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3D PRINTING FILAMENTS

A QUICK GUIDE TO CHOOSING 3D PRINTING PLASTICS

This prototype quadrotor frame that I designed was printed with PLA, but I'm looking into more durable materials, like PET or polycarbonate, for the final version. The arms are "off-the-shelf" F450 plastic arms, but making my own center plates allows me to move away from the classic X-configuration, with more clearance at the front for a camera and more space inside for electronics.

If you're new to 3D printing or planning on trying it out, then you may have been overwhelmed by the variety of plastic filament out there: ABS, PLA, PET, HIPS, TPE ... it's like standing in front of the shampoo aisle at the supermarket: should I pick the organic one, or the one with the moisturizing conditioner? I've printed with ABS and PLA, but wondered if there could be a better option, especially for multirotor applications. So I reached out to two 3D printing stores, RepRap Warehouse and Voxel Factory, who sent me samples of various specialty 3D printing filaments.

Who wouldn't love a glow-in-the-dark quadcopter? This one was printed with ColorFabb glowFill.

I did several test prints, then compared them for rigidity and strength. Although not strictly scientific, this article should give you a general idea of the distinguishing properties of various filaments and help you decide which one to pick for your next project.

But first, let's start with the bread and butter of 3D printing: ABS and PLA. Those are the most common filament materials and should be everyone's starting point.

ABS: Workhorse of the 3D Printing World

Acrylonitrile butadiene styrene is the same plastic as used in household plumbing. It's also what Lego bricks are made of. It's durable and has good heat resistance. It can be sanded, glued, painted, machined or reworked in various ways after printing. ABS is soluble in acetone, allowing you to weld parts together with a few drops, or create high gloss by brushing or spraying full pieces. ABS is also a good choice when creating interlocking pieces for mechanical purposes.

The printing temperature for ABS is between 210 and 260°C, depending on the printer. Unfortunately, ABS has a bad tendency to warp when it cools, especially with large parts. A heated build platform will mitigate this issue and should be considered mandatory.

You can dissolve some scrap ABS into acetone to make ABS glue. The RepRap site says that ABS will stick to Kapton tape, but I recommend applying a thin layer of ABS glue over the Kapton tape to get a solid first layer every time.

Unfortunately for the multirotor hobbyist who wants to make airframe components, ABS is easy to bend and break, which means having to make thicker and heavier parts.

There is an alternative to ABS called Bendlay. It's a modified ABS filament that is similar, but more flexible than ABS, clear looking and food-safe. It prints at temperatures between 215 and 240°C and I found it fairly easy to use. It printed on bare glass with a heated bed at about 100°C.

PLA: A Friendly, Easygoing Companion

Polylactide is a biodegradable thermoplastic derived from plants such as corn, potatoes and sugar beets. It melts at a lower temperature than ABS, between 180 and 220°C. For that reason, some low-end 3D printers may be designed to only print PLA.

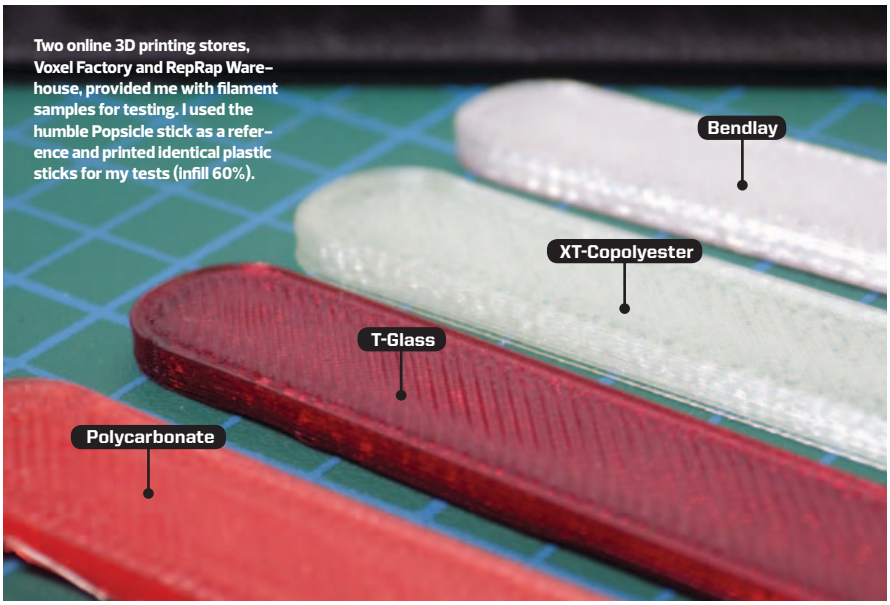
This plastic is far more susceptible to heat than its ABS counterpart. For instance, it can droop and deform if left too long in a warm car during the summer. That's why you shouldn't print motor mounts with PLA.

This greater meltability also means that some external cooling (such as a fan pointing at the tip of the hot end) may be necessary when printing small parts.

On the upside, PLA doesn't warp and is one of the most rigid materials. It's also the easiest filament to work with.

You can print with PLA without using a heated bed. It is recommended that you use a sheet of polycarbonate (Lexan), which you can buy at your local hardware store for a few dollars. Coat it with a thin layer of cooking oil before printing.

If you have a heated bed, like I do, you can print directly on glass, but I've had better results by first coating it with diluted polyvinyl acetate (commonly called wood glue, white glue, carpenter's glue or school glue).



Two online 3D printing stores, Voxel Factory and RepRap Warehouse, provided me with filament samples for testing. I used the humble Popsicle stick as a reference and printed identical plastic sticks for my tests (infill 60%).

PET: The Classy Family with Lots of Shiny Relatives

Polyethylene terephthalate, or PET, is a clear-looking, very strong and durable polyester. It's what plastic bottles are made of. But to make things confusing, companies have come up with an array of various derived polymer mixes, with brand names like PETT, PET+, PET-G --all similar, but not identical. For the purpose of this article, I tested two products: Taulman 3D T-Glass and Colorfabb XT-Copolyester.

PET is usually extruded at moderately high temperatures, between 230 and 260°C. A heated bed is mandatory to prevent warping. You may be able to print on bare glass. If that doesn't work, try coating it with diluted wood glue, the same as when using PLA.

T-Glass is effectively strong and beautifully translucent, which is why it's a favorite among those who print custom jewelry.

I preferred the surprisingly rigid XT-Copolyester, which was the only rigid plastic (other than nylon) that would not break when bended. It's definitely an interesting alternative to ABS or PLA.

Nylon: The Temperamental Queen

Elegant, tough and flexible, nylon is less brittle than ABS, PLA or PET, which means you can use it to print thin structures that will bend, but not break. That's why it has been embraced by the prosthetic 3D printing community. It has a low friction coefficient and high melting temperature, which makes it an ideal choice for printing gears or parts that rub against each other. It's too flexible to print large airframe

I applied weight at the center of each stick until it failed. This gave me an approximate idea of its rigidity and strength. Hang in there polycarbonate! This is the strongest material that I tested.

CHOOSE YOUR FILAMENT WISELY

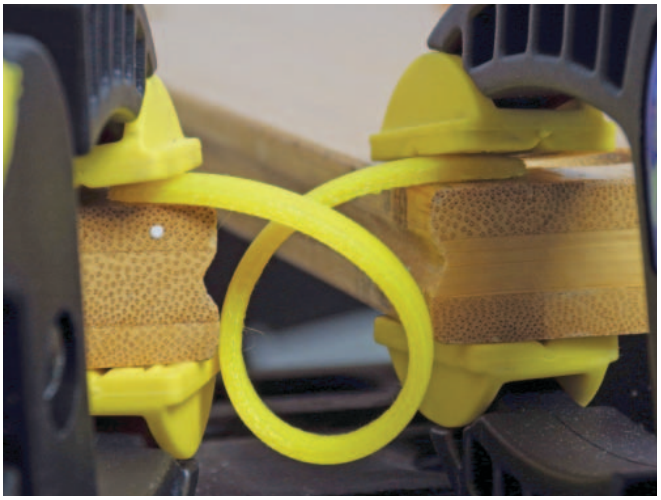
Quality filament has a constant diameter, a smooth curve, no imperfections, and contains no contaminants or air bubbles. Unfortunately, filament quality is hard to predict when you shop online. "There is a lot of junk [online]," warns Godreau. He imports a lot of filament for his store and he has seen the best and the worst. He recommends purchasing from a reliable distributor.

DON'T PRINT GARBAGE!

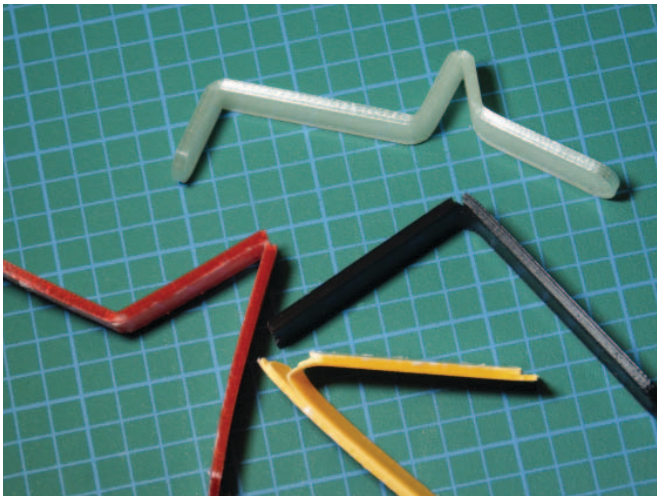
Keep in mind that 3D printing, especially trial and error prototyping, can create a lot of trash. We need to avoid having landfills full of failed prints. Recycling facilities reject 3D printed objects because they can't tell what it's made of. You can recycle your own ABS, but only with expensive equipment. Consider printing your prototypes out of PLA, which is biodegradable.

KEEP IT DRY

Most filaments, such as ABS, PLA, nylon and polycarbonate, will absorb humidity over time if left out in the open. Then, when you try printing with it, the water causes bubbles that prevent good layer adhesion and greatly weaken the part. It also ruins the surface finish. Store your filament in a sealed container with a desiccant. If a roll of filament has become unusable due to humidity, it can be dried at a low temperature in an oven.



Nylon is the only rigid 3D printing material that can be curled up like this and not break. It did not even lose its shape. I was able to straighten it back afterward.



Among the samples that Voxel Factory sent me was an unexpected surprise: ColorFabb XT-Copolyester (top) was the only plastic that I could bend this way and not break. And it proved almost as rigid as polycarbonate. It's definitely one of the better filaments in the PET family.

parts, but definitely a contender for hinges, joints, servo arms, mounts, etc.

Unfortunately, nylon has the reputation of being difficult to work with and has caused me more frustration than any other filament.

But like everything in the 3D printing world, experiences may vary, and Steve Godreau, president of RepRap Warehouse, has a different opinion. "I've had no problems with nylon," he says, "which means I don't have a ton of advice." His method is to print at temperatures of 255 or 260°C, on bare glass coated with hair spray. He uses a bed heated at 70°C to prevent warping.

Some may suggest using nylon weed-whacker wire from the hardware store. That can work, but those wires may contain unknown additives that could damage your printer or vaporize into the air, so experiment at your own risk.

Polycarbonate: The King of Filaments

PC is what digital disks and bulletproof windows are made of. It is HARD! Polycarbonate is about as rigid as PLA, but stronger and with a better tolerance to heat. It's definitely a good choice for performant and reliable airframe parts. It can only be extruded at high temperatures, between 255 and 315°C, so you need a 3D printer that goes that high. I managed to print my samples at 265°C, but slowed down the rate of the printer to 30 mm/s to compensate for the relatively low temperature.

I printed on Kapton tape with a coating of ABS glue, so basically the same thing as when I print with ABS. My heated bed was set to its maximum, 120°C, since PC is prone to warping.

TPE: Flexibility is Both a Blessing and a Curse

Thermoplastic elastomers are usually marketed as "flexible filament" and they have a rubbery texture. I can imagine using them to make a custom vibration-dampener system for motors or cameras, for example.

The properties of this thermoplastic and rubber mix will vary greatly between brands. Printing temperatures are usually between 190 and 240°C. The one sold by Makerbot melts very easily and can be extruded at temperatures as low as 100 to 120°C. That also means that it's more susceptible to heat, but may remain flexible in the cold, so choose wisely.

TPE doesn't require a heated bed. "I printed it on my Replicator 2," says Godreau, "with an acrylic plate and hair spray, and that was it." If you're using glass with a heated bed, he recommends warming it up to around 50 to 70°C and coating it with hair spray if needed.

Flexible filaments may cause problems on some feeders that end up squishing rather than pushing it. Some extruders may require a modified guide to get that filament right into the thermal tube. Similarly, TPE will not work with a Bowden type extruder, which has a long tube separating the hot end from the motor that pushes the filament.

DON'T KILL YOUR HOT END

Some of the filament materials mentioned, like nylon and polycarbonate, require a hot end that can handle high temperatures (above 250°C). Opinions may vary, but if your hot end is insulated with PEEK and/or PTFE (in most cases they are), it's probably a good guideline to stay below 240°C. To go above that, you may need a Bowden type extruder with an All-metal hot end.

DON'T BREATH IN THE SMOKE

Heated ABS smells like burning plastic and some preliminary studies have shown that 3D printing with this material can produce potentially-carcinogenic fumes. Nylon and polycarbonate also emit potentially hazardous fumes. For that reason, always operate your printer in well-ventilated spaces. That goes double if you accidentally burn plastic. Having the printer itself in an enclosure can also help mitigate the health risks. PLA is a bioplastic and is considered safer than the rest since it doesn't produce any carcinogenic fumes. It also smells better during printing, like sweet syrup.

Soluble (PVA) vs Dissolvable (HIPS)

These filaments are intended for 3D printers that have more than one extruder. They are used to build easy-to-remove support structures for overhanging parts.

Polyvinyl Alcohol (PVA) is soluble in water. After printing your part, just give it a bath and the support material just melts away. Very cool! Unfortunately, it's also VERY expensive ($100 per kg).

High Impact Polystyrene, or HIPS, is more affordable and works in a similar fashion, with the exception that it must be dissolved in a chemical called Limonene rather than water. D-Limonene is the most common type and comes from the oil pressed from the rind of citrus fruits. It is sometimes sold as a solvent for cleaning purposes.

Is That All of Them?

This overview covers the most common and currently available filaments. But new kinds come out all the time. Sometimes it's a custom mix of the same common plastics that we've seen, like ABS combined with Polycarbonate, so you get the benefits of both. Other times it's a common plastic mixed with something new and original, like PLA with chalk in it to make sculptures that look like sandstone. Obviously, these more "creative" types of filaments are not that interesting for the multirotor hobbyist.

Nonetheless, there are several specialty filaments that I didn't have a chance to cover in this article and that you may find interesting. In my next piece, I'll tell you about my experience 3D printing with carbon fiber!

OVERSET. POSSIBLE TO CUT TEXT?