FDM 3D Printing materials compared

Written by 3d Matter

Introduction

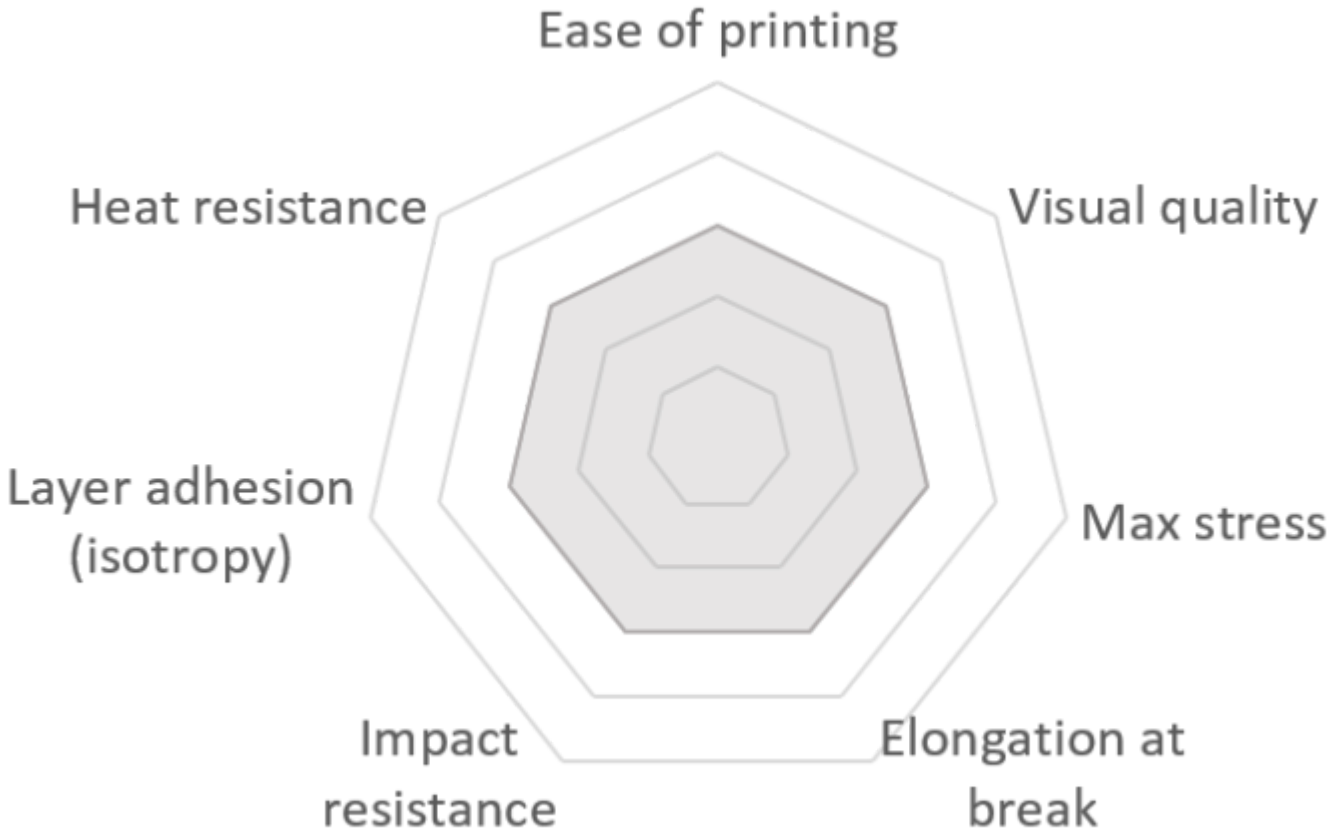
Choosing the right type of material to print a given object is becoming increasingly difficult, as the 3D Printing market sees the regular emergence of radically new materials. In FDM 3D Printing , PLA and ABS have historically been the two main polymers used, but their initial dominance was mostly fortuitous, so there should not be any major roadblocks for other polymers to play a key role in the future of FDM.

We are now seeing new products become more popular, both pure polymers and composites. In this study, we focus on the main pure polymers that exist in the market today: PLA, ABS, PET, Nylon, TPU (Flexible) and PC. We sum up the key differences

between their properties in snapshot profiles so that users can make a quick decision about the best polymer to use for their application.

Methodology

Materials are usually graded along 3 categories: mechanical performance, visual quality, and process. In this case, we further break down these categories to paint a clearer picture of the polymer's properties. The choice of material really depends on what the user wants to print, so we listed the key decision criteria needed to choose a material (other than cost and speed):



A spider web graph showing the material properties that will be compared

- **Ease of printing:** How easy it is to print a material: bed adhesion, max printing speed, frequency of failed prints, flow accuracy, ease to feed into the printer etc.
- **Visual quality:** How good the finished object looks. More info on how we test it here.
- **Max stress:** Maximum stress the object can undergo before breaking when slowly pulling on it.
- **Elongation at break:** Maximum length the object has been stretched before breaking.

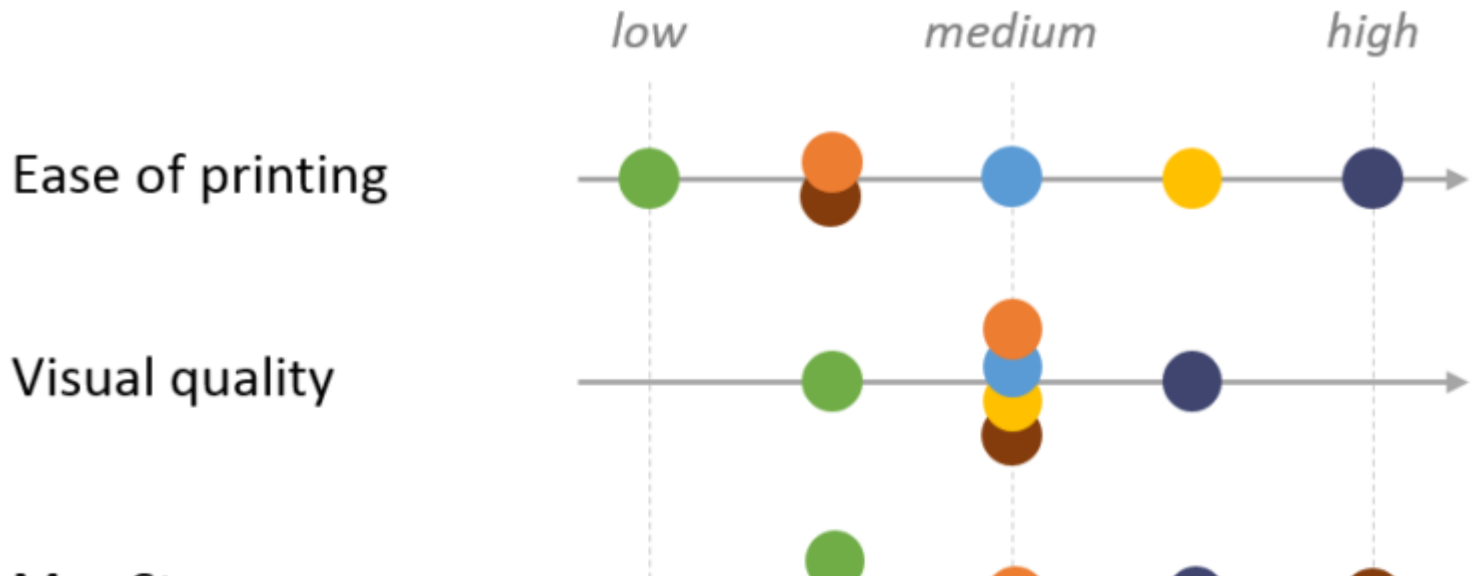
- **Impact resistance:** Energy needed to break an object with a sudden impact.
- **Layer adhesion (isotropy):** How good the adhesion between layers of material is. It is linked to “isotropy” (=uniformity in all directions): the better the layer adhesion, the more isotropic the object will be.
- **Heat resistance:** Max temperature the object can sustain before softening and deforming.

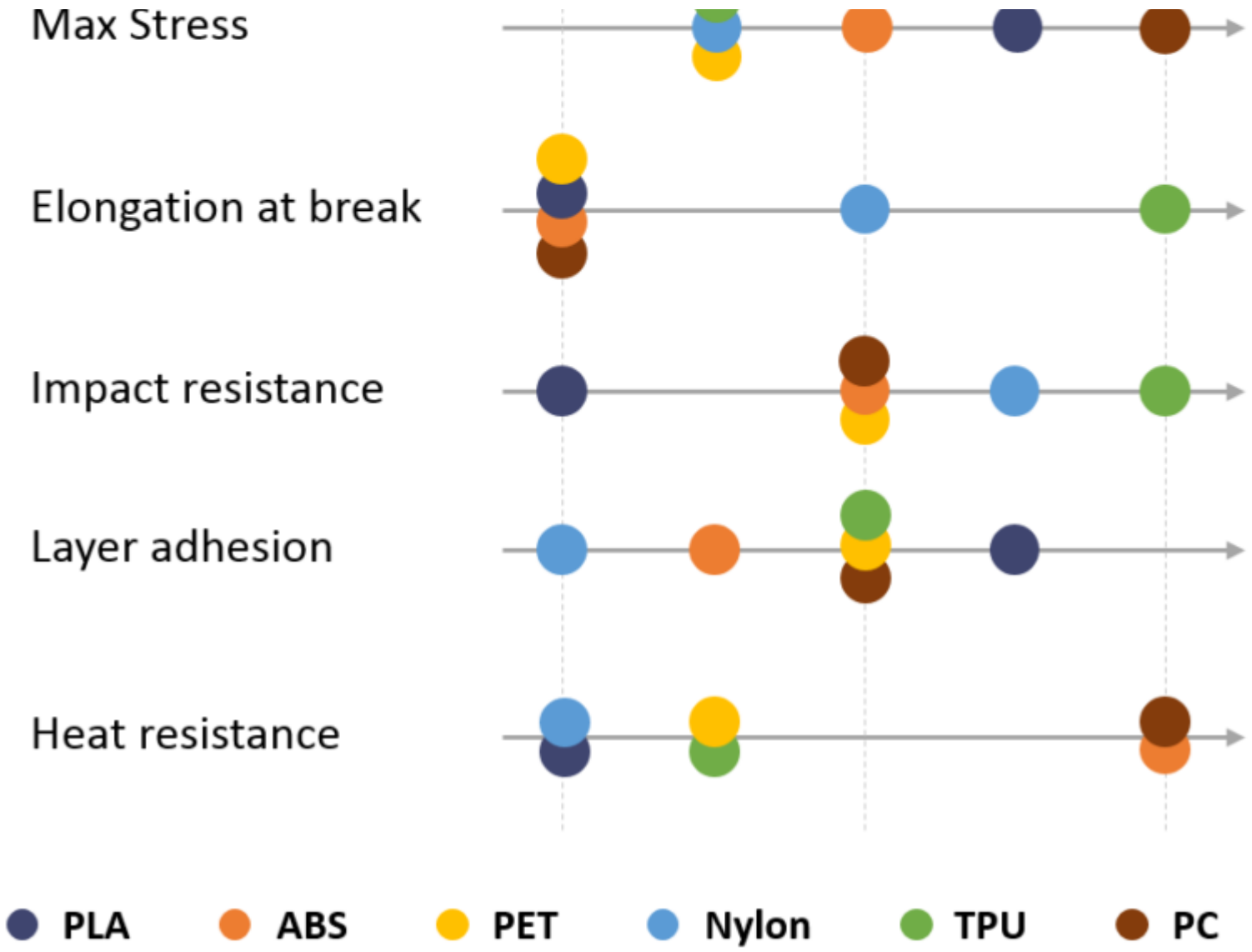
We also provide additional information that is not captured in the diagram, for one of two reasons:

- They are neither “good” nor “bad” in essence; they are just properties that are suitable for some applications and not for others, such as rigidity.
- We don’t have a good quantitative assessment of it, but we know it is an important factor, such as humidity resistance or toxicity.

Results

Each material has been ranked along the following criteria on a 1 (low) to 5 (high) scale. These are relative grades for the FDM process - they would look quite different if other manufacturing technologies were taken into account. Using the data from Optimatter, the polymers have been ranked along the different criteria considered:



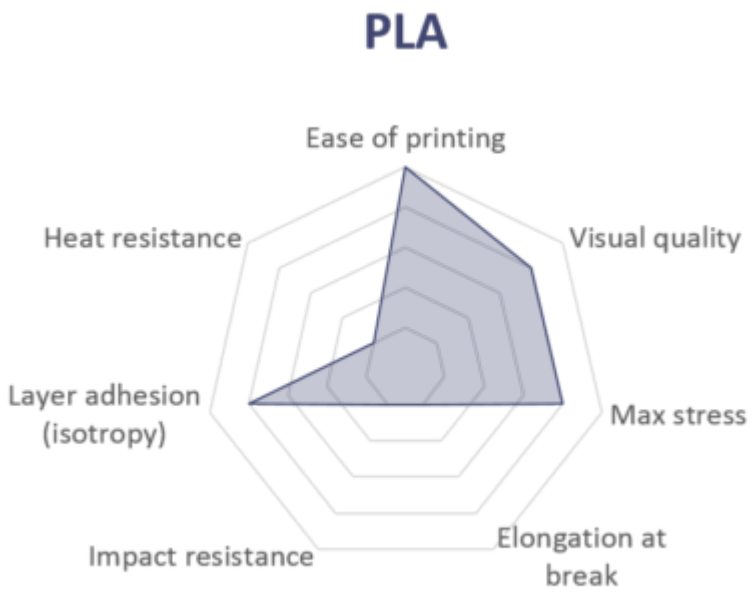


Research results for all six polymers displayed in one graph.

Get your parts printed in these materials:

PLA

PLA is the easiest polymer to print and provides good visual quality. It is very rigid and actually quite strong, but is very brittle.



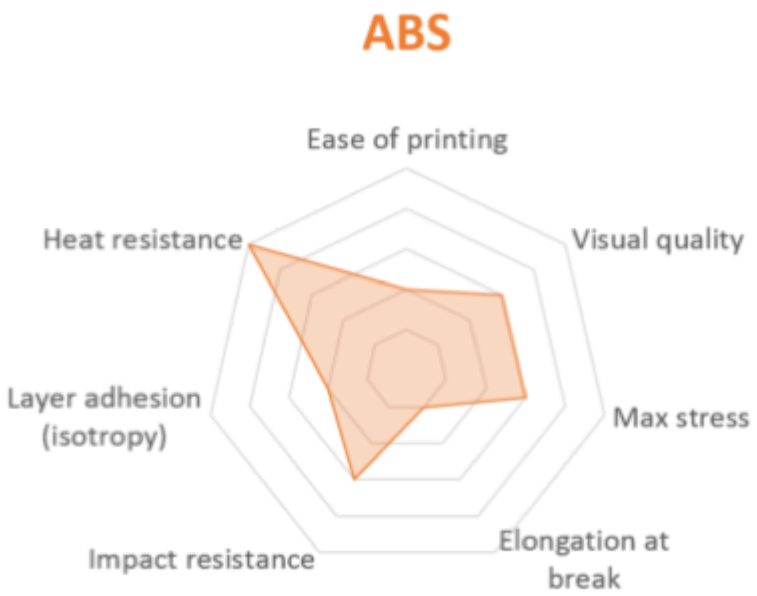
The material profile of PLA

Pros	Cons
Biosourced, biodegradable	Low humidity resistance

Pros	Cons
Odorless	Can't be glued easily
Can be post-processed with sanding paper and painted with acrylics	
Good UV resistance	

ABS

ABS is usually picked over PLA when higher temperature resistance and higher toughness is required.



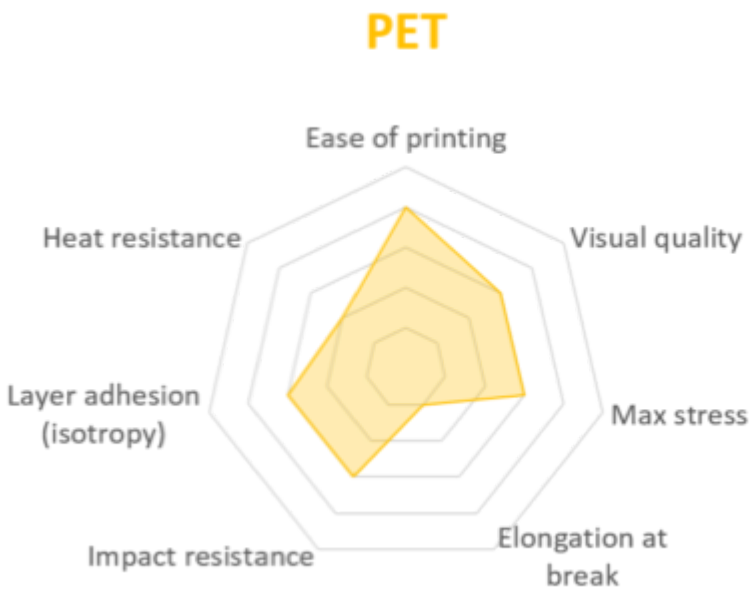
The material profile of ABS

Pros	Cons
Can be post-processed with acetone vapors for a glossy finish	UV sensitive
Can be post-processed with sanding paper and painted with acrylics	Odor when printing
Acetone can also be used as strong glue	Potentially high fume emissions

Pros	Cons
Good abrasion resistance	

PET

PET is a slightly softer polymer that is well rounded and possesses interesting additional properties with few major drawbacks.



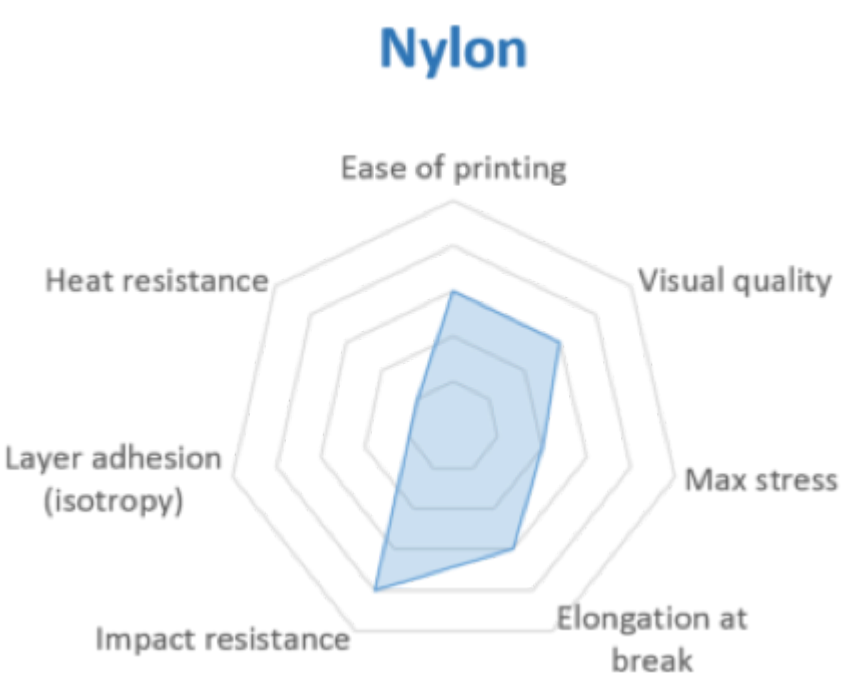
The material profile of PET

Pros	Cons

Pros	Cons
Can come in contact with foods	Heavier than PLA and ABS
High humidity resistance	
High chemical resistance	
Recyclable	
Good abrasion resitance	
Can be post-processes with sanding paper and painted with acrylics	

Nylon

Nylon possesses great mechanical properties, and in particular, the best impact resistance for a non-flexible filament. Layer adhesion can be an issue, however.

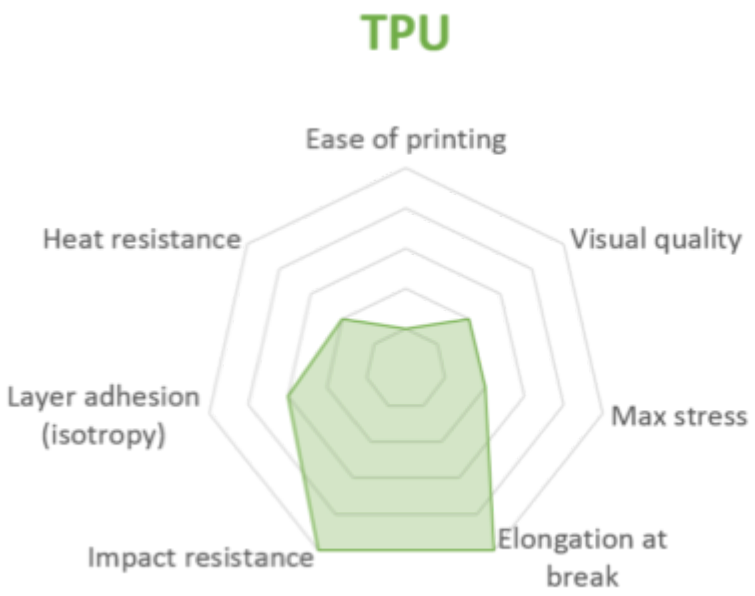


The material profile of Nylon

Pros	Cons
Good chemical resistance	Absorbs moisture
High strength	Potentially high fume emissions

TPU

TPU is mostly used for flexible applications, but its very high impact resistance can open for other applications.

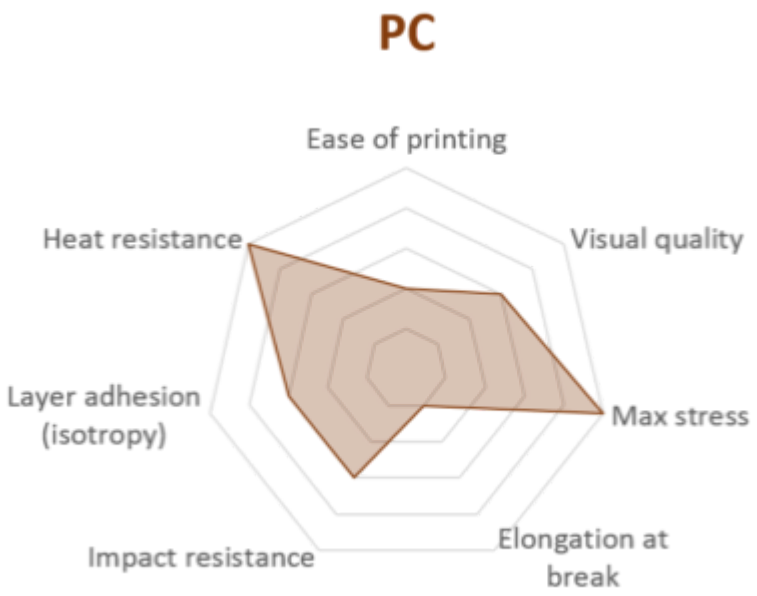


The material profile of TPU

Pros	Cons
Good abrasion resistance	Difficult to post process
Good resistance to oil and grease	Can't be glued easily

PC

PC is the strongest material of all, and can be an interesting alternative to ABS as the properties are quite similar.



The material profile of PC

Pros	Cons
Can be sterilized	UV sensitive
Easy to post-process (sanding)	

Conclusion

Choosing the right polymer is critical to get the right properties for a 3D printed part, especially if the part has a functional use. This article will help users find the right material depending on the properties they need. However, material suppliers also often provide blends or add additives to modify the properties of the pure polymer (e.g. adding carbon fiber to make the material stiffer). We are not addressing these more complex formulations in this article, but you can find data on some of these products in our optimization tool at OptiMatter.

Disclaimer

- The grades given in this article are for an average polymer representing the general chemistry, but the performance will vary depending on the actual product or supplier the user buys from.
- All the data underlying our grades in this study was measured by 3D Matter, with the exception of Heat Resistance, for which we used the glass temperature given by multiple filament suppliers.
- For the sections called “Additional considerations”, we are using a combination of third-party assessments and our own observations.
- The Nylon type we discuss in this article is Nylon 6, not Nylon 11 or 12.
- Visual quality is tested without any significant post-processing. There are ways to smoothen the prints and improve the visual quality of a given polymer significantly (e.g. using acetone vapor on ABS).
- The toxicity of 3D printing polymers is still not very well understood and is a factor that might play a bigger role in the future. We are basing our comments regarding toxicity on one study by Azimi et al. [1]

[1] *Azimi et al, Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop Three-Dimensional Printers with Multiple Filaments, Environmental Science & Technology, 2016*