WHITE PAPER

# Extruding High-Performance Thermoplastic Filaments for 3D Printing

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ENGINEERING

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# Extruding High-Performance Thermoplastic Filaments for 3D Printing

| Industries | Challenge | Solution |
|---|---|---|
| **Automotive, Aerospace, Biotechnology, Defense, Industrial, Medical, Optical, and more.** | Create an advanced thermoplastics solution, that is faster to make and more cost effective, to replace metals and thermoset materials in critical applications. | Utilize IPE's vast experience with a variety of polymers to create a high performance thermoplastic filament for use in 3D printers for critical applications. |

Over the last few years, high performance thermoplastics have become a widely discussed topic in the 3D printing community. The manufacturing sector has also seen an expansion in high performance materials research in recent years, particularly for polymers. These include high performance thermoplastics, better known by their acronyms PEEK, PEKK, and PEI (ULTEM). These materials are sparking manufacturers' interest as they offer greater mechanical strength and wear resistance properties. PEEK, in particular, is as strong as steel and often weighs 80% less than typical metal does, which makes it incredibly desirable. Some of these materials can even be reinforced with carbon fiber or glass, which gives them interesting and extremely useful properties.

**The Challenge**

Conventional machining methods of producing complex parts are time consuming and expensive. Additive manufacturing technologies produce inexpensive, versatile, extremely accurate, rapid prototypes and functional parts with very little waste.

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The materials used in 3D printing tend to be softer plastics and can be quite porous. This significantly affects the structural integrity of the parts and can affect the functional properties. The materials also tend to react poorly when exposed to water, alcohol, or other organic solvents. Melting the filament during the printing procedure can also substantially modify its microstructure. This process adds another heat cycle to the material. High performance plastics tend to handle more heat cycles without mechanical degradation to the strength characteristics.

IPE identified a growing customer demand for extrusions made of high performance thermoplastics due to their ease of manufacturing and strong property profile. In particular, the company has seen a major shift toward replacing metals and thermoset materials with advanced thermoplastics in medical applications.

“We were in the process of building a new economy which included the ability to print your own parts at home with reasonably priced 3D printers. Most of these home printers made toys and fun stuff. This changed during the early days of the pandemic. People were printing PPE in their own homes for friends, family, and commercially. This technology will truly be a game changer in the future.” stated IPE’s President, Anthony Green.

Due to the characteristics of high performance polymers, they cannot simply be used in any 3D printer. The printer must be capable of reaching at least 230°C (446°F) in a closed chamber environment. High performance plastics have greater mechanical and thermal resistance. They are very strong while being much lighter on a volumetric basis.

**The Solution**

International Polymer Engineering (IPE) worked diligently with a variety of customers and partners, such as Solvay Polymers, on the spooling and fabrication issue. IPE designed and

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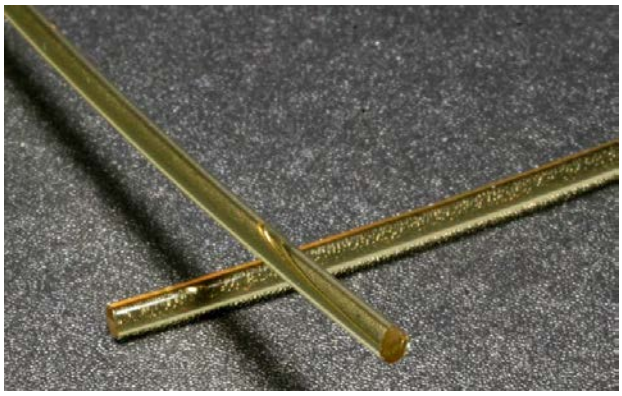
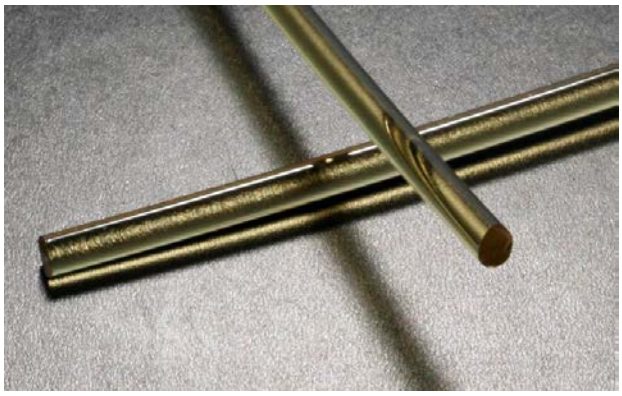
fabricated a broad new range of high-precision microbore tubing, monofilaments, and profiles made of high-performance thermoplastics.

IPE now manufactures high performance microtubes and filaments, spooled or cut to length, which offer exceptional strength and rigidity, on a state-of-the-art extruder specially designed for high temperature materials which process at very high melt temperatures in the range of 370°C (700°F).

IPE is able to achieve the small diameter size through optimized processing; that is, achieving a balance between line speed, processing temperature, and appropriate tooling and drawdown ratio, according to Anthony Green, "High performance plastics are the future of 3D printing. We have seen instances of people printing entire cars. The new economy may include this entrepreneurial spirit as we move into the further. The stay at home economy may be our best yet."





**Materials IPE Works With to Create High-Performance Filaments**

IPE utilizes a variety of advanced thermoplastic materials to create their new line of high performance 3D printer filaments. Some of the materials listed below can also be reinforced with carbon-fiber or glass.

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| Material | Key Properties |
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| **PAEK (polyaryletherketone)** | Exceptional mechanical and thermal resistance of up to 260°C (500°F). Resistant to dissolving in oils and other substances. When exposed to fire, almost no gas or noxious fumes are released. |
| **PEEK (polyetheretherketone)** | PEEK is one of the industry's most chemically resistant plastics and offers excellent strength, superior fatigue resistance, and a continuous-use temperature of 240°C (464°F). It can withstand more than 1,000 cycles of steam sterilization without any significant loss of properties and is compatible with other sterilization methods (including ethylene oxide, vaporized hydrogen peroxide, and gamma radiation). PEEK is also biocompatible as it demonstrates no evidence of cytotoxicity, sensitization, intracutaneous reactivity, or systemic toxicity.<br><br>PEEK is an advanced biomaterial typically used for shielding in magnetic resonance imaging (MRI) devices, medical implants, and in reinforcement rods and spinal fusion devices. It can withstand boiling water and super heated steam, which makes it perfect for objects that need to be sterilized in extremely high temperatures. |
| **PEI (polyethylenimine)** | High strength-to-weight ratio, exceptional dimensional strength, flexible, good electrical properties, excellent mechanical properties, high temperature resistance, good UV light resistance, and good hydrolytic stability. |
| **Kepstan® PEKK (polyetherketoneketone)** | Outstanding high temperature performance, very high stiffness, tensile & compressive strength, impact resistance, combustion resistant, low smoke toxicity, resistant to virtually all organic & inorganic chemicals, high dialectic strength, exceptional barrier properties, and outstanding coefficient of friction. |
| **PPSU (polyphenylsulfone)** | Heat & chemical resistant, good tensile strength, impact resistance, good chemical resistance, and exceptional long-term hydrolytic stability. |

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IPE also has extensive experience with quite a few exotic and challenging materials. IPE is always willing to extruded materials that other companies may be hesitant to work on.

**Sizes and Tolerances**

| Product | Material | Size |
|---|---|---|
| ***Outer diameter = OD, Inner Diameter = ID*** | | |
| **Microbore tubing** | KetaSpire® Polyetheretherketone (PEEK) | 0.012" OD x 0.010" ID (0.3 mm OD x 0.25 mm ID) |
| **Microbore tubing** | Radel® Polyphenylsulfone (PPSU) | 0.50" (12.7 mm) with OD of 0.012" and ID of 0.010" (0.3 mm OD x 0.25 mm ID) |
| **Microfilament** | KetaSpire® Polyetheretherketone (PEEK) | 0.012" OD x 0.010" ID (0.3 mm OD x 0.25 mm ID) |
| **Microtubes** | Unfilled Polyetheretherketone (PEEK) | As small as 0.029" OD by 0.016" ID (0.74-mm OD by 0.41-mm ID) and 0.077" OD by 0.057" ID (1.96-mm OD by 1.45-mm ID) |
| **Monofilaments** | Udel® Polysulfone (PSU) | 0.02" (0.5-mm) |
| **Monofilaments** | Radel® Polyphenylsulfone (PPSU) | 0.06" (1.5 mm) and 0.11" (2.8 mm) |
| **Monofilaments** | Polyaryletherketone (PAEK) | 0.06" (1.75 mm) |
| **Monofilaments** | Torlon® Polyamide-Imide (PAI) | 0.06" (1.5 mm) |
| **Monofilaments** | PrimoSpire® Self-Reinforced Polyphenylene (SRP) | 0.06" (1.5 mm) |
| **Monofilaments** | Halar® Ethylene Chlorotrifluoroethylene (ECTFE) | 0.06" (1.5 mm) |
| **Tubes** | Polyetheretherketone (PEEK) | Up to 0.25" (6.35 mm) diameter |

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IPE chose to extrude many different Solvay polymers due to their excellent clarity, stiffness, hardness, steam sterilizability with excellent resistance to chemicals and high temperatures. For example, IPE fabricates microtubes made from Solvay's KetaSpire® polyetheretherketone (PEEK) resin that deliver greater strength and rigidity than polytetrafluoroethylene (PTFE) microtubes, and they are easier to work with compared to those made of stainless steel. The company further introduced monofilaments made of Solvay's Torlon® polyamide-imide (PAI) resin, which offers the highest strength and stiffness of any thermoplastic up to 275°C (527°F). KetaSpire® PEEK is one of the industry's most chemically resistant polymers that offers excellent strength, superior fatigue resistance, and a continuous-use temperature of 240°C (464°F).

Additional monofilaments are fabricated with Solvay's PrimoSpire® self-reinforced polyphenylene (SRP) resin, one of the stiffest and strongest unreinforced polymers in the world. Solvay's Halar® ethylene chlorotrifluoroethylene (ECTFE) resin, a partially fluorinated, melt-processable polymer, is also specified by IPE for monofilaments due to its excellent chemical resistance and lubricity.

IPE specializes in custom extruded profiles, tube, sheet, and rod made of nylon, PTFE, polyurethane, polycarbonate, and other thermoplastics for the medical, lighting, and industrial markets. The company is able to achieve its products' small diameter sizes by finding an optimal balance between line speed, processing temperature and appropriate tooling and drawdown ratio.

IPE also has the capacity to manufacture PEEK profiles, both open and hollow, for a wide range of applications.

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**About IPE**

IPE (International Polymer Engineering) is one of the only companies worldwide engineering fully custom FluoroFlex™ ePTFE solutions. IPE also utilizes advanced engineering, creativity & experience to provide thermoplastic extrusion solutions for the most demanding applications. As an ISO 13485:2016 certified company, we ensure the most stringent quality standards. We strive to be your total solution provider – we also offer design & development services, material testing & analysis, and class 10,000 clean room processing. We have experience in a diversity of industries, including medical, automotive, and aerospace, among others. IPE's machining division, IPE Aerospace, designs and builds many of the machines used in our facilities. They can design and build yours too!

If you are interested in our polymers for your next project, if you'd like to find out more information, or if you need assistance designing your project please contact IPE directly to talk with experts about your application.

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