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THERMOPLASTICS: THE STRONGEST CHOICE FOR 3D PRINTING

WHEN MATERIAL STABILITY AND LONG-TERM PERFORMANCE IS PARAMOUNT

By Fred Fischer, Stratasys

The majority of today's consumer products — and many commercial ones — are composed of thermoplastics. When designing a new product, engineers can best predict its end performance by prototyping with a material as similar to it as possible. That's why 3D printing with thermoplastics is so widely practiced. Using fused deposition modeling (FDM®) machines, engineers have the option of making parts with the most commonly used thermoplastics, such as ABS, polycarbonate, a variety of blends, as well as engineered thermoplastics for aerospace, medical, automotive, electronic and other specialty applications. When using 3D printing for the production of finished goods, using a thermoplastic is all the more important, and it may be the only choice for many applications.

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Materials characterize manufacturing processes. In turn, manufacturing processes influence the material properties of the final product. Additive manufacturing is no different. The technologies are identified by the materials they use, and the quality of the output is controlled by the processing methods. In the case of FDM, the materials are industrial-grade thermoplastics and include some high-performance engineered thermoplastics.

Additive manufacturing uses a layer-based process to convert computer models into plastic parts. Direct from computer-aided design (CAD) files, automated machines add layer after layer of material, which makes very complex parts easy to produce. The FDM process creates functional parts by extruding and depositing the materials.

Using the same types of raw materials found in injection molding facilities around the globe, FDM makes plastic parts with properties suited for applications from concept modeling through product development and manufacturing. As with molded parts, there are a variety of material options, each with unique characteristics designed to meet the application needs.

SELECTING A THERMOPLASTIC

For production of finished goods, there are no shortcuts. Material stability and durable performance is key. So, carefully consider the mechanical, thermal, electrical and chemical properties and any changes that result from aging or environmental exposure. However, because parts created with an FDM machine share many of the characteristics of the molded thermoplastics, you can leverage what you already know.

For all other applications, including functional prototypes, patterns, tooling and manufacturing aids, the selection process is much simpler. The key is having an understanding of the characteristics that make each FDM material unique. What you will consider are the following qualities:

- Material characteristics
- FDM machine availability
- Support material type
- Color

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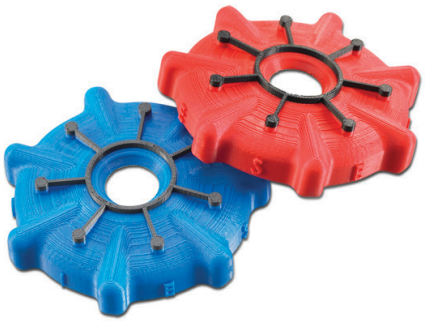
To pick the right material, seek the best combination of these material traits while placing priorities where they belong. As you review the material options, you may find the choice is simple because of a critical performance standard (e.g., chemical inertness) or personal preference (e.g., no-touch post processing).

All FDM materials have a lot in common. Each material is similar in terms of loading and building parts, office compatibility, and is safe enough to handle with no protective gear. Also, parts produced by each material are dimensionally stable and durable enough for demanding applications.

ABS

ABS, one of most commonly used thermoplastics, has been the foundation for FDM for many years. Measured by annual consumption, it is the most widely used material in FDM machines. It is so widely used that it can be labeled general purpose, which is accurate but misleading. The ABS materials are an excellent choice for models, prototypes, patterns, tools and end-use parts. Forty to seventy percent stronger than the FDM materials of just a few years ago, today's thermoplastics for FDM machines offer greater tensile, impact and flexural strength.

ABS-M30



The ABS-M30™ plastic formulation is the plastic commonly used in the FDM process, and is specific to the Fortus™ line of production 3D printers. This material formulation is also known as ABS*plus*™ for the Dimension® line of 3D printers.

In raw filament form, these are identical materials with equal mechanical properties. However,

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as you review the data sheets for ABS*plus* and ABS-M30, you may be surprised to see a difference in finished part material properties. As with molded parts, processing makes a difference. Developed for manufacturing applications, Fortus 3D Production Systems have advanced hardware and software controls that process the materials differently. By doing so, the material characteristics achievable from ABS-M30 are improved. While ABS*plus* produces tough parts, ABS-M30 is generally stronger in all categories.

Both materials will produce parts that are stable, strong and durable. Both come in a range of colors that include white, black, red, blue, green, fluorescent yellow and more.

Another common quality that makes these two materials the workhorses of FDM is that they are easy to finish. As with most additive manufacturing processes, FDM machines use a sacrificial support structure to build the part, but the ABS materials have something few others do: no-touch support removal. A soluble support material eliminates manual labor. Parts are placed in a tank and the supports are dissolved away.

The surface finish of ABS*plus* and ABS-M30 parts is more than adequate for concept modeling, functional prototyping and creating manufacturing tools. If the application is for master patterns, marketing models or finished goods, and the user wants a surface finish similar to that of injection molding, FDM has an optional hands-free smoothing process in the form of the Finishing Touch® Smoothing Station that can smooth parts in under a minute.

ABS-ESD7

ABS-ESD7™ is Stratasys' electrostatic dissipative material available for FDM. This material prevents a buildup of static electricity, so it's ideal for applications where a static charge can damage products, impair performance or cause an explosion. For these reasons, ABS-ESD7 is well-

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suited for carriers and organizers for electrical components, fixtures for electronic component assembly and production line and conveyor parts. Other applications include product design and validation for electronic product enclosures, electronics packaging materials and powder or mist conveying or dispensing.

ABS-ESD7 also eliminates another common static electricity problem: the attraction and buildup of particulate, such as dust or powders, which can degrade product performance. ABSESD7 also avoids attracting atomized liquid so it's beneficial for medicine inhalers that must deliver the entire drug dose to the patient and not leave mist clinging to inhaler's internal surfaces. All mechanical properties of ABS-ESD7 are within five percent of the ratings for ABS-M30.

ABS-M30i

Medical, pharmaceutical and food handling equipment have stringent regulations to protect consumers from illness and disease. Regulations include standards such as ISO 10993 and USP Class VI, which classify a material as biocompatible. ABS-M30i™ meets these criteria so it can be used for products that come in contact with skin, food and medications.

ABS-M30i blends strength with sterilization capability – another criterion for products that come in contact with our bodies and the things we ingest. ABS-M30i can be sterilized using either gamma radiation or ethylene oxide (Eta) sterilization methods.

ABSi

ABSi™'s advantage is translucency. Although it has good mechanical properties, it excels in lighting applications. It is widely used for functional evaluation of lenses for items such as automotive lighting. The popularity of ABSi for lens application is apparent through its color

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options: red, amber and natural. It is also useful for monitoring material flow in applications that process or transfer material in powder or bulk solid form.

ASA

An excellent general-purpose thermoplastic is ASA (acrylonitrile styrene acrylate). ASA has improved mechanical properties versus ABS, and one important distinction: UV stability. ASA builds UV-stable parts that won't degrade with prolonged exposure to sunlight, plus it offers some of the best aesthetics of any FDM thermoplastic. Easy to use and reliable, ASA is ideal for automotive parts, sporting goods, outdoor functional prototyping and end-use parts for outdoor infrastructure and commercial use, like electrical housings. ASA's

excellent mechanical properties and aesthetics are also great for general-purpose prototyping. It also offers 10 color choices, more than any other FDM

PC

Stratasys is serious about production applications, so it doesn't ignore the most widely used industrial thermoplastic, polycarbonate (PC). PC is available on all Fortus 3D production systems, and when parts come off these machines, they are accurate, stable and very durable.

PC has excellent mechanical properties and heat resistance. It has the second highest tensile strength of all FDM materials and a high heat deflection temperature of 280 °F (138 °C). This is a serious material for tough applications: functional testing, tooling or production.

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PC-ABS

There's a good reason for the blend of polycarbonate and ABS. It gives the most desirable properties of both PC and ABS materials. It has the superior mechanical properties and heat resistance of PC, including one of the highest impact strength ratings of all the FDM materials. Meanwhile, it has good flexural strength, feature definition and surface appeal of ABS. Like all versions of ABS for FDM, PC-ABS offers the no-touch finishing option with soluble supports.

PC-ISO™

Like ABS-M30i, PC-ISO is a biocompatible (ISO 10993 and USP Class VI) material, which makes it the other FDM alternative for medical, pharmaceutical and food packaging industries. Another trait shared between them is that it is sterilizable using gamma radiation or ethylene oxide (Eta) methods.

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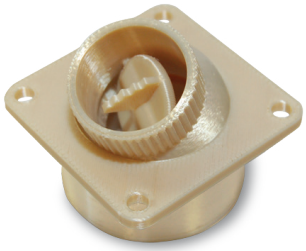
Characteristics that distinguish PC-ISO are its higher tensile and flexural strength, and its higher heat deflection temperature. In these categories, its values are 33% to 59% higher than those of ABS-M30i.

ULTEM™ 9085 resin



One of three high-performance engineered thermoplastic materials available for FDM, ULTEM 9085 resin is a product of SABIC Innovative Plastics, and it is found in many aircraft and aerospace products. ULTEM 9085 resin is FST rated, which means it satisfies flame, smoke and toxicity standards. When processed in a Fortus system, the material's FST characteristics are unchanged. So, transportation companies that must adhere to stringent requirements often demand ULTEM 9085 resin. Also available in ULTEM 9085 resin Aerospace, this option offers full production traceability in compliance with rigorous aerospace certification requirements.

If your application doesn't require FST rating, don't overlook this material. You will still want to consider ULTEM 9085 resin for its strength, durability and resistance to heat and chemicals. It is a tough material that can take a beating. Of the 15 FDM materials, ULTEM 9085 resin has well-rounded thermal, mechanical and chemical properties that make it superior in most categories. In terms of material sales for FDM use, it is the fastest growing.

ULTEM 9085 Aerospace grade filament

ULTEM 9085 is also available in two types of aerospace grades that meet the procurement requirements for materials to be used for production parts by many aerospace manufacturers.

- General Aerospace Specification: A general specification that meets the requirements of most aerospace manufacturers.

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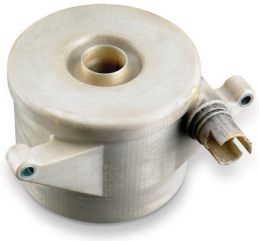
- Custom Aerospace Specification: A custom manufactured product that meets the requirements of a specification that is jointly developed with an individual customer.

ULTEM 1010 Resin

Another product of SABIC Innovative Plastics, ULTEM 1010 resin is the newest high-performance FDM thermoplastic and offers excellent strength and thermal stability. With the lowest coefficient of thermal expansion of any FDM material, ULTEM 1010 resin is perfect for many industrial tooling applications and other parts that require the unique combination of strength and thermal stability. ULTEM 1010 resin's ability to withstand steam autoclaving and its food-contact (NSF 51) and bio-compatibility (ISO 10993) certifications make it perfect for specialized applications including food-production tools and custom medical devices. The first Stratasys material approved for food contact, ULTEM 1010 resin also offers the highest heat resistance, chemical resistance and tensile strength of any FDM thermoplastic. It's ideal for everything from aerospace applications to under-the-hood automotive applications to composite tooling.

PPSF/PPSU Polyphenylsulfone



The first high-performance engineered thermoplastic available for FDM was PPSF (also called PPSU). This super material was added for under-the-hood and other advanced applications, where other plastics can succumb to heat and chemical attack. PPSF has excellent heat resistance (372°F/189°C heat deflection temperature) and chemical resistance. It is mechanically superior to other FDM materials outside the high-performance materials. PPSF is resistant to oils, gasoline, chemicals and acids.

Like ABSi and ABS-M30i, PPSF is sterilizable. But because of its temperature and chemical

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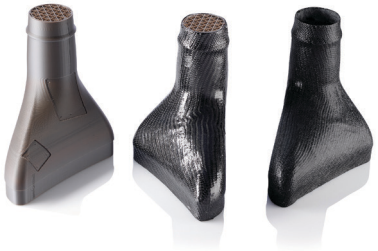
resistance, you can use other sterilization methods, such as steam autoclave, plasma, chemical and radiation sterilization.

FDM Nylon 12

FDM Nylon 12 is the first material in Stratasys' new family of nylon offerings. Nylon 12 complements the current portfolio of FDM materials and enables new applications requiring repetitive snap fits, high fatigue resistance, strong chemical resistance and press (friction) fit inserts. Primarily used in aerospace, automotive and consumer goods industries, nylon 12 offers unparalleled toughness and a simple, clean process that's free of powders. FDM Nylon 12 parts exhibit 100 to 300 percent better elongation at break and superior fatigue resistance over any other additive manufacturing technology.

ST-130



The only FDM model material designed and tested specifically for composite tooling applications, ST-130 helps build complex, hollow structures in one seam-free piece through sacrificial tooling.

ST-130 offers more control over interior accuracy and surface finish of hollow composite parts without time-consuming mold-making processes, interior wrinkles from clamshell tooling or the extra bonding and finishing steps needed in multi-piece construction.

ST-130 model and the ST-130_S support material dissolve easily, producing lightweight, strong, seamless composite parts with complex geometries.

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MATERIAL	KEY CHARACTERISTICS
ABS-M30, ABS*plus*	Versatile, tough
ABS-ESD7	Electrostatic discharge resistant
ABS-M30i	Biocompatible
ABSi	Translucent
ASA	UV stable
PC	Strong (tension)
PC-ABS	Strong (impact)
PC-ISO	Biocompatible
ST-130	Designed for sacrificial tooling
ULTEM 9085 resin	Mechanically well-rounded. FST certification. ULTEM 9085 resin Aerospace available.
ULTEM 1010 resin	Food-safety and bio-compatibility certification. Highest heat resistance.
PPSF	Resistant (thermal/chemical)
Nylon 12	Strong (high fatigue resistance)

CONCLUSION

The 15 FDM materials share many characteristics that make them well-suited for in-office modeling as well as low-volume manufacturing. Yet, each has unique properties that distinguish them from one another. Their unique properties include transparency, biocompatibility, FST certification, chemical resistance, thermal resistance and strength, and it is these properties that make material selection a fairly simple task.

In manufacturing, materials define the process. In additive manufacturing, FDM is recognized as the process that offers a selection of thermoplastic materials for functional use.

Stratasys takes seriously market feedback about which materials are important to users, and it is always exploring options for future material releases. It will continue to research and develop new thermoplastic material formulations for use in its FDM machines.

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