PBT compounds are very much in demand for electromobility, including for parts of the battery, electric transmission and the charging infrastructure.
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Polybutylene Terephthalate (PBT): Demand for Products with Added Benefits

Electromobility and Sustainability Are Driving Growth

The global market for PBT has recovered well from the aftermath of the corona pandemic. However, there is a lot going on among manufacturers at the moment. Several companies have disposed of their PBT business to competitors. Product developments involving the material are being driven by the trends of digitalization, electromobility and sustainability, as evidenced by numerous exciting innovations.

According to market research firm Wood Mackenzie, global consumption of polybutylene terephthalate (PBT) base resin increased in 2021 by over 6 % year-on-year to around 1.53 million t. This was slightly down on 2019, i.e. before the Covid-19 pandemic. For 2022, an increase to approx. 1.58 million t is expected worldwide. However, major uncertainty factors still exist that could threaten not just the further performance of the PBT market; these include the war in Ukraine, current inflationary trends and the consequences of the Covid-19 pandemic, all of which are slowing down economic growth. The chip shortage, which is particularly impacting the automotive industry, and the supply chains disrupted by Covid-19 lockdowns in China continue to have an inhibiting effect.

As in previous years, China was the largest consumer of PBT in 2021, with a share of over 50 %. The Asia-Pacific region, including China, accounted for three-quarters of volume sales. The European economic area and the American continent followed in second and third place, with 16 % and 9 % respectively. Slightly more than two-thirds of the base resin was upgraded into compounds in 2021, with the remainder mainly converted into fibers. More than 50 % of PBT compounds went to the automotive industry. The second-largest application segment was the electrical and electronics (E&E) sector, with a share of around 30 %, followed by the consumer and industrial goods industry with 16 %.

Fig. 1. PBT base resin is produced in Europe at the Hamm-Uentrop site of DuBay Polymer, a joint venture of Lanxess and DuPont. © Lanxess

New PBT Production Plants for PBAT and PBS too

To date, global demand for PBT base resin had been met through existing production capacity (**Fig. 1**). However, capacity in Europe is now too low, and so the supply gap is having to be closed by imports from Asia and Saudi Arabia. In China, several local companies have announced their intention to invest in further capacity to cover the disproportionate growth of PBT sales in the People's Republic. Interestingly, many of these are versatile production plants that can produce not only PBT but also the biodegradable polyesters polybutylene adipate terephthalate (PBAT) and polybutylene succinate (PBS). PBAT and PBS are also synthesized in a polycondensation reac- »

tion starting with the monomer 1,4-butanediol (BDO).

One such investment is Changhong Biomaterial's plant in Shengzhou in Zhejiang province, which started operations in 2021 with a capacity of 120,000 t/a. Capacity at the site is to be expanded to 600,000 t/a in the coming years. Junzheng Chemical, Haihui New Material and Henan Kaixiang are also planning to start up new PBT, PBAT and PBS plants soon. It remains to be seen how the strong growth in global consumption of PBAT and PBS will affect demand for BDO and how that will influence the price of PBT products.

As a result of the high demand for PBT compounds, the number of compounding lines worldwide is growing. For example, in Malaysia, BASF is currently adding 5000 t/a capacity for PBT and other compounds at its Pasir Gudang site. Meanwhile, at its site in Changzhou in China, Lanxess intends to open a second compounding plant, with a capacity of 30,000 t/a, in the first quarter of 2023 that will be able to produce PBT compounds as well. In April of this year, Lanxess also inaugurated a new compounding line for PBT and polyamide (PA) at its Krefeld-Uerdingen plant in Germany. And DSM completed the expansion of its compounding capacity for high-performance materials in Evansville, Indiana/USA, in the third quarter of 2021.

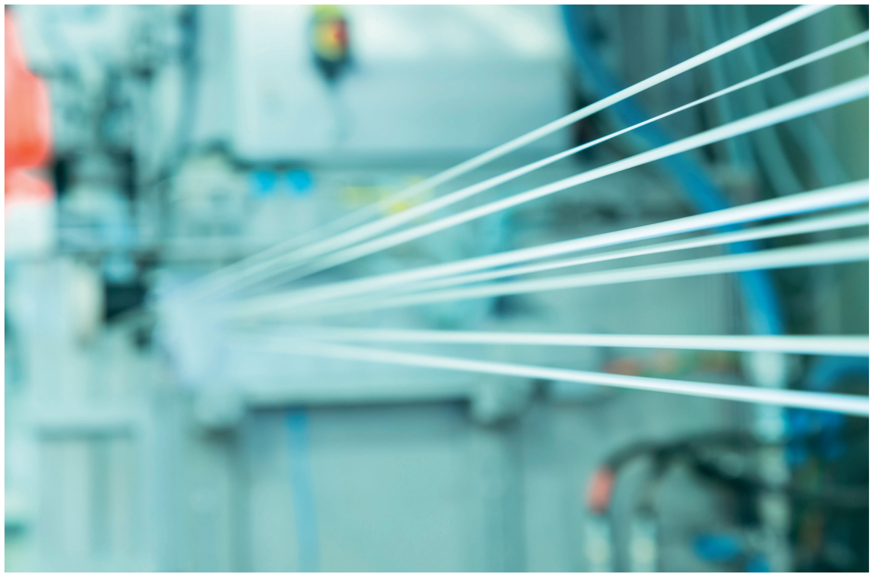

Fig. 2. Lanxess uses scrap glass in its glass fiber production in Antwerp to increase the sustainability of its products. © Lanxess

Consolidation among Manufacturers

The market for engineering plastics such as PBT is currently consolidating, as companies seek to align their businesses more efficiently with new markets, such as that of electromobility, and to boost their competitiveness against rivals from, for example, the Far East. Celanese, for instance, is acquiring a large portion of DuPont's Mobility & Materials business, which includes engineering plastics, such as PBT. The transaction is expected to be closed by the end of 2022.

In addition, Lanxess intends to set up a joint venture for high-performance engineering polymers with Advent, a private equity investor. An agreement to this effect was recently signed to acquire the engineering plastics division of the Dutch group Royal DSM, which will be integrated into the joint venture. Lanxess's contribution to the new company will be its High Performance Materials (HPM) business, one of the world's largest suppliers of compounds based on PBT, PA6 and PA66. Subject to regulatory approval, the new company is expected to start operations in the first half of 2023. Sustainability is also becoming a defining issue for PBT, due to climate change and diminishing resources. For example, attempts are underway in the production of PBT base resins to replace the previously fossil-based monomers with chemically and physically identical counterparts (drop-in solutions) that are derived from sustainable raw materials, such as bio-based or recycled materials. These attempts are not new and primarily concern BDO. Back in 2013, for example, Lanxess produced bio-based PBT on a world-scale line that started with a BDO sourced from a fermentation process that utilized sugar as the raw material. The aim of that proof-of-concept trial was to show that such a conversion is possible in principle and does not entail any loss of product quality.

Investments in Bio-Based BDO

However, there has been hardly any investment so far in industrial-scale production lines for bio-based BDO. These are essential for securing supplies of large quantities of this raw material over the long term. A major step in this direction is the Qore joint venture formed by the two companies Cargill and Helm. These two partners intend to build a line at Cargill's Biotechnology Campus in Eddyville, Iowa/USA, that will produce bio-based BDO using technology provided by Genomatica, a US biotechnology company. The plant is scheduled to come on stream in 2024 and will have a capacity of 65,000 t/a.

Different Development of Precursors

As for the second monomer for PBT, namely terephthalic acid (PTA) or dimethyl terephthalate (DMT), synthesis routes based on sustainable raw materials have yet to be developed into industrial-scale processes. However, carbon-neutral terephthalic acid is available on the market. The greenhouse gas emissions generated during its production are offset by investments in climate-change-mitigation projects. An example of this is PTAir Neutral from Ineos.

It has not yet proved possible to establish large-scale material recycling loops for PBT compounds. However, many PBT producers are currently working hard on evaluating possible sources of recycled materials from both post-consumer and post-industrial waste (PCR and PIR). Unlike the case for PBT, large quantities of recycled polyethylene terephthalate (PET) are available, from beverage bottles. This recycled PET is used to produce sustainable PBT/PET blends, one example being the Pocan-ECO T series from Lanxess. Sabic utilizes chemical processes to depolymerize end-of-life PET obtained from bottles and other sources in order to use the resulting raw materials in an upcycling process to produce the PBT products LNP Elcrin iQ .

Recycled reinforcing fibers, too, improve the sustainability of plastics. Lanxess, for example, uses glass obtained from glass fiber production scrap to produce recycled fibers (**Fig. 2**). These find application in the PBT compounds Pocan ECOB3235 and the flame-retardant Pocan ECOB4239, among others. The content of 30 wt.% recycled fiber is certified in accordance with the ISCC Plus mass balance process (International Sustainability and Carbon Certification), which is increasingly being adopted by plastics producers worldwide. In this process, both fossil raw materials and chemically identical alternatives obtained from sustainable sources – such as the chemical recycling of PIR and PCR waste – are blended in production and the respective proportion of each is mathematically assigned to the end products. The properties of the end product, such as a PBT compound made with recycled fibers sourced from glass scrap, match those of conventional material. Injection molders can therefore process the compound as usual on their existing equipment and will benefit from the sustainability of the ISCC Plus-certified product.

New applications and growth markets are emerging for PBT compounds, especially with the rise of electromobility and associated charging infrastructure and the trends toward driver-assistance systems, the digitalization of everyday life (internet of things, IoT) and the miniaturization of electrical and electronic assemblies. Fundamental material strengths demonstrated by PBT in these application segments are its high stiffness, strength, heat resistance and, because it absorbs very little water, very good dimensional stability. It also exhibits good electrical insulation behavior, such as high volume resistance and dielectric strength. However, PBT compounds also have to satisfy new, tougher application requirements. The high electrical power densities of high-voltage systems in electric vehicles generate greater thermal stress and impose stricter requirements on hydrolytic stability and aging resistance as well as flame retardancy. In addition, the components must remain electrically insulating even though they are often exposed to combinations of high voltages, strong currents and high temperatures.

Three Current Focuses of Development Work

The manufacturers of PBT compounds are concentrating their development efforts primarily on optimizing the materials' hydrolysis and permanent heat stability as well as on improving their electrical characteristics, such as high tracking resistance. Often they have to give the materials a high flame retardancy, too. An additional focus of development is on efficient processing of the compounds. This applies especially to laser transmission welding, which is becoming more and more established in the gentle series production of filigree-designed PBT parts for the automotive, E&E, IT and consumer goods industries. It is used, for example, in the production of housings for sensors, control units and display systems.

Developments Aimed at Greater Hydrolytic Stability

One example of a new generation of hydrolysis stabilized PBT compounds is the Pocan XHR (Xtreme Hydrolysis-Resistent) range of products from Lanxess (**Fig. 3**). It exhibits very good hydrolytic resistance in specimen tests based on the stringent long-term finished- »

Fig. 3. One potential application of hydrolytically stabilized PBT such as Pocan XHR is in automatic parking brake powertrains. © Lanxess

part tests SAE USCAR-2 Revision 7 issued by the Society of Automotive Engineers (SAE). For example, Pocan B3216XHR and B3233XHR, which contain 15 and 30 % glass fibers respectively, achieve the highest rating of Class 5. Particularly noteworthy is the unreinforced Pocan B1205XHR, which passes with the second-highest rating of Class 4. It can be processed almost without any warpage and therefore lends itself to the construction of highly filigree geometries.

In addition to their high hydrolytic stability, the members of the XHR product range have other material advantages that are of relevance to many applications. Their elongation behavior and good resistance to temperature changes, for example, make them ideal for overmolding metal parts that are exposed to fluctuating temperatures and that could therefore exhibit a tendency to undergo stress cracking. Candidate applications include busbars, connectors, terminal blocks, main frames and housings. Another material advantage is the enhanced alkali resistance, which is already quite good in the case of standard PBT. Thus, the elongation at break of Pocan XHR is reduced by only about 40 % when conditioned in one-molar sodium hydroxide solution for 100 h at 55 °C.

The good processing behavior of the PBT product range is reflected, among other things, in the good melt flow behavior, which is up to 35 % better than that of standard PBT products. Other manufacturers, too, offer PBT compounds that have yielded with very good results in the SAE/USCAR test. Examples include the toughness-modified Ultradur B4330 G3 HR from BASF and the toughness-modified CrastinX HR5330HF from DuPont, which achieve Class 5 and Class 4 ratings respectively.

Laser-Transparent and also Hydrolytically Stabilized

One of the goals of developing new PBT compounds for laser transmission welding is to improve laser transparency to enable components of greater wall thickness to be joined together as well. One approach here is to blend the semi-crystalline PBT with amorphous polycarbonate (PC). Examples of this are the unreinforced Pocan C1202LT (Laser Transparency), which is very tough and has low warpage, and Pocan C3230LT, which is reinforced with 30 % glass fibers. The latter facilitates the production of low-warpage, stiff and strong components, such as electronic housings.

Products that also exhibit very high hydrolytic stability are rare specialties in the market for laser-transparent PBT compounds. This is because the two properties normally exert a detrimental influence on each other. Lanxess now offers several compounds that solve this conflict. One example is Pocan B3233HRLT, which achieves a Class 3 rating in the long-term test of SAE USCAR-2 Revision 7 and is thus highly resistant to hydrolysis at temperatures of up to 125 °C. At the same time, when pigmented black, it is laser-transparent

Fig. 4. The lid of the actuator housing is made of Pocan B3233HRLT, which is pigmented in laser-transparent black, while the laser-absorbing half of the housing is made of Pocan B3233HR. © Lanxess

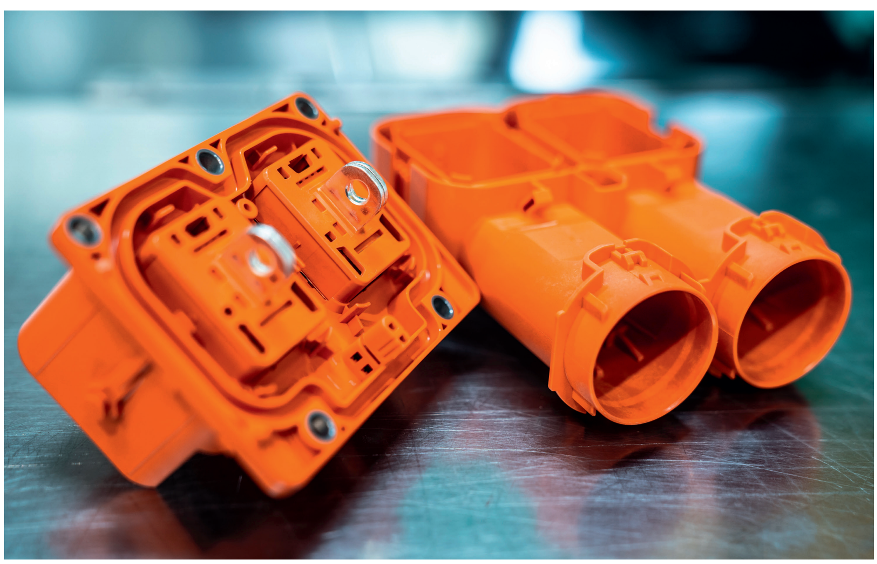

Fig. 5. Halogen-free flame-retardant PBT compounds are in demand for high-voltage connectors. Lanxess has introduced various types for this in its Pocan HRE series. These are characterized by very good hydrolytic stability, flame retardancy and tracking resistance (CTI A 600). © Lanxess

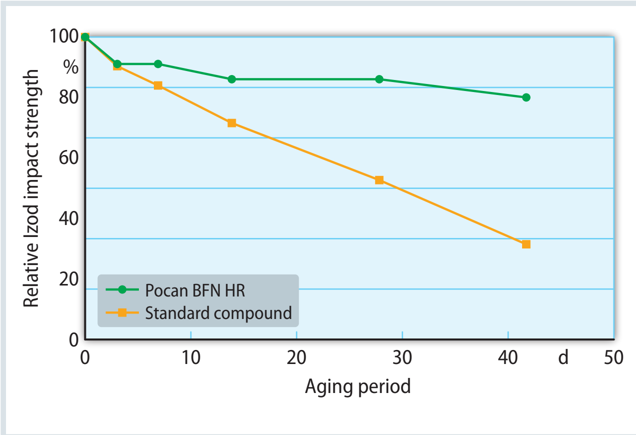

Fig. 6. The Izod impact strength of the PBT compound Pocan BFN HR barely decreases after hydrolytic aging at 85 °C and 85 % relative humidity – unlike a standard product. © Lanxess

in the very wavelength range typically employed in laser transmission welding of plastics. It can be joined in a stable, efficient process. This material is used, for example, to produce low-warpage, dimensionally stable housings for mechatronic swirl control actuators in diesel engines (**Fig. 4**). Another example of a hydrolytically stabilized and simultaneously laser-transparent PBT compound that also has a 30 wt.% glass fiber content is Ultradur B4300 G6 HR LT from BASF.

Growing Demand for Optimized Tracking Resistance

In many classic E&E applications and in high-voltage components for electromobility the requirements on the tracking resistance of plastics are increasing. This trend is being reinforced by the progressive miniaturization of electrical and electronic assemblies. For example, the distances between the metal pins on printed circuit boards are becoming smaller and smaller. PBT compounds have inherently good tracking resistance, but still offer room for improvement, especially in the case of glass fiber-reinforced product variants. Many manufacturers of PBT compounds are therefore working to produce correspondingly optimized materials. Lanxess is currently building up the wide-ranging Pocan E product series with its glass fiber contents ranging from 10 to 30 %. All members of this series achieve the best-possible score of 600 in the tracking resistance test CTI A (Comparative Tracking Index, IEC 60112). This means they meet the specifications for the highest insulation material Class I set out in IEC 60664–1.

Compounds with Further Added Benefits

Several of the compounds possess other advantageous properties, » such as very good melt flow and hydrolytic resistance, high flame retardancy or optimized mechanical properties, such as improved impact strength. One example from the Pocan HRE series is Pocan B3216XHRE, which features very good hydrolytic resistance in addition to high tracking resistance. A further highlight from the series is a halogen-free flame-retardant compound with a CTI A of 600 (**Fig. 5**) that is also hydrolytically stabilized. This construction material, reinforced with 25 wt.% chopped glass fibers, achieves a good Class 3 rating in specimen tests based on the SAE USCAR-2 Revision 7 hydrolysis resistance test. In an industry-standard hydrolysis test conducted at 85 °C and 85 % relative humidity, it retains 80 % of its initial impact strength even after 1000 h (**Fig. 6**). It passes the UL 94 fire test of Underwriters Laboratories, achieving an excellent classification of V-0 at 0.75 mm test specimen thickness. The compound is available in bright colors, such as orange. Material and dyes are permanently color-fast, even at high operating temperatures (**Fig. 7**).

Fig. 7. Orange-pigmented, color-fast compounds are needed for high-voltage applications. The color orange is used in electric vehicles to denote current-carrying components. The corresponding PBT compounds, among others, are offered by Lanxess. © Lanxess

Driver Assistance Systems as a New Area of Application

An attractive application for PBT compounds is advanced driver assistance systems (ADAS) and especially ADAS radar sensors and housings. PBT compounds offer good radar transparency, dimensional stability, high hydrolytic stability, good laser welding behavior as well as very good mechanical properties. For radomes, for example, PBT compounds with low dielectric constants (Dk) and loss factors (Df) are available that are also highly permeable to the ADAS radar frequencies of 77 to 81 GHz which are becoming more and more commonly employed. In this way, hardly any radiation losses occur. The good growth potential of PBT compounds for radar sensors has led Lanxess to develop a concept for these components that offers more freedom in the choice of materials compared to previous design methods (**Fig. 8**). It enables heat to be dissipated from the inside of the sensor with the aid of heat-conducting plastics in combination with metallic cooling elements. Assembly is done with integrated snap hooks or by hot riveting, which is much less time-consuming and cost-intensive than screwing together. ■

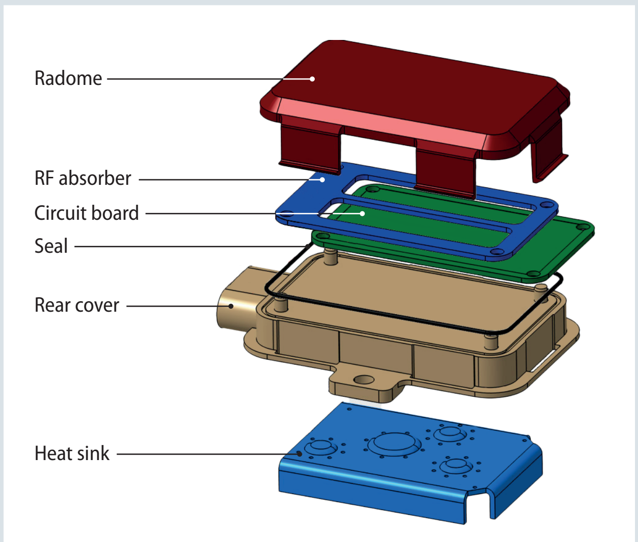

Fig. 8. Construction of a radar sensor according to the Lanxess concept: PBT is ideal for manufacturing the radomes © Lanxess

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Data Basis and Sources

All market data are based on surveys and assessments made by Lanxess. Additional information on investments and technical developments also comes from Lanxess and from press releases issued by the various companies mentioned.

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