



SMARTER MATERIALS™

High-Performance Thermoplastics



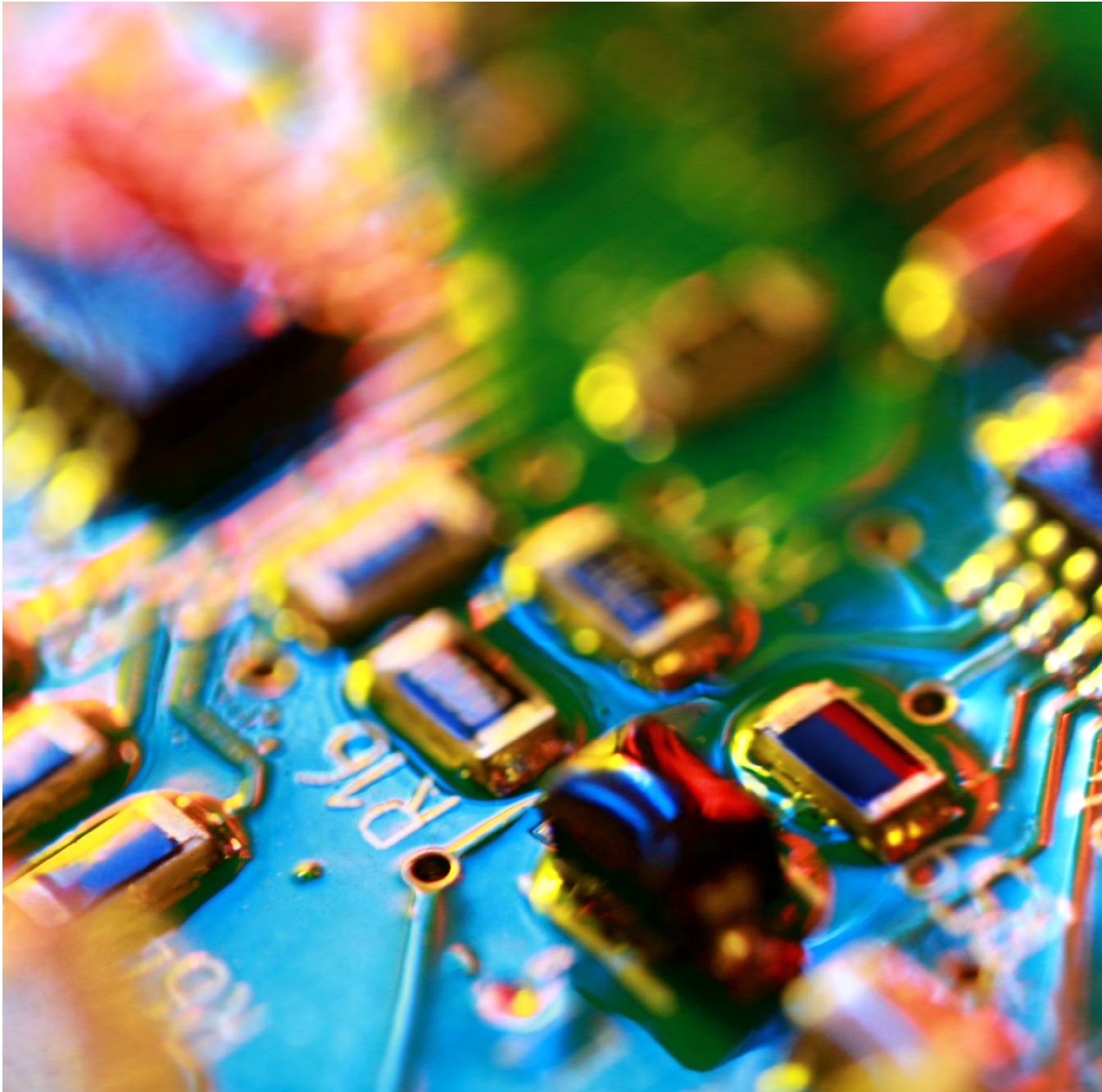


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SMARTER MATERIALS

High-Performance Thermoplastics

Higher, Stronger, Tougher

Just like elite athletes who surpass the limits of typical human accomplishment, high-performance thermoplastics surpass commodity and even engineering resins with their exceptional capabilities. These materials typically offer very high temperature and chemical resistance, along with excellent mechanical performance, inherent flame retardance and radiation resistance. When conventional thermoplastics can't measure up, high-performance thermoplastics can meet the most stringent requirements. In addition, these technologies can exceed the core benefits of commodity resins and engineering thermoplastics by providing greater design freedom, ease of colorability, and efficient processing.

And it's no secret that they're on an upward trajectory...





SMARTER MATERIALS

High-Performance Thermoplastics

The Driving Forces

Today's technology and regulatory trends are driving greater demand for high-performance thermoplastics across many global industries. For example, hospitals are applying increasingly aggressive disinfectants to combat infections, and consumer electronics continue to shrink in size while adding greater functionality. Further, aircraft manufacturers are seeking additional weight reductions, and automotive engine compartments are becoming more crowded with vehicle enhancements that raise underhood temperatures.

According to an in-depth analysis by Report Ocean, the global high-performance thermoplastics market is projected to jump to \$65.6 billion by 2026, up from \$36.5 billion in 2018. This would result in a CAGR of 7.7 percent from 2019 to 2026.*

WHAT TO EXPECT...

This eBook will examine high-performance thermoplastics to answer a range of important questions, including the following:

- What is the value proposition of these materials?
- How do they differ from commodity or engineered resins?
- How are they processed?
- Which types of applications call for high-performance thermoplastics?

To answer these, we will look at five different material families:

- Polyaryletherketones (PAEK)
- Polysulfones (PSU)
- Liquid crystal polymers (LCP)
- Polyetherimides (PEI)
- Polyphenylene sulfides (PPS)

Read on to discover the diverse and growing uses for these elite-level performers of the thermoplastic world.





What Makes High-Performance Thermoplastics Stand Out?

A combination of several important characteristics.

One of the main differentiators between high-performance thermoplastics and other resins is their ability to be used in higher temperature applications. While commodity plastics can typically maintain performance only up to 100°C, and engineering plastics do the same up to 120°C, a high-performance thermoplastic can withstand continuous use temperatures of 230°C while also maintaining low temperature impact.

Why is heat resistance important?

Elevated heat resistance is required for a range of applications exposed to harsh environmental conditions, such as parts used in petrochemical exploration or components placed near automotive and aerospace engines. The ability to withstand high heat is also essential for certain processes, including printed circuit board manufacturing with lead-free soldering and autoclave sterilization for medical devices.

OTHER NOTABLE PROPERTIES

High-temperature thermoplastics also have other properties in common.

- » **CHEMICAL RESISTANCE:** This is required to allow medical and dental equipment to be disinfected, and to improve the durability of components used in the chemical processing industries.
- » **FLAME RETARDANCE:** Inherent flame retardant properties allow these materials to pass important flame/smoke/toxicity (FST) tests needed for use in aircraft cabins and railway compartments.
- » **RADIATION RESISTANCE:** This property is needed for some medical sterilization techniques and also for components used in nuclear power plants.
- » **NO BPA:** Most high-performance thermoplastics do not contain BPA (Bisphenol A), which is associated with concerns about possible health effects.



Going Above and Beyond

Determining a material's cost-benefit ratio is particularly important when it comes to high-performance thermoplastics. Although they typically cost more than traditional resins, these materials deliver added value in demanding applications.

In some cases, they make it possible to surmount performance and processing barriers to create next-generation products and components.

Following are top reasons why many manufacturers and designers choose high-performance thermoplastics:

- High-temperature resistance
- Flame/smoke/toxicity (FST) performance
- Chemical resistance
- Chemically inert

PLUS, ALL THE BENEFITS OF PLASTIC

In addition to their elite-level properties, high-performance thermoplastics deliver the typical advantages of polymers over other material types such as metal, glass and ceramic, including:

- Light weight
- Design freedom/part consolidation
- Easy colorability
- Efficient, high-volume processing
- Elimination of secondary operations
- Enhanced product experience for the end user
 - quieter environment
 - improved tactile feel
 - better usability

All in the Family

There are five major families of high-performance thermoplastics

Polyaryletherketones
Polysulfones
Liquid crystal polymers
Polyetherimides
Polyphenylene sulfides

POLYARYLEETHERKETONES

- Semi-crystalline structure
- High marks for thermal stability, chemical resistance and mechanical properties over a wide temperature range
- Better-than-average levels of combustion resistance and electrical performance
- Some PAEK materials, like polyetheretherketone (PEEK), are also extremely tough and have excellent impact strength
- Best for: aerospace, automotive, industrial and medical components
- May be used to create stock shapes such as rods, bars, and tubes

POLYSULFONES

- Amorphous structure
- High marks for toughness, chemical resistance, hydrolytic stability, resistance to boiling water, and extreme thermal capabilities
- Best for: aerospace interiors, hot water fittings, and medical and dental devices that are subjected to repeated steam sterilization
- Also used in food equipment exposed to temperature extremes, such as coffeemakers or freezer-to-microwave cookware



All in the Family

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LIQUID CRYSTAL POLYMERS

- Semi-crystalline structure
- High degree of anisotropy: strength, stiffness and thermal expansion will be greater in one direction vs. the other
- High marks for temperature, chemical and electrical resistance
- Exceptional mechanical strength and high flow rates; often used to fill extremely long parts with thin walls
- Best for: electronic connectors, sensors, bullet-resistant vests, jet engine enclosures, brake and transmission friction parts, and gaskets

POLYETHERIMIDES

- Amorphous structure
- High marks for thermal, mechanical, and chemical properties
- Often selected for demanding applications requiring ultra-high mechanical strength combined with high temperature, corrosion and wear resistance
- Impact resistance may be lower than that of PSUs and PAEKs
- Best for: aerospace interiors, automotive lighting, medical devices, and electrical and fiber optic connectors

POLYPHENYLENE SULFIDES

- Semi-crystalline structure
- Excellent temperature resistance with continuous service temperatures up to 230°C
- High marks for modulus and resistance to creep, corrosion, and chemicals
- Above-average electrical properties
- Best for: complex parts with extremely tight tolerances; often used as an alternative to metals and thermosets in automotive underhood parts, appliances, electronics, and industrial applications



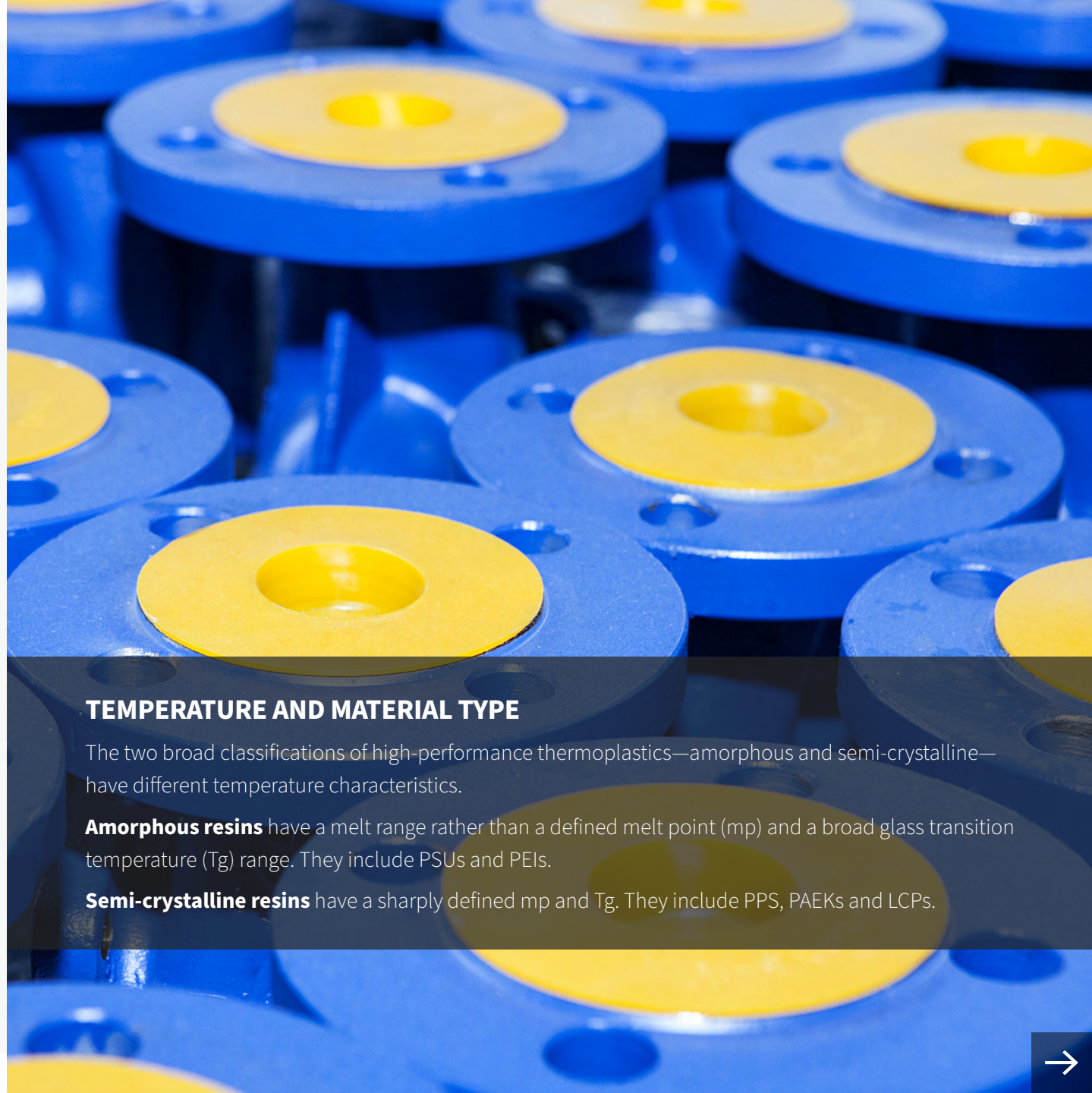


How Hot Is Hot?

High temperature capability is a hallmark of high-performance thermoplastics, but it's a bit complicated. There are several essential metrics used to quantify thermal performance:

- 1. Heat Deflection Temperature (HDT):** Temperature at which a polymer deforms when heated or cooled under a specified load.
- 2. Continuous Service Temperature:** Maximum temperature at which a material can perform reliably in a long-term application.
- 3. Melting Point:** Melting point is the temperature at which a crystalline polymer becomes a disordered liquid.
- 4. Glass Transition Temperature:** Glass transition temperature is the point at which an amorphous polymer becomes hard and brittle.

Important to note, semi-crystalline polymers feature crystalline regions dispersed within amorphous material. The crystalline molecules have a melting temperature, while the amorphous regions have a glass transition temperature.



TEMPERATURE AND MATERIAL TYPE

The two broad classifications of high-performance thermoplastics—amorphous and semi-crystalline—have different temperature characteristics.

Amorphous resins have a melt range rather than a defined melt point (mp) and a broad glass transition temperature (T_g) range. They include PSUs and PEIs.

Semi-crystalline resins have a sharply defined mp and T_g. They include PPS, PAEKs and LCPs.





Meeting the Demands

There's a common thread linking different classes of high-performance thermoplastics; namely, the markets and highly demanding applications in which they are used. These include:

Aerospace: Need for lightweight, pre-colored cabin materials that meet stringent FST regulations.

Automotive: Demand for plastics to handle increasing temperatures due to the proliferation of electronics in engine compartments and tighter spaces.

Electrical/electronics: Pressure to find materials suitable for lead-free reflow soldering common in printed circuit boards, and for molding electrical connectors and housings.

Food contact: Need for food contact compliant materials in household appliances.

Healthcare: Requirements for materials to withstand steam sterilization and harsh chemical disinfectants.

Industrial: Demand for polymers offering thermal chemical resistance to a wide range of environments for bushings, valves, and instrumentation.





Choose Your Color Wisely

Color choices have traditionally been limited for these materials because the high temperature required to process them destroys many pigments that are used in engineering thermoplastics. When a lower-performing pigment is used in a material that is processed at a high temperature, the results are not pretty... the material often turns black or degrades.

Also, the natural color for high-performance thermoplastics is yellow or brown, which makes achieving blues and grays much harder. Pigments can also affect the food contact compliance or biocompatibility of the material.

In high-performance thermoplastics, color can be achieved in two ways:

1. Using pre-colored resin, where every pellet is precisely the right color
2. Adding a concentrate (masterbatch) to the natural resin during processing

Pre-colored resins are formulated to an exact target shade, making it possible to create customized colors. Concentrates, however, are typically lower in cost and can be a good choice when exact color is not critical, such as for color coding in wire and cable applications. However, they do have some limitations:

- In parts with thin walls, concentrates can lead to color variations. Therefore, pre-colored resin is highly recommended.
- In transparent parts, it is advisable to avoid concentrates as they are sensitive to local variations in pigment loading and dispersion.



Learn how Avient helped one appliance maker counteract yellow tones to find just the right color balance.

[CLICK HERE](#)





Handling the Challenge

High-performance thermoplastics can be processed using injection molding, compression molding, and extrusion. However, these high-heat materials require much higher mold and melt temperatures than typical plastics such as polypropylene (PP), nylon and polycarbonate (PC). To mold high-performance thermoplastics, processing equipment must be capable of melt temperatures up to 400°C and mold temperatures up to 200°C.

Another consideration is moisture absorption. Most high-heat plastics are hygroscopic, so careful drying is needed to avoid potential processing issues. These can range from viscosity changes that affect consistency of the molding process to dimensional stability and aesthetics of the finished part.

HOT STUFF

427°C: The glass transition temperature of polybenzimidazole (PBI), one of the world's highest-performing plastics.

Source: <https://pbipolymer.com/>

Source: <https://www.engineering.com/3DPrinting/3DPrintingArticles/ArticleID/14465/3D-Printing-Filaments-Whats-the-Deal-with-ULTEM-and-PEEK.aspx>





Additive Manufacturing

Many companies are producing 3D printed parts from high-performance polymers for specialized aerospace, medical and industrial applications. These materials can be 3D printed using selective laser sintering (SLS) and fused filament fabrication (FFF).

For example, PEEK is an excellent candidate for FFF due to its low moisture absorption. The material typically works best with a nozzle temperature between 360–400°C and a heated bed of 120°C. Also, PEEK powders—typically reinforced with carbon—can be used in SLS.

PEI offers a less-expensive alternative to PEEK while still delivering high performance. When using PEI filament for FFF, it is important to keep the print chamber at an evenly distributed high temperature. Any cool areas can cause the material to shrink unevenly, potentially resulting in warpage or a lack of bonding to the previous layers.

For amorphous polymers like PSU, the cooling rate in FFF is critical. If cooling is too slow, adequate solidification may not take place, which could result in a deformed or collapsed part.

BRASS OR STEEL DIE?

The metal used for FFF dies depends on the polymer: unfilled materials can use softer brass dies, while fiber-reinforced materials need harder steel to prevent premature wear.





YOUR NEXT MOVE



**DURABILITY
PERFORMANCE
HEAT RESISTANCE**

Bring on the Heat

High-temperature polymer formulations provide robust material performance at elevated temperatures, even those in excess of 300°F (150°C). Regarded as some of the highest performing thermoplastics in the industry, these light and versatile alternatives to metals and ceramics can accept the challenges posed by a broad range of applications and industries.

Want to learn more?

Avient can offer colorant and additive solutions that are focused on these high-performance polymer resins and tailored for your requirements. Contact us at **+1.844.4AVIENT (1.844.428.4368)** or visit **[avient.com](https://www.avient.com)** to find out more.

Challenge Accepted.

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