MakerBot

A GUIDE TO 3D PRINTING MATERIALS

Picking the right material at the right time

berwicks
TECHNOLOGY SERVICES

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INTRODUCTION TO 3D PRINTING MATERIALS

In 1989, the first FDM (Fused Deposition Modeling) 3D printer was invented and, with it, the dawn of an era of possibilities for product design and manufacturing. The first material for that printer was a mix of wax and plastic. Over the next 30 years, material scientists developed a range of new and exotic materials, while hardware and software advancements in 3D printing enabled the use of these new materials. Most of the early 3D printers and materials developed were only available to companies who could afford their six-figure (or more) price tags, but recently there has been a renaissance in which major material manufacturers are flocking to the space. With that popularity, a wealth of new materials are being developed and optimized for 3D printers.

While some of these materials print spectacularly, others still have a ways to go in terms of reliability, print quality, or material performance. Some materials are extremely affordable and others can be costly. With all of these options and variables, it can be daunting to someone who is relatively new to 3D printing. For that reason, we've created a guide that will take you through the ins and outs of FDM 3D printing materials, when to use them, and what to expect along the way.

3D Printing Materials: From Concept to Production with Base Polymers

Explaining the properties and pros and cons of materials is helpful, but it might not be clear which material is right for your application(s). In this section, we'll take some base FDM polymers and organize them in the context of the product development cycle – with the first materials being best for the initial concepts, and the last more suited for the manufacturing line or final end-use parts.

	Conceptual Prototyping	Functional Prototyping	Manufacturing Aids	End-Use Parts
ASA	◧□□	■■■	■■■	■■■
ABS	◧□□	■■■	■■■	■■■
NYLON	◧□□	■■■	■■◧	■□□
PET-G	◧□□	■■■	■■◧	■□□
TOUGH	■■□	■■■	■■◧	◧□□
PLA	■■■	■□□	◧□□	◧□□

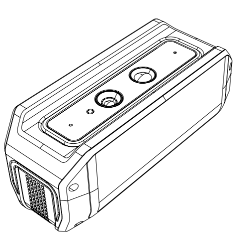
Model Materials

PLA

Fast, Easy, Rigid

Best Uses: Concept prototypes

PLA (polylactic acid) is a great material for early concept models because it is easy to use, office-friendly, and works well with breakaway supports which print faster and can be removed faster than dissolvable supports. PLA is a corn-based plastic and is considered biodegradable under industrial processes. PLA is strong in tensile strength and modulus relative to other base polymers, which may be surprising to some because it is generally viewed as a fairly basic material. One potential downside of PLA is its brittleness – if it fails, it fractures catastrophically whereas some of the other polymers may bend.



Parts: 3D Laser Scanner
Support: Breakaway Support
Print Time: 23h 58m

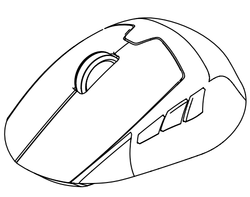
These 3D laser scanner prototypes are printed using PLA with breakaway supports and showcase how multiple iterations can be printed quickly and cost-effectively to help with concept development.

TOUGH MATERIAL

Fast, Easy, Durable

Best Uses: Functional prototypes

Tough is a relatively new category of material that has a PLA base with modifiers to increase its tensile modulus to make it more impact-resistant. The combination of ease of use, office-friendliness, and durability / machinability make it great for mid-stage prototypes. Tough has an incredibly high elongation before break making it highly durable – this can be seen when printing extremely thin living hinges, which can be bent back and flexed many times before breaking. While highly durable, Tough can lack the higher quality surface and detail finish of both PLA and ABS.



Parts: Mouse
Support: PVA
Print Time: 26h 31m

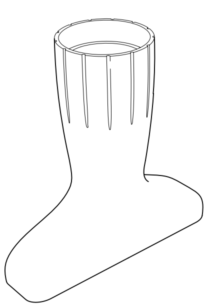
This computer mouse assembly prototype is printed using MakerBot Tough Material with PVA dissolvable supports. The PVA support washes away with water allowing for more complex geometries without harming the surface finish.

PETG

Chemical Resistant, Durable

Best Uses: Functional prototypes

PETG's (glycol-modified polyethylene terephthalate) chemical resistance makes it a choice material for liquid containers and bottles, which also makes it great for prototyping those types of products. While available in a range of colors, PETG's glycol addition removes haziness to give it a nice translucence. The glycol also increases the strength and heat-resistance compared to PET. In addition to containers, the liquid / chemical resistance can benefit a range of uses from the machine shop to the lab.



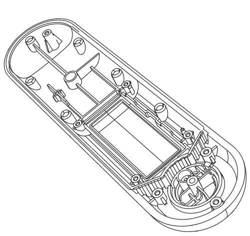
Parts: CNC Shop Vac Vaccum Nozzle
Support: PVA
Print Time: 6h 41m

This vacuum nozzle was printed as an attachment for a shop vac for removing waste material from a CNC machine. PETG is a great choice for this application due to the material's chemical resistance to the CNC coolant.

ABS
Smooth, Durable, Heat-Resistant

Best Uses: Functional prototypes, manufacturing tools

ABS (acrylonitrile butadiene styrene) is one of the most popular materials for injection molded consumer products due to its clean surface finish, durability, and heat resistance. For this reason, it is often used for prototyping consumer products that will later be injection molded. By using ABS, the prototype is more likely to look, feel, and perform like the final product. ABS's durability and high heat deflection temperature also makes it a good material for use in the lab or on the factory floor.



Parts: Thermocouple Thermometer
Support: Stratasys® SR-30
Print Time: 16h 16m

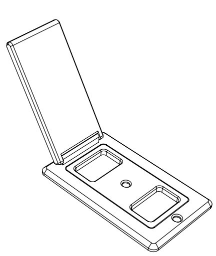
This meat thermometer from OXO is is a great example of a complex assembly being prototyped in the same material as the final injection molded part – ABS.

ASA

UV and Weather Resistant, Durable

Best Uses: Functional prototypes

ASA (acrylonitrile styrene acrylate) combines the qualities of ABS with the added benefit of UV resistance and additional moisture resistance, making it ideal for equipment exposed to sunlight and rain over long periods of time – such as products for the agriculture, transportation, and power and utility industries. Because the use of ASA is fairly common in production parts for these industries, the prototyping of the same parts in ASA allows test engineers to better understand how their products will hold up in extreme weather conditions. In the field, a utility worker or a farmer could benefit from printing replacement parts as needed for broken equipment.



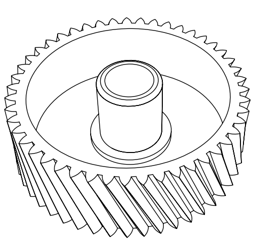
Parts: Electrical Outlet Cover
Support: Stratasys® SR-30
Print Time: 4h 29m

This electrical outlet cover is printed in ASA and is a great example of a prototype for testing products that will be exposed to outdoor elements.

NYLON
Abrasion-Resistant, Strong

Best Uses: Replacement Parts

Nylon's ability to withstand high temperatures and its durability combine to give it above average abrasion resistance. While the storage of replacement parts can be costly, the ability to instead store the CAD file and print the parts as needed is an alternative that can save space and provide flexibility. Gears take consistent punishment and high abrasion, making Nylon an ideal material for this type of part.



Parts: Conveyor Gear
Support: PVA
Print Time: 10h 19m

This conveyor gear is an example of a replacement part for a manufacturing facility or distribution center.

Support Materials

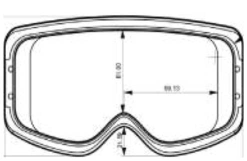
Whether you're working with FDM, SLA, SLS, or another type of 3D printer, unless you're printing in space, you have to account for gravity. If you're printing something like a solid cube, this isn't really an issue because each layer has a corresponding layer beneath it for support. But what if you have an object that has portions of the model that are essentially floating in midair with no structure directly underneath them? This is where removable supports come into play. Depending on the type of FDM 3D printer you are working with, there are a few good options you can use.

BREAKAWAY (USING MODEL MATERIAL)

Breakaway supports aren't so much a type of material, but rather a software trick in which the slicing program fills in the void below the model with a removable structure printed in the same material. Breakaway supports are popular because they can use the same material as the printed model with a single extruder (as opposed to dissolvable supports requiring a second extruder and material). The quality of the print then depends on a couple of variables. The first is dependent on the slicing algorithm. A good slicer will ensure that the prints are well supported, but also leave a seam along which a clean break can be made. The second thing to consider is which material is being used. A hard, rigid plastic like PLA is really best for this because it is more apt to having a clean fracture whereas a less rigid plastic will bend and tear when removing support, leaving remnants on the model part.

PVA

PVA (polyvinyl alcohol) is a water soluble support material that is compatible with many lower temperature model materials such as PLA and PETG. Printing PVA alongside a model material requires at least two extruders so you'll need a printer with dual extrusion for this. Because PVA is water soluble, it is extremely office-friendly - you can place your part in water and after a few hours, the supports will dissolve. Using a dissolvable material like PVA allows you to create much more complex parts because the solvent (in this case water) can reach deep within channels and crevices of the part. It also can reduce the damage caused to the print, which might be more prevalent when using breakaway supports.

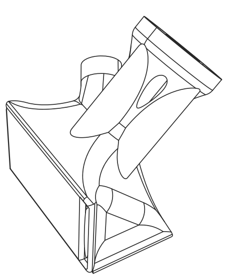


Parts: Ski Goggles
Model: Tough
Print Time: 25h 48m

This single cylinder engine block is printed in MakerBot Tough with PVA water-soluble supports. The PVA supports in this example showcase the ability to print deep channels without compromising the dimensional accuracy or surface finish of the part itself. Putting the part in water overnight will yield a clean part that is ready to bolt into place for a fit test in this case.

SR-30

SR-30 is a proprietary material developed by Stratasys to work seamlessly with ABS, ASA, and various other high-temp materials. Because of this focused development, using SR-30 with these typically more challenging materials can yield exceptional results that wouldn't be possible with something like PVA, which is very difficult to use with ABS. Like PVA, SR-30 is dissolvable and can enable extreme complexity of geometry while maintaining excellent surface finish at the support site. Unlike PVA, SR-30 requires a specialty solvent along with heat, to efficiently dissolve. Users of SR-30 will need to invest in additional equipment, and possibly use in a more controlled environment like a lab.



Parts: EOA Robotic Sander
Model: ABS
Print Time: 66h 15m

This robotic sander is an end of arm tool that can be attached to a Universal Robots UR10e arm for automated hand sanding. The part benefits from the use of Stratasys® SR-30 dissolvable support, which allows for the design of an internal cavity in which sawdust can be channeled from the surface to a shop vac hose fitted to the exhaust vent.

COMPOSITES: THE NEXT GENERATION OF 3D PRINTING MATERIALS

While it's important to have a firm core of base polymers for your printer, there is growing excitement around composite materials, or materials that combine multiple polymers to enhance properties and increase performance. The MakerBot LABS Experimental Extruder for METHOD, for example, gives users the possibility of using MakerBot's primary base polymers, alongside a massive array of third-party composites and other advanced polymers. While it's not realistic to cover each and every composite, there are a few examples below that give insight into a world of new possibilities through these offerings.

CARBON FIBER + BASE POLYMER

Carbon Fiber is one of those materials that creates a buzz whenever it comes up, and for good reason. The use of carbon fibers can create incredible strength while keeping weight low. Carbon fibers can be composited with a number of other polymers, for example ABS carbon fiber can provide the clean surface of ABS with the added strength of carbon fibers.

ESD

ESD (Electrostatic Dissipative) is a property that reduces static electricity in order to protect electrostatic-sensitive devices, or to contain flammable liquids or gases. Through modifications in chemistry, 3D printing base polymers, such as PETG, can take on ESD characteristics, making them ideal for creating test fixtures or housings for circuit boards.

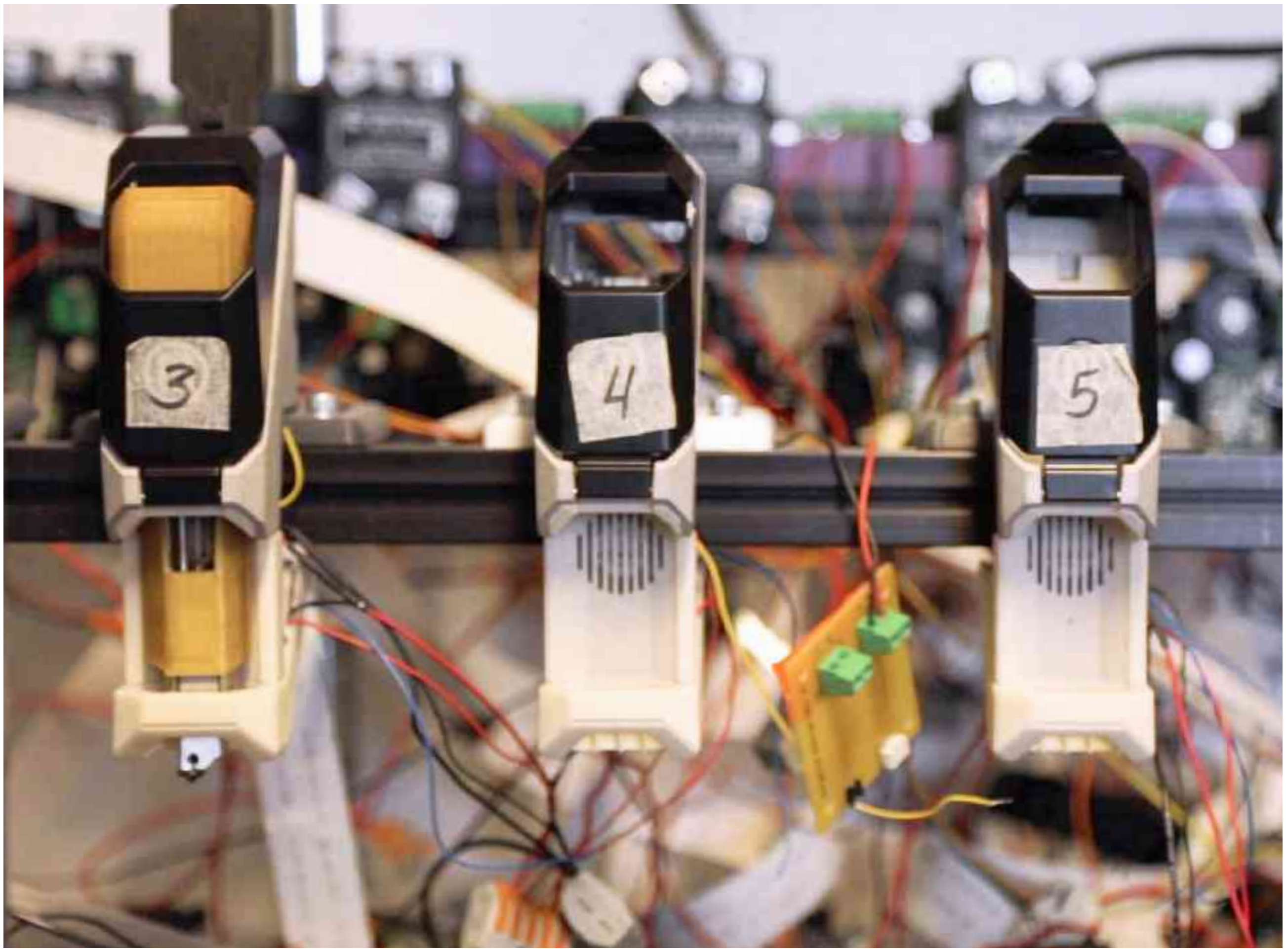
FLAME RETARDANT

Preventing or slowing the spread of fire can be important in many testing or end-use applications. By modifying a base polymer like polycarbonate, it is possible to 3D print parts that are not only strong, but also have extinguishing properties that prevent flames. FR is an important characteristic for parts made for the automotive, railway, and aerospace industries.

Not All 3D Printers are Equal: 5 Things that allow MakerBot METHOD to Print Materials Better

While FDM (also known as FFF) is a specific category of 3D printers, that doesn't mean all FDM 3D printers are created equally. Within the family of FDM, costs can range from $200 to $200,000. While the most basic 3D printing technology is a build plate, with an extruder and a gantry, there are many things you can do to improve print quality, material diversity, complexity, and more. For this section, we're going to focus on the industrial processes and features that enable the MakerBot METHOD to print with a unique blend of speed, dimensional accuracy, and reliability. We'll go in chronological order from initial development through to final print.

1. Testing and Optimization



PRINTER OPTIMIZATION

Once the decision is made to optimize a new material for the METHOD platform, MakerBot typically works with a material supplier to get samples and suggested settings. From there, a collaborative effort between MakerBot's software development team and test engineering group will develop and optimize slicing profiles that will yield best results in part quality, surface finish, dimensional accuracy, and print time. Depending on the material type, this process can take up to several months.

TORTURE TESTING

During the optimization, ABR tests are conducted across dozens of printers to ensure consistency of these settings while printing some of the most challenging geometries. These tests can be grueling and push the printers to their limits to find the limits of both the hardware and the material, and ensure the user will have a good experience when they print with the new material.

2. Shipping and Handling

SMART SPOOL / MYLAR BAG

Once the material is manufactured, it is spooled up and bagged. METHOD utilizes the Smart Spool system, which is a purpose-built spool that contains sensors read by the printer when loaded into the material bay. The RFID chips contain information about the material type, color, amount remaining on the spool, etc. This information allows the printer to use the optimized print settings with the material type, further streamlining the user experience. The spools are shipped in resealable mylar bags, which are impermeable to light and moisture and help protect the filament from potential damage. Within the spool there is also desiccant to keep the environment moisture-free.

3. Loading and Storing

SMART ASSIST MATERIAL LOADER

Once the spool is loaded into the drawer of the material bay, you only need to insert the tip of the filament into the material slot. The printer recognizes the presence of filament and will do the rest of the work loading the filament up the routing tube and into the extruder. This hands-free process is not only convenient for users but also prevents the user from accidentally adjusting a calibrated extruder.

DRY-SEALED MATERIAL BAYS

Once material starts loading, the drawers on the material bays can be closed. The two Dry-Sealed Material Bays are sealed from the outside environment. This seal, combined with the desiccant cartridge of the Smart Spool, ensures that the material is stored in a low-humidity environment even during printing and in between prints. A sensor in the bay can show the humidity level within the bay and humidity levels can be tracked across Smart Spools. Protection from humidity is especially important when printing with materials like Nylon and PVA – both of which are prone to absorb moisture which can cause damage to the end print.

4. Printing

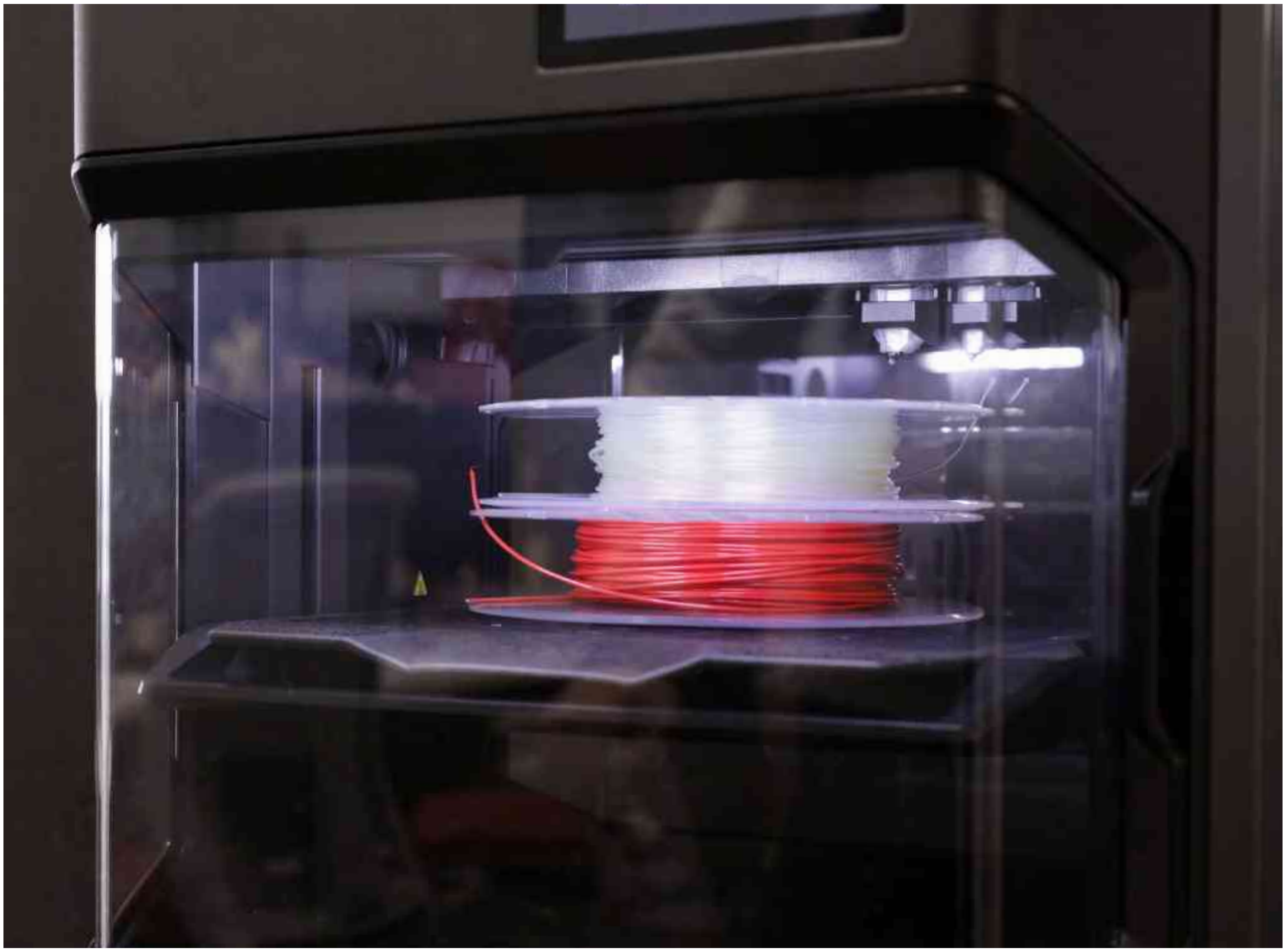
PERFORMANCE EXTRUDERS

METHOD has two extruders – one for model material and one for support material. These extruders are packed with a sensor suite and chip set that enable them to accurately control print temperature so as not to damage materials. The sensor suite also includes active jam detection, and auto-stop when filament runs out. With a range of temperatures, METHOD's extruders can handle higher temp materials such as ABS and ASA, or when active cooling is turned on, single extrusion low temp materials can be printed with ease.

CIRCULATING HEATED CHAMBER

One of the marquee features of METHOD that distinguishes it from other 3D printer options in its price class is the Circulating Heated Build Chamber. Using two active heat exchangers on either side of the printer, METHOD warms the chamber temperature from 40ºC and 100ºC depending on the material. By creating a consistent chamber temperature throughout, METHOD is able to achieve a printed part dimensional accuracy within ±0.007in (±0.2mm) of the CAD design. The added heat also increases the strength of the bond between vertical layer lines – giving the part strength on all three axes (not just two).

5. Drying



CHAMBER MATERIAL DRYING

A new feature added to METHOD is the ability to dry spools using the heat within the Circulating Heated Chamber. This is great if you have a spool that's been left out of the bag for a long period of time, or if the spool is older and the desiccant has become saturated. To run this function, use the touchscreen to navigate to Settings > Advanced and select Dry Filament.

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