Materials for Digital Production

In this workout, 4 important

3D filament materials are compared

PLA / PETG / HP-PO / PA

Material: **DIPRO®blend H** Source: Grauts GmbH

1) **Polymer Properties**
2) **Chemical Resistance**
3) **Density**
4) **Reinforcement GF/CF**
5) **Industrial Applications**
6) **Processing, Pre-Drying**
7) **Partial Crystalline / Amorphous**
8) **Recyclability**

1.1. PLA - Polylactide, Specialty Polyester - Polymer Properties, Crystalline

PLA is made from renewable raw materials, e.g. corn or sugar cane, and is biodegradable. Thus, PLA is well suited for short-lived items or for products that may end up in the environment, e.g. food packaging.

The stiffness and strength are high in a narrow temperature range. The impact strength is very low. The notched impact strength is also very low.

The printability is very good and easy. The parts are not suitable for industrial applications because the lifetime is short and the degradation is accelerated by UV.

1.2. PLA – Chemical Resistance

PLA is resistant to oils and fats as well as alcohol.

PLA is otherwise, except against cold water and that also only for a short time, not resistant against most chemicals.

This is helpful for the sometimes intentional degradation, but not useful for technical parts, e.g. in the automotive industry or electrical engineering. The properties at room temperature are quite good for a short time, but end already at a temperature load of 60 °C.

It may be asked whether it is sustainable if a component has to be printed again and again because it degrades strongly over time.

1.3. PLA – Density

It is often overlooked that polymer density is also a cost factor.
With a density of 1.28 g/cm^3, PLA is 41 % heavier than polyolefins, especially also than DIPRO®blend H (high-performance polyolefin). Thus PLA belongs to the heavy polymers which do not float.

1.4. PLA – Reinforcement, e.g. with carbon fiber

There are some PLA types which are reinforced with little CF. Mostly cosmetic effects, the parts will be nice with smooth matte surface and a little stiffer.
Also not suitable for industrial applications. Technical data are hardly available.

1.5. PLA – Industrial Applications

PLA can be used well for illustrative models that do not have a technical function. The biodegradability is in conflict with the durability.

1.6. PLA – Processability and Pre-Drying

PLA is easy to process. The opened spool must be elaborately protected against moisture or must be pre-dried. This is also a cost factor. Moisture measuring technology is not to be expected from private consumers.

The residual moisture should not exceed 0.01% before injection molding and 0.025% before extrusion. Moisture measurement technology is not expected to be used by the private consumer.

Because the heat deflection temperature of PLA is so low, there is a risk of filament damage during pre-drying.

1.7. PLA – Crystalline vs. Amorphous

The crystalline parts of PLA melt between 80 °C and 90 °C. Temperature reserves between softening of the amorphous portions and DSC of the crystalline portions (e.g. with PP and PA) are not present here.

The limits of application are 53 °C to 56 °C (source: Omnexus).

1.8. PLA – Recycling

Due to the high density, which is close to PETG, separation is difficult.
Often composting is the better solution.

2.1. PETG – Polymer Properties, Amorphous (Polyethylene Terephthalate Glycol Modified)

PETG is produced from crude oil. The mechanical properties are higher than those of PLA. The softening temperature is 70 °C. The HDT-B is 68 °C. Since the thermoplastic is amorphous, there are no thermal reserves above it as with semi-crystalline polymers. PETG is not lacquerable. Young's modulus and strength are good at normal temperatures.
Charpy impact strength is moderate. Water absorption is low. However, PET is very sensitive to hydrolytic degradation during processing and must be pre-dried. The transparent material can be colored as desired.

A building plate temperature of 50 °C to 80° C is necessary. The chamber temperature should be 50 °C to 70 °C (source: IEAI).

2.2. PETG – Chemical Resistance

PETG is resistant to most acids and alkalis as well as to most oils and greases.

2.3. PETG – Density

PETG is also approx. 40% higher than polyolefins and DIPRO®blend H / unreinforced. This must be taken into account in the calculation. PETG also belongs to the heavier polymers and does not float.

2.4. PETG – Reinforcement, e.g. with carbon fiber

The reinforcing effect is present but without a significant increase in temperature resistance, since PETG is amorphous. The values achieved are not in proportion to the higher costs.

2.5. PETG – Industrial Applications

If the thermal load remains below 70 °C, PETG can be used for industrial applications.

2.6. PETG – Processability and Pre-Drying

PETG is somewhat more demanding than PLA, but is easy to process with good ply adhesion. The maximum residual moisture should be 0.04%. At approx. 60 °C the filament must be dried for 6 h.

The effort required for drying and the high density must be taken into account in the calculation.

Shrinkage is minimal at approx. 0.1% and build plate adhesion is good. Types with small amounts of carbon fiber are available on the market. The strength increases, as does the stiffness. Heat resistance is only slightly higher.

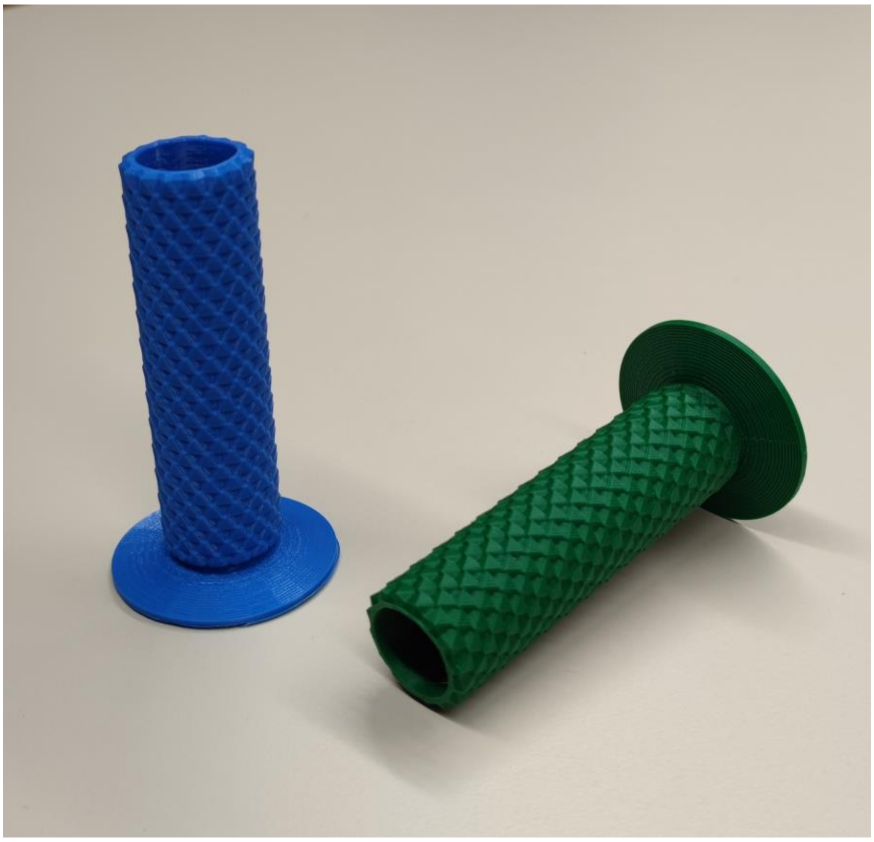
2.7. PETG – Crystalline vs. Amorphous

PETG is amorphous and therefore very dimensionally stable. Above the Tg of approx. 70 °C, no applications are possible.

2.8. PETG – Recycling

PETG is well recyclable.

3.1. DIPRO®blend H, High-Performance-Polyolefin – Polymer Properties, Semi-Crystalline



Material: DIPRO®blend H, unreinforced Source: Grauts GmbH

Polyolefins are the most available polymers. The density is low at approx. 0.9 g/cm³ and the polymers float. Compared to PLA and PETG, polyolefins are
40% lighter. The products do not need to be pre-dried, which significantly facilitates spool handling. However, the warpage is large and unmodified cannot be used for AF.

DIPRO®blend is a ***ROTFELD/DIPRO®mat*** development and has the following special features:

- Very low mold shrinkage and therefore highest precision.
  Shrinkage freezes at a melt temperature of 160 °C immediately after mold filling or after filament deposition, resulting in low warpage.
- Impact and Charpy impact strength is unmatched without loss of heat resistance.
- Materials between 90 Sh A and E-modulus 11,000 MPa (tensile modulus) are ready for series production.
- The layer adhesion is very good even without building space heating
- Due to the properties and ease of processing, DIPRO®blend H materials can be used for industrial and private processing. In many cases, even polyamide can be replaced.

▪ Hard/soft combinations with TPS, **DIPRO®flex** and TPO are possible.

Material: DIPRO® blend H / GF 15 % + DIPRO® flex S60
Source: DIPROmat GmbH

▪ UV-stabilized grades are used for permanent outdoor applications.

3.2. DIPRO®blend H – Chemical Resistance

At room temperature, **DIPRO®blend H** is resistant to most greases and oils, as well as to acids and alkalis, except oxidizing acids such as nitric acid.
DIPRO®blend H is dissolvable in halogenated solvents, cyclic hydrocarbons and aromatics.

Permanent contact with gasoline and diesel is not recommended.

3.3. DIPRO®blend H – Density

An often overlooked drastic advantage is the very low density of approx. 0.89-0.91 g/cm³. This must be taken into account when calculating the price per volume. Filled materials are correspondingly higher.

3.4. DIPRO®blend H – Reinforcement GF/CF

Unlike PETG, **DIPRO®blend H** is a semi-crystalline thermoplastic. By reinforcing it with special glass fibers, which provide high cross strength, the thermal values in particular can be drastically improved. Increases of up to 70 °C in HDT-B improvement are normal. Carbon fibers are occasionally required, but in our view they are not as effective as PA.

Material: DIPRO®blend H / GF   Source: GRAUTS GmbH

3.5. DIPRO®blend H – Industrial Applications

DIPRO®blend H is suitable for industrial applications as well as for private use. The ability to produce hard/soft applications easily in the printer is an advantage for its versatile use. The aging behavior is very good. Stabilizations can be adapted. For industrial use, the high heat deflection temperature of the special glass fiber reinforcement with an HDT-B (heat deflection temperature) of up to 155 °C is possible.

3.6. DIPRO®blend H – Processability and Pre-Drying

The High-Performance Polyolefins do not need to be pre-dried. This makes handling of opened spools very easy.

Material: DIPRO®blend H / GF15 %, ultra-tough Source: DIPROmat GmbH

3.7. DIPRO®blend H – Crystalline vs. Amorphous

DIPRO®blend H is semi-crystalline and has low mold shrinkage due to the polymer modification. The semi-crystalline structure makes the high mechanical and thermal values possible.

3.8. DIPRO®blend H – Recycling

DIPRO®blend can be recycled together with all known polyolefins.

4.1. DIPRO®mid C - Precision Polyamides, Semi-Aromatic, up to 25 % GF and 15 % CF – Polymer Properties

Polyamides are construction materials. Polarity and water absorption depend on the number of C atoms in the repeating amide group. Polyamides with low water absorption, such as PA11 and PA12, are relatively nonpolar and have moderate strength with low water absorption but good tensile strength.

PA 66 and PA6 are again relatively polar and have high tensile strength but a lot of water absorption. The water absorption in turn influences the Tg.

DIPRO®mid C is a semi-aromatic blend with DSC of 211 °C and very little influence of water absorption on properties and very low mold shrinkage. Several polymer families for injection molding and 3D printing are available.

Fiber reinforcements up to 62 % with excellent surface finish are produced by **DIPRO®mat** for injection molding.

If you want to produce technical parts with high properties, you have to deal with solid drying technology. Dry air dryers for the spools are ideal.
The range is still relatively limited.

Polarity, water absorption and strength are unfortunately related.
For 3D printing, we only use special glass fiber, which produce 30% higher tensile strength and minimize warpage.

Radiation cross-linkable DIPRO®mid grades are available on request.

4.2. DIPRO®mid C – Chemical Resistance

Polyamides are polar and resistant to dilute alkalis, aliphatic and aromatic hydrocarbons, fuels as well as alcohols, esters, ketones, fats and oils.

PA is affected by acids and oxidizing chemicals. The polarity causes water absorption, depending on the PA.

4.3. DIPRO®mid C – Density

The density of PA is between the density of PBT, PETG, PLA and polyolefins.

4.4. DIPRO®mid C – Reinforcement

Material: DIPRO®mid C / 15 % CF Source: GRAUTS GmbH

Due to the polarity, a good adhesion to the glass fiber and carbon fiber reinforcement is possible, better than with all the aforementioned polymers. The special fibers with 30 % higher tensile strength values in combination with the polymer modification allow almost 0 % shrinkage and highest precision.

Material: DIPRO®mid QC4H2GF5T1*900G / 25 % GF Source: Q.BIG 3D GmbH

4.5. DIPRO®mid C – Industrial Applications

For private users we rather recommend **DIPRO®blend H/GF** due to its easy processing.

For industrial use, this new precision polyamide family is an excellent choice (see 4.1).

Very high strengths and stiffnesses are achieved with minimum shrinkage.

The professional processor should be familiar with the drying technique for PA.

It has been shown that slightly higher moisture values work for filament processing than for injection molding (up to 0.4 % filament moisture).

4.6. DIPRO®mid C – Processability and Pre-Drying

When processing standard polyamide, large differences in shrinkage (md/pmd) are inconvenient for precision parts. Nozzle freezing and water absorption with drastic influence on properties limit some applications.

The properties from the DIN/ISO data sheets are always in the fiber direction. Transverse to the fiber, only 60 % of the properties such as tensile strength and modulus of elasticity still exist. With **DIPRO®mid C**, the transverse properties are 25 % to 30 % better.

With the polymer development of **DIPRO®mid C**, all the above problems have been eliminated.

Pre-drying of spools is also essential. The processing window compared to non-modified PA is very large. Moisture measurement technology should be available.

4.7. DIPRO®mid C – Crystalline vs. Amorphous

DIPRO®mid C is semi-crystalline with controlled solidification rate and relatively low DSC melting point of 211 °C.

4.8. DIPRO®mid C – Recycling

DIPRO®mid C is well recyclable and blendable with all PA66, PA6 and COPA grades.

DIPRO®mat*, powered by* ***ROTFELD-Consulting****, is the only production company that produces 3D thermoplastics for additive manufacturing and, with appropriate polymer modifications, also for injection molding and extrusion.*

This ensures a smooth transition from prototypes or small series to industrial series production.