about ten times as large as that of other amorphous high-temperature materials. The material can also be sterilized under harsh conditions, and is therefore suitable for valves in sanitary and food applications.

Challenging applications, such as those in oil regulating pistons or oil pumps (Fig. 3) are only made possible by the continuous development of amorphous HT thermoplastics. Such parts are suitably made of BASF's carbon fiber-reinforced PESU, which soon will be incorporated into its range as Ultrason E 2010 C2 TR, not only because of its dimensional stability. Another principal reason is that – compared with its predecessor Ultrason KR 4113 – the material has further improved tribological properties. Carbon fiber-reinforced polyethersulfones can compete with metals in particular applications in terms of thermal expansion and at temperatures up to 200°C.

**Automotive Engineering**

The main applications of polyarylsulfones in automotive engineering continue to be headlamp reflectors, but also bezels and housings (Fig. 4).

The halogen lamps that are widely used develop severe heat, which the materials used must be able to tolerate. Headlamps can get as hot as 200°C nowadays. Besides high softening temperatures, a very high dimensional stability is required, since the shape and size of the light cone shouldn't change even in continuous operation. That results in requirements for low water absorption, low coefficient of thermal expansion (CTE), low shrinkage and low crystallization tendency. Furthermore, no fogging or aging effects should occur even at high temperatures. The crucial advantage over thermoplastic BMC is the possibility of direct metallization. Polyethersulfones such as Ultrason E 2010 Q26 from BASF and polyetherimide (PEI) from Sabic have proven suitable here. Solvay also offers directly metallizable polyethersulfones for the lighting sector, which are designed for service temperatures up to →



**Fig. 2. The new Ultrason Dimension, a newly formulated polyethersulfone from BASF, combines three properties that could otherwise not be combined in these materials: It is very dimensionally stable compared to standard and competitor materials, even at the temperature of hot oil (right), very stiff (left), and can be readily processed despite its very high glass fiber content**

205°C and are also characterized by high melt flow rates (Radel LTG-3000 PES). High requirements on the part geometry can hardly be fulfilled without PESU or PEI; that also applies to interior room lighting now (Fig. 5). In addition, easy flowing polysulfones, such as Udel LTG-2000 (Solvay) are beginning to compete with polycarbonate and (PC+PEI) blends in lower temperature ranges. The amorphous HT thermoplastics are in direct competition with thermosets here. Despite their significantly higher material price, polyethersulfones have also shown clear growth in recent years thanks to advantages such as design freedom and weight saving.

In addition, special black-pigmented plastics offer new possibilities. However, their high heat absorption in the headlamp is a disadvantage. Nevertheless, black PESU from BASF, Ultrason E 2010 MR black HM heats up far less than classical grades in service thanks to the use of an infrared-transparent pigment (HM = heat management). The stricter ECE R19 F3 regulation for reducing the dazzle of fog lamps could make such



**Fig. 3. Oil pump piston from SHW (Schwäbische Hüttenwerke Automotive): A BASF polyethersulfone specially optimized for dynamic friction properties soon will be officially adopted into the range under the name Ultrason E 2010 C2 TR (TR: tribology); its wear rate – without the use of lubricant – is several hundred times that of traditional PESU**

materials more interesting in future. If a part of the reflector is no longer metallized, the plastic will heat up further in this area.

To eliminate the slight golden tint of the amorphous HT thermoplastic, an opaque appearance can have the same effect instead of the pigmentation. For this, the company offers Ultrason E 2010 MR HP – a PESU blend, which is attractively opaque even without special pigments. The material is characterized by a low density and significantly reduced water absorption and al-

so has 10 to 20 % improved flowability.

### Electrical/Electronics

In the electrical and electronics market, PSU and PESU can still enjoy healthy demand in latches for circuit breakers (Fig. 6), where the reduced creep tendency and high dimensional stability of these plastics is valued. Here, BASF's PESU Ultrason E 2010, E 3010 (with high impact resistance and stress cracking resistance), and the PSU Ultrason S 2010 G6 are

used. Otherwise, amorphous HT thermoplastics are used in a wide range of small applications in the electrical and electronics sectors, for example in fuel cell components, housing parts for air humidifiers or industrial batteries. In addition, transparent displays are made of polyethersulfones, such as Ultrason E 2010 HC (HC: high clarity). The plastic displays are not only more flexible, but also much more slender and lightweight compared to glass displays. The development of these displays is currently principally being advanced in Asia, and the Asian supplier Sumitomo is also very highly committed to this.

### Kitchen and Bathroom

PESU, PPSU and PSU have a variety of applications in the household. Fiber-reinforced alternatives are used, e.g., for parts of coffee machines or samovars, which come into contact with hot steam. Here, metals face competition from polyarylsulfones, which of course must have the necessary food approval (Fig. 7). They are required to have high hydrolysis resistance and low absorption of food dyes,

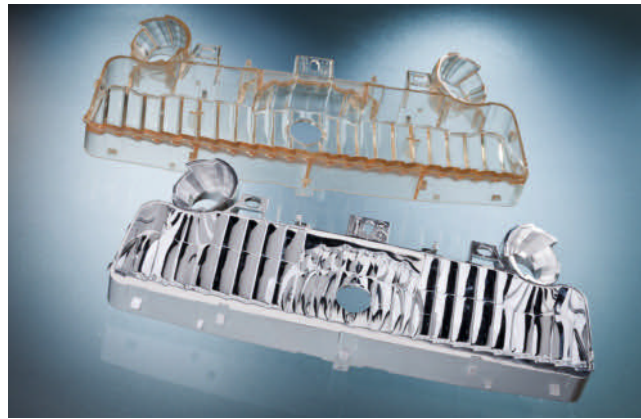


**Fig. 4. Due to the changed light technology and because headlamps are increasingly used as design elements, the requirements on the materials for reflectors (right), but also for bezels (left) and housings have become considerably stricter. There have been some recent product improvements in this application field**



as well as resistance to detergents and high temperatures as reached by hot fats in the microwave. At the same time, high toughness is necessary, which counts if plastic parts are cleaned together with steel pans in industrial dishwashers.

PESU is also growing in importance in baby bottles, where light-colored material grades are successful. Polyethersulfones such as Ultrason E 2010 can be readily sterilized at high temperatures. PPSU is required in the household, for example for pipe connection fittings. Here, it is necessary to avoid any formation of micro-



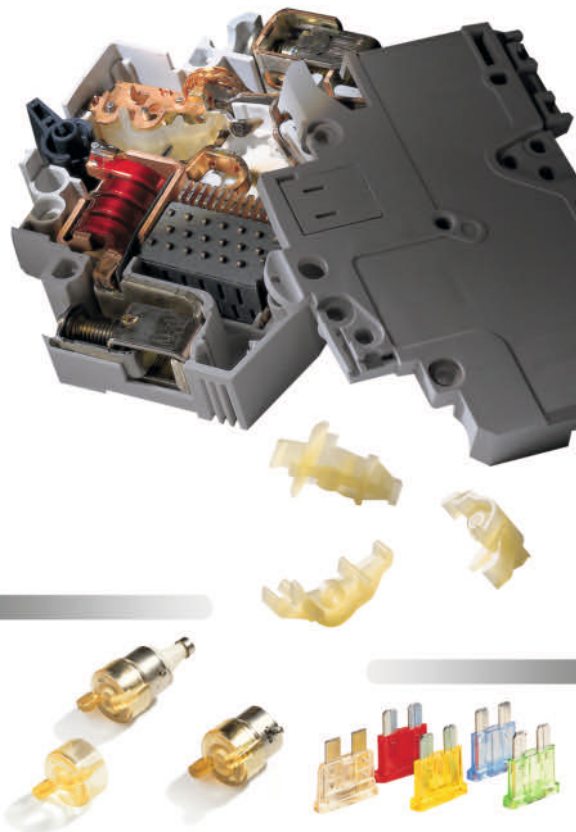
**Fig. 5. Ultrason E 2010 MR (MR: mold release) is ideal to allow ready demolding of complex geometries such as this reflector for car interior lighting. Despite the material's good demolding properties, it is highly transparent, so that it can not only be used for coated applications like this, but also for optically challenging household appliances, such as deep-fat fryer covers**

cracks. For this application, BASF recently launched a particularly notch-impact and stress-cracking resistant grade, Ultrason P 3010, which also has a proven track record as robust trays and in aircraft interiors. To be successful in the fittings market, however, it is necessary to provide an extensive data package on the inter-

ments precipitated from organic solvents with water are characterized by extraordinarily highly reproducible porosity. PSU and PESU membranes are used in micro- and ultrafiltration, which play an important role in medicine, beverage processing and drinking water treatment (Fig. 8). The necessary sterilizability requires especially chemically resistant materials, which cover a particularly wide range of viscosities. For technical water treatment and purification, the material must also feature high mechanical stability. To ensure high throughput and therefore high productivity of the systems, high-molecular PESU grades, such as Ultrason E 6020 P or E 7020 P, are used. Compared to PVDF membranes, they are not only more permeable but also remove viruses more reliably. In dialysis membranes, polyarylsulfones have established themselves while the →

**Water Purification, Medical and Aviation**

Entirely different properties are required from polyarylsulfones in the field of membrane technology. For this purpose, it is of great significance that polyarylsulfone films and fila-



**Fig. 6. Typical electrical/electronics applications: switch latches, fuse holders, and circuit breaker covers of polyarylsulfones**

nal pressure resistance of test bodies according to ISO 9080. These data, which are now completely available for Ultrason P, are essential for designing DIN-compliant fittings. Solvay also offers PPSU under the trade name Radel R. Sales of polyarylsulfones in the household sector have been growing steadily for years.

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**Fig. 7. Coffee machines and samovars require materials such as polyarylsulfones, which can come into contact with hot water without being damaged, and have the necessary approval for food use**

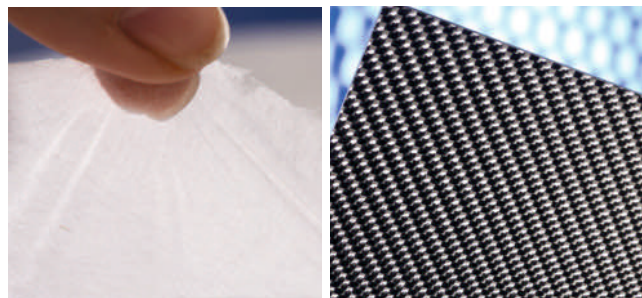
PEI Ultem from Sabic is used in sterilizable containers. Medical technology therefore offers very attractive growth possibilities for PESU and PSU, but also PEI.

In aeronautics, high-performance materials such as polyarylsulfones have proven themselves, since they are inherently flame retardant without additives. In contrast to many other polymer materials, in which smoke gas density and toxicity increase if they are made flame retardant with additives, polyarylsulfones feature good intrinsic FST (= flame smoke toxicity) values. Polyetherimides, par-

ticularly as blends and foam, also combine high flame resistance with low weight and are therefore used in the aero industry. The outstanding fire safety properties of both material classes therefore also qualify them for use in many other, similarly safety-critical means of transport, such as subway trains. Interesting opportunities in the aeronautical sector are opened up by lightweight carbon-fiber-reinforced epoxy carbon pre-pregs. It is possible to reduce their cracking tendency and increase their impact strength by modifying the resins by adding polyether sulfones. In this business, BASF is represented with the Ultrason grades E 2020 P and E 2020 P SR (Micro). Their special feature consists in the hydroxyl groups of the polymer chains, which result in good compatibility with epoxy resins. The material is supplied as flakes or powder to facilitate processing in conventional solvents. A special variant are thin PESU nonwovens, which are produced on special machines and can be pressed between epoxy resin-carbon fiber pre-pregs (Fig. 9): Thus, the toughness-modifying effect of Ultrason is introduced even more homogeneously into the high-performance part. Powders with similar properties are also available from Sumitomo and Solvay. Readily soluble powder PESU grades, such as Sumikaexcel 5003 P (Sumitomo) still play an important role in paints,



**Fig. 8. Precipitated polyarylsulfones have pores with very easily controllable, low diameters, and are increasingly used in the micro and ultrafiltration, as in the hollow fiber bundle shown here. The high thermal and hydrolysis resistance permits repeated sterilization**



**Fig. 9. The Czech company Elmarco uses the BASF high-performance plastic Ultrason E2020 P SR to produce nonwovens (left). These layers of thin fibers serve as toughness modifiers and impart especially high strength to carbon-fiber-reinforced composites (right)**



**Fig. 10. The visor of the firefighter's helmet is made of the high-transparency PESU variant Ultrason E 2010 HC. The combination of high heat resistance, inherent fire retardancy, high transparency and break resistance are exploited here. These special grades feature significantly reduced inherent yellowness, thereby achieving high optical purity**

resistant coatings and high-temperature resistant adhesives.

### Challenges and Outlook

All suppliers of this material family are concentrating their development efforts on PESU and PPSU grades with ever lighter colors. The light to medium yellow hue is a familiar phenomenon of all high-temperature plastics. With Ultrason E 2010 HC (Fig. 10), BASF has taken another big step further. Other changes in the market will come from the

fact that, following the expiry of patents, PPSU can now be used worldwide in sterilizable boxes without restriction. Yet another principal characteristic of polyarylsulfones is and remains the versatility of their applications compared to other engineering plastics. Their high processing temperature does require somewhat more care in injection molding: Stress cracks, for example, as a result of the good adhesion to metal, or silver streaks caused by high moisture content and sever shearing, are a challenge that are unknown in this form for polyamide or PBT. But after optimization of their tools and machine settings, processors are then rewarded with high-quality, high-performance and stylish parts, which offer high value creation in their niche markets. ■

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