Delivering Efficiency Even in Harsh Environments

Polyetheretherketone (PEEK)

Across many industry sectors, the quest for enhanced performance of applications and cost-efficiencies is on. In addition to these traditional requirements, societal and environmental trends, such as the need to reduce carbon dioxide (CO_2) emissions and maintaining a healthy and active ageing population, are important needs that must be addressed as well. Due to its high-performing properties polyetheretherketone thermoplastic polymer is being used more and more frequently in many products.

In contrast to commodity and technical polymers, polyetheretherketone (PEEK) is a high-performance polymer located at the top of the polymer pyramid and ideally suited to extreme and demanding environments typically replacing metals. This is due to their high-performing properties such as light weight, high strength and very good dimensional stability, as well as their high resistance to wear, high temperatures, fatigue and aggressive chemicals.

As a consequence, PEEK can support a variety of key engineering requirements at the same time. For example, operating in more extreme environments to unlock new and unconventional resources in the oil and gas industry requires resistance to aggressive chemicals, high strength and performance in extreme temperatures. The options are to find a material to meet these, or compromise on requirements. Whilst, as a medical implant, biocompatibility, wear resistance and modulus close to bone are among the most important performance criteria.

The PEEK supplier with the worldwide highest production capacity of more than 7000 t/a is Victrex plc., Thornton-Cleveleys, United Kingdom. Focusing on PEEK products for industrial and implantable medical devices, the group of companies not only pioneers new grades but also develops product forms and parts for selected industries and applications to address unmet needs in the supply chains.

The transportation market is subject to fundamental change. Government

PEEK can replace fluoropolymers in cryogenic applications. Advanced Engineering Valves uses PEEK from Victrex for sealings in ball valves © Advanced Engineering Valves

regulators are demanding more CO_2-efficient solutions and the environmental awareness of customers is growing. The result is a wave of OEM vehicle launches in battery electric vehicles (BEV), plug-in-hybrid electric vehicles (PHEV), hybrid electric vehicles (HEV), eVTOL (electric vertical take-off and landing), electric buses, e-scooters, and e-bikes.

Across a variety of under-the-hood applications, PEEK has already become a material of choice for OEMs/Tier1s to increase efficiency. In electric machines for example, PEEK-based electrical insulation can help to improve thermal management, enable more reliable operation and reduce overall system cost. Also, in tribological applications such as seal rings or thrust washers, PEEK has been found to offer longer component life due to its resistance against aggressive media and excellent wear resistance, which help outperform not only metals but also other polymers. PEEK also enables functional integration and miniaturization in smaller spaces while withstanding the high loads and high temperatures.

Using PEEK polymers NVH (Noise, Vibration, Harshness) issues, i.e. rattle and whine of metal gears in mass balance systems, crank gears, pump and accessory drives, can be reduced by up to 50%. Compared to machined metal scissor gears, Victrex HPG (High-Performance Gears) solutions developed in close collaboration with the customer, have been shown to lower the moment of inertia, reducing energy consumption and improving total system costs. In addition, extensive durability testing has demonstrated that Victrex HPG polymer gears can handle the high and dynamic loads required of mass balance systems, while bringing the already mentioned benefits to a vehicle. The considerable weight savings of switching from a metal to such a polymer is an additional benefit.

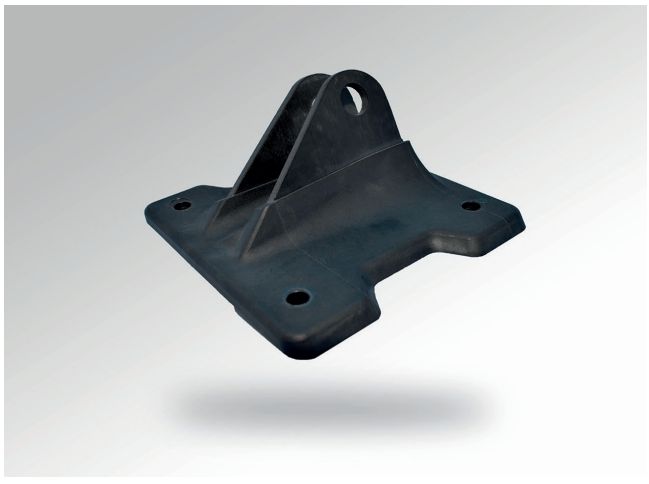


Fig. 1. Prototype of an aircraft cabin bracket: the part was produced via hybrid overmolding and has shown up to 50% weight savings compared to the original aluminum part © Victrex

Hybrid Overmolding Technique

PEEK is also used in the aerospace industry. Reduced weight, standardized parts, streamlined manufacturing, and potential installation savings were the objectives of Safran Cabin, Huntington Beach, CA/USA, and Victrex, when they worked together to qualify thermoplastic composite parts for aircraft. They utilized an innovative technique where Victrex AE 250 thermoplastic composite is overmolded with Victrex PEEK high-performance polymer. This hybrid overmolding technique is a scalable, repeatable technology with the potential to help commercial aerospace customers face the challenges of needing much lower scrap rates, faster cycle times, parts consolidation and reduction in the number of secondary operations. Complex testing and stringent qualification test program (QTP) have indicated that structural aircraft parts produced from Victrex AE 250 via hybrid overmolding can withstand high levels of mechanical stress. Compared to the original aluminum part, the prototype composite of an aircraft cabin bracket (**Fig. 1**) for example has shown up to 50% weight savings, 20% cost savings and a 5 x better buy-to-fly ratio.

The aerospace industry has seen increased investment in the development of flying taxis or eVTOL vehicles for both inter- and intra-city travel over the recent years. Light-weight composite material solutions are being considered for structural elements of eVTOL vehicles. In contrast to thermoset resin, thermoplastic composite products based for example on Victrex AE 250 composites have a weight similar to that of thermosets but offer additional advantages. They can be produced more quickly, require less infrastructure to manufacture, are recyclable, do not use solvents and can be stored for up to ten years prior to processing.

Reduced Cooling Time for Semiconductors

In the semiconductor industry the development and production of smaller and faster chips with more storage for data and increased functionality is an ever-present trend. High volume production and shorter time-to-market are additional needs. However, miniaturization resulting in smaller nodes down to 5 nm potentially makes chips more prone to damage during processing. Longer operating time, less downtime and an up to 3% productivity increase can all be »

Fig. 2. CMP rings are used in semiconductor manufacturing. Made from PEEK they can result in longer operating times © Victrex

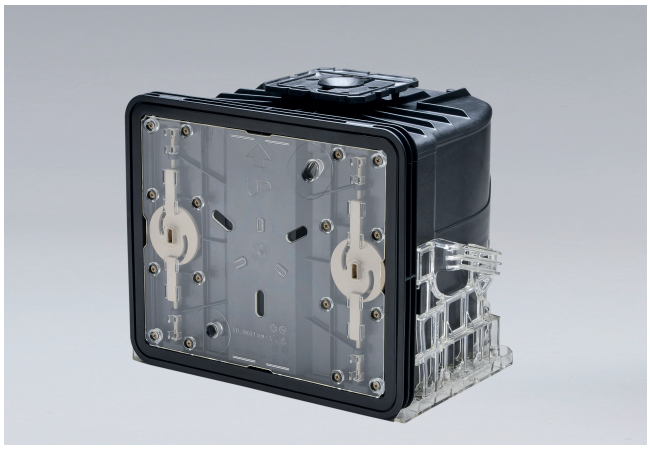


Fig. 3. In semiconductor manufacturing, FOUP (Front Opening Unified Pod) prevent wafer from contamination. They benefit from PEEK´s high resistance to aggressive chemicals and high temperatures © Miraial

Fig. 4. PEEK polymer supports lower ionic contamination and prevention of haze formation on reticles © Gudeng

achieved for example by using CMP rings made from Victrex PEEK (**Fig. 2**). The material is around two times more wear-resistant compared to polyphenylene sulfide (PPS), i.e. they have been proven to run up to two times longer than PPS before replacement is necessary.

In addition, high temperature resistance allows PEEK to endure challenging fabrication processes in both semicon and other electronics manufacturing processes with temperatures up to 260 °C, and also potentially while in contact with harsh chemicals. PVD (physical vapor deposition) or anodization processes can now utilize the same process tools without fear of exhaustive degradation. This can in turn improve fabrication productivity by reducing additional time for cooling.

Today, semiconductor industry engineers are also turning to PEEK polymer to achieve manufacturing yield enhancements. For example, the polymer is used for a specialized enclosure, the FOUP (Front Opening Unified Pod), which is designed for wafer isolation from cleanroom air due to different clean class inside and outside of FOUP and securely hold wafers in a controlled environment (**Fig. 3**), and to allow wafers to be transferred between machines for processing or stored in a wafer stocker.

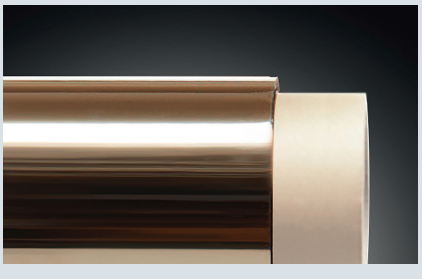
Preventing Particle Contamination

FOUP and wafer carriers are using PEEK for wafer SECC (Surface Environment Contamination Control), a control level requirement reaching molecular levels for both organics and inorganics, in addition to other prevention measures of particle contamination. Due to its inherently inert nature, durability and chemical resistance, PEEK efficiently contributes to overcome these challenges. In addition, PEEK´s heat resistance enables handling of hot wafers which contributes to reduced wafer cool-down times, consequently increasing semiconductor fab productivity through equipment efficiency. In reticle handling, PEEK polymer supports lower ionic contamination and prevention of haze formation on reticles (**Fig. 4**). The lower outgassing also enables reticles to be stored in a mini environment with low contamination risk.

As more and more people consume visual and audio media, such as videos, music and games on their smartphones and other mobile devices, the highly competitive consumer electronics industry is facing a challenge to produce improved micro speakers with higher quality and performance. They should support better sound output and a broader range of frequencies for a louder and richer sound experience, without compromising the functionality of the device. In micro speakers, diaphragms of only a few microns thick play a key role in delivering an excellent acoustic experience. However, even a minute variability in film and diaphragm thickness could cause defects in acoustic performance and reliability. Improved material quality and in-depth design and processing know-how are required, amongst other things, to avoid such defects. Such diaphragms are now also made of PEEK (**see Box**).

In home appliances, high-performing PEEK polymer can enable lighter-weight and smaller designs that remain capable of powerful performance. Indeed, the use of PEEK polymer can also reduce the cost of parts, when replacing metals. A case in point are the recent advancements in vacuum cleaners to meet efficiency and noise requirements. The processing flexi-

Ultrathin Membranes



Film products in micro speakers of smart phones have to be very thin © Victrex

To help advance micro speakers in various types of mobile devices, including smartphones and headphones, Victrex launched an ultrathin APTIV DBX film product line. The new films' tighter thickness tolerance is designed to result in a more uniform thickness to enable laminators, speaker builders and OEMs to improve consistency and yield – and consequently to help meet quality, reliability and performance requirements. The film products are available in thicknesses from 3 to 6 µm and can potentially enhance the sound experience and reliability of micro speakers.

bility of Victrex PEEK injection molding polymers and their consequent advantages in manufacturing have allowed designers to mold very thin wall components with very high dimensional stability to explore new approaches to the design of smaller, yet powerful, vacuum cleaner components.

Victrex PEEK enables for example the production of impellers for vacuum cleaners which are able to cope with high speeds and in some cases faster than 100,000 rpm (**Fig. 5**) – jet engines only rotate at approximately 15,000 rpm. The material´s stiffness to weight ratio also allows the impeller to maintain its shape at these high speeds, potentially resulting in stronger suction compared to more ductile materials. In addition, the high-performing polymer is resistant to a wide range of household chemicals, heat and moisture – and can enable reductions in the weight of parts and the size of motors and components needed. Injection molding contributes to potential cost savings for manufacturers compared to the machining of parts out of metals, and also enables the rapid scaling up of new designs, shortening time to product launch, and allowing faster less capitally intensive scale up of manufacture.

In the oil and gas industry PEEK contributes to produce reliable sealings. Advanced Engineering Valves (AEV), Verviers, Belgium, for example specifically sought an improved sealing reliability solution to meet needs in the extreme cold temperatures found in compressing and liquefying natural gas. After successfully passing Design Validation Testing (DVT), carried out according to the Shell "Material and Equipment Standards and Code" (MESC) at AEV, the company selected the cryogenic PEEK polymer Victrex CT 100 for use in its class 900 ball valves (**Title figure**). These so-called 2XC C-ball valves are designed to meet very stringent demands, potentially reducing the cost of ownership, due to their high reliability (zero maintenance) in cryogenic service.

Many sealing applications in cryogenic temperature ranges have been made with fluoropolymers. Victrex´s cryogenic PEEK series provides a range of properties over a temperature range from –196 °C to +200 °C, which fluoropolymers cannot meet. In this temperature range, chemical resistance is still important, but other aspects such as creep resistance, low temperature toughness and tribological performance, and »

Fig. 5. Impellers for vacuum cleaners manufactured from PEEK: they are able to cope with high speeds and due to PEEK´s properties maintain their shape © Victrex

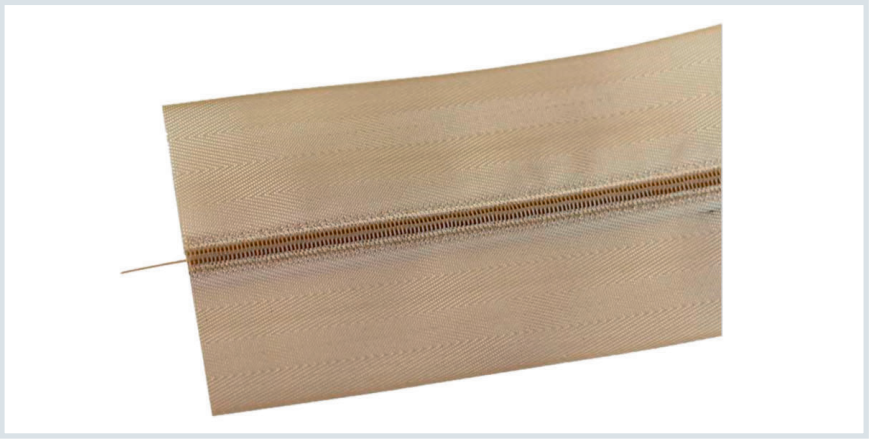


Fig. 6. Spiral lace closure solution for conveyor belts made from Zyex fibers from Victrex: the use of PEEK contributes to extended belt lifetime potential © Victrex

thermal properties such as conductivity and expansion, are the most important to applications such as valve seats and packings and a reason to use cryogenic PEEK.

The food processing industry needs materials that are certified for food and water contact. Lippert international Inc, Nassau, Bahamas/USA, chose Zyex fibers made from PEEK from Victrex for its spiral lace closure (**Fig. 6**) for conveyor belting. The high purity material is certified according to the US Food and Drug Administration (FDA), EU and KTW regulations of the German Federal Environment Agency (Bundesumweltamt) for sanitation and food contact.

Abrasion and Hydrolysis Resistance

It has the strength and reliability needed for use in applications in very tough environments including thermal endurance with a continuous operating range from –60 °C to +260 °C as well as chemical resistance at very high temperatures. In addition, low creep, abrasion and hydrolysis resistance offer extended belt lifetime potential along with a removeable pin design which saves hours of downtime with each cleaning.

The PEEK fastening system is 100 % non-metallic, which means that it can be used in x-ray metal detection scanning to identify potential contaminants in food processing.

Across the world, over nine million medical devices using PEEK-Optima polymers have been implanted. In the US alone, more than 500 medical devices with these polymers are cleared by the FDA. The implantable material from Invibio Biomaterial Solutions, Thornton-Cleveleys, United Kingdom, a Victrex company, is used for example in spine, trauma, orthopaedic and dental applications.

Support Bone Growth

The "Boxcar" offered by Omnia Medical, Morgantown, WV/USA, is one of them (**Fig. 7**). The system has been designed for use in cervical-corpectomy procedures – that is, the replacement of a collapsed, damaged, or unstable vertebral body located in the cervical spine. Available in two footprints, the device allows fine adjustments of height and lordosis using spacers and endplates. Its specific design may encourage for example the formation of new bone. The hydroxyapatite (HA) component in PEEK-Optima HA Enhanced, is a well-known osteoconductive material, i.e. it enhances bone apposition. The polymer offers a modulus similar to cortical bone – unlike the metal or mesh cages in earlier use, plus imaging that allows for unobstructed views during and after the procedure.

In the future, PEEK may also enable connected electronic drug delivery devices that have the potential to lower treatment costs and improve patient outcomes.

Across industries, the quest for the right materials to address multiple requirements, will continue. Being a robust alternative to other polymers and, more importantly to metals, high-performing PEEK thermoplastic-based solutions have the potential to play a pivotal role in next-generation products. ■

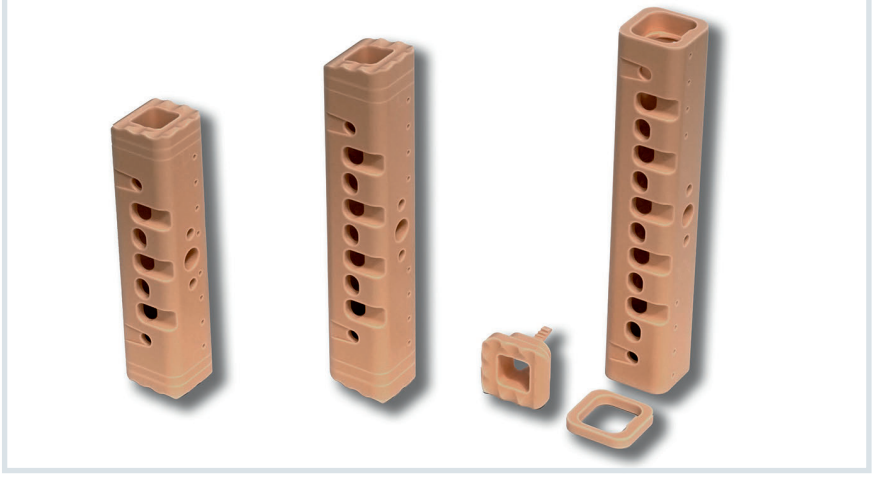


Fig. 7. Boxcar implants can be used to replace collapsed or damaged vertebral body located in the cervical spine. The hydroxyapatite (HA) component in the PEEK used enhances bone apposition © Jalex Medical

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Service

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