Types of Plastics

Abstract

Chapter 3 of Library Technology Reports *(vol. 50, no. 5) "3-D Printers for Libraries" covers the two major types of filaments used in 3-D printing, ABS and PLA. The chapter also covers in brief several other less common plastics.*

The substrate for FDM printers is almost exclusively some form of thermoplastic that is delivered in an extruded wire-like form on a spool and is usually called "filament" in the generic. The two common diameters for use in FDM printing are 1.75 mm and 3 mm, and a specific diameter is called for by the printhead being used for the printer in question. A printer that uses 1.75 mm diameter filament won't be able to use 3 mm without retrofitting the hardware for the difference, and vice versa. The 1.75 mm size is slightly more commonly used and is the filament diameter used by the most popular manufacturer of FDM printers, MakerBot Industries.

As I talk in chapter 5 about the different printer types and manufacturers, I'll make a point of mentioning what type of filament they can print because that turns out to be a major limitation and will affect any purchasing decision.

ABS

The original fused deposition printers almost exclusively used ABS (acrylonitrile butadiene styrene) as their substrate for printing. ABS has nearly ideal properties for rapid prototyping in plastic: it's a strong, slightly flexible plastic that extrudes cleanly at between 220° and 240° Celsius. ABS is used in Lego bricks and is one of the most commonly used industrial and commercial plastics.

For FDM printing, ABS requires a heated print bed to ease the thermal shock. Heating the print build plate helps the plastic adhere to the plate for stability and prevents it cooling too quickly, which could lead to thermal deformation (a sort of curling or separation when ABS cools rapidly after being extruded). ABS is sensitive enough in this arena that many people who print ABS learned early on that enclosing the printer would increase the stability of prints because it regulated the temperature around the printer. I discovered early in my printing experiments with an early MakerBot printer (Replicator 1) that even a strong breeze blowing in the wrong place (i.e., across the print bed) could wreak havoc with getting a good print out of the printer. Higher-end printers will have an enclosed print area built in, while less expensive ones won't.

One of the advantages of ABS is that it dissolves in acetone. Acetone dissolves ABS completely, but used sparingly it can act as a glue to fuse two ABS printed pieces together permanently. Acetone is also used to make a "glue" for print beds to make them sticky for the initial printed layers. Acetone vapor is heavier than air, and some people have used this property to build acetone vapor baths that act to smooth the edges of layers of an FDM ABS print.

ABS has caught some bad press recently as the potential effects of off-gassing of the heated plastic and microparticulate effects are studied. As a petroleum-based plastic, ABS does produce a distinctive stink when printing. Fumes have been reported to cause headaches, and some studies link ABS fumes to olfactory loss.[1] One study found ABS printing releases high volumes of ultrafine particles that could be dangerous when inhaled.[2] These are preliminary studies.

Most haven't been repeated, and the science is still rough on the health effects. But if you need to print with ABS, it may be a good idea to take venting into account.

PLA

PLA (polylactic acid) is the second-most popular printing substrate for FDM printers. PLA is a bioplastic, made from corn, beets, or potatoes, and is compostable in commercial compost facilities (the heat and bacterial action in home composting aren't high enough to break it down). It melts at a much lower temperature than ABS (150–160°C), but it is typically extruded at a higher temperature, anywhere from 180°C to 220°C depending on the PLA itself. Because of its lower temperature, it's not suitable for uses that involve high temperatures and direct sunlight. PLA is also very different from ABS in term of fragility; PLA is far more crystalline and shatters or cracks more readily than ABS, rather than deforming under pressure.

However, MakerBot and other major manufacturers are now starting to go with PLA as their primary printing plastic. PLA doesn't require a heated bed to promote adhesion or prevent thermal curling, which lowers the price of the printers that use it. It's far more thermally stable during printing than ABS as well, and much less likely to warp or curl due to errant breezes. It is possible to reliably print PLA without needing to enclose your printer, which can be a huge benefit in many circumstances.

The other significant advantage is that PLA is far more pleasant when printing than ABS. Because it is a bioplastic, when heated it smells like waffles or syrup and not like an oil spill. It also hasn't been linked to any type of medical issues from being heated, although the study of all these plastics is young when it comes to 3-D printing specifically.

One of the other advantages of PLA is that it's available in dozens and dozens of colors, including both opaque and partially transparent, as well as a couple of glow-in-the-dark colors. It also is available in a flexible form, which can produce prints that are almost rubber-like in consistency.

If you are printing in a library setting, I would suggest concentrating on using PLA. Between reliability and ease of working with it, it's a far better choice than ABS for printing in a public space.

Other Plastics

Once you get beyond ABS and PLA, you're in the realm of specialized plastics that are used for specific properties rather than for general 3-D printing. There are more and more of these practically every day, but generally they fall into a couple of categories: dissolvable support material, specific required material qualities, or nonplastic powder suspended in a thermoplastic resin. I'll describe the most common of these below.

HIPS

High impact polystyrene, or HIPS, is a plastic filament used for dissolvable support structures in FDM printers. It extrudes at around 235°C, and its material properties are very similar to ABS. The main difference is that HIPS is completely soluble in a liquid hydrocarbon called limonene. This means that if you have an FDM printer with more than one printhead, you can extrude ABS from one and HIPS as a support material from the other. If you sit the final printed model in a bath of limonene, the HIPS will dissolve away, leaving only the ABS behind, thus allowing for nearly impossible geometries to be printed, including moving ball bearings and more.

Nylon

There are at least four types of nylon currently available for use in FDM printers: Nylon 618, Nylon 645, Nylon 680, and Nylon 910. These vary in their color from medium transparency to fully opaque white, and all are extraordinarily strong compared to other FDM substrates. They are also very resistant to solvents and such, although they are dyeable with acid-based dyes.

Nylon is more expensive than PLA or ABS. The major reason for using nylon would be for specific material properties (resistance to specific chemicals) or because of the need for FDA-approved materials, as both Nylon 680 and 910 are undergoing FDA approval for use, something rare in the 3-D printer world.

T-Glase

T-Glase is a brand name for a filament composed of polyethylene terephthalate. Of all 3-D printer filaments, it is the most glasslike. Nearly transparent, especially at small sizes, it could easily be mistaken for glass. At larger sizes, it is still very light-transmissive, if not fully transparent. T-Glase prints at around 221°C on a heated bed, but it is very stable and resistant to curling.

LayBrick and LayWood

LayBrick and LayWood, another type of printing material for FDM printers, fall squarely in the experimental realm. They are made by a single manufacturer and are both a sort of hybrid filament, with a powdered material being supported inside a resin. In the case of LayWood, fine wood particles are suspended in a thermoplastic resin; in the case of LayBrick, very finely crushed chalk and other minerals are suspended in the resin.

Both LayBrick and LayWood have the interesting property of variability in appearance depending on the temperature at which they are printed. LayBrick can range from a very smooth, almost ceramic feel to very rough sandstone when the heat of extrusion is increased. For very smooth, you print at a low temperature (165–190°C); going up from there to around 210°C will render the printed part rougher and rougher. For LayWood, the difference is in the appearance of the final product. By increasing the temperature, you get darker and darker wood grain from the output, so you can actually vary the look from light to dark wood (or, if you have a printer that supports variable temperatures during a single print, you can get different colors in a single print by varying the temperature).

One of the risks, however, with both of these is that the filament isn't uniform in construction, which means that it's possible to clog your extruder if the nozzle opening is smaller than the particulate in the filament itself. FDM printer nozzle openings range from .35 mm to .5 mm, and on the lower end of that, especially with LayWood, you risk clogging a nozzle (it is harder to ensure regular sizes with organic particles than with inorganic particulate). I know 3-D printers that have clogged even at .4 mm nozzle using LayWood; for printing these sorts of filaments, the larger the nozzle the better.

Polypropylene

Still very experimental, polypropylene (PP) offers the possibility of food-grade 3-D prints. Polypropylene should work with any FDM printer at an extrusion temperature of 210°C and a heated print bed set to 90°C. It looks like PP is really available only in black.

Notes

1. Shu-Fang Cheng, Mei-Lien Chen, Po-Chen Hung, Chiou-Jong Chen, and I-Fang Mao, "Olfactory Loss in Poly (Acrylonitrile-Butadiene-Styrene) Plastic Injection-Moulding Workers," *Occupational Medicine* 54, no. 7 (October 2004): 469–74, available on PubMed .gov, www.ncbi.nlm.nih.gov/pubmed/15486179.
2. Brent Stephens, Parham Azimi, Zeineb El Orch, and Tiffanie Ramos, "Ultrafine Partile Emissions from Desktop 3D Printers," *Atmospheric Environment* 79 (November 2013): 334–39, doi:10.1016/j .atmosenv.2013.06.050.