SOLVAY
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Solef® PVDF AM Filaments

Processing Guide

SPECIALTY POLYMERS

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Introduction

Fused Filament Fabrication

Additive Manufacturing (AM), and specifically Fused Filament Fabrication (FFF), has emerged as a way for organizations to improve speed to market with new products, enhance supply chain efficiency, enable part consolidation, increase design complexity, and lower manufacturing costs. This method of producing parts complements other methods such as injection molding and machining from material stock shapes. It is most useful for producing low quantities of customized or specialized parts that cannot be fabricated by machining or molding.

Solvay AM-ready Fluoropolymer Filaments

As additive manufacturing technology continues to improve and accommodate higher performing materials, parts made using FFF can serve in roles previously not possible. Solvay's portfolio of AM-ready filaments offers high strength and stiffness, ultra-high purity, flame resistance, ability to withstand aggressive chemical environments, and functionality in a wide range of temperatures. These polymers can offer corrosion free metal alternatives that enable long life-time solutions.

Solef® polyvinylidenefluoride (PVDF) is a fluorinated semi-crystalline thermoplastic, which is obtained by polymerizing vinylidene fluoride (VF2). Without any additives, it has the intrinsic stability inherent to fluoropolymers even when exposed to harsh environments, providing the user with a unique combination of properties resulting in longer equipment life.

Solef® PVDF resins are extremely pure polymers and, unlike many other plastics, they do not require the use of stabilizers, plasticizers, lubricants or flame-retardant additives. Thanks to their chemical inertness and to the virtual absence of released contaminations, natural Solef® PVDF resins are ideal materials for distribution of ultrapure water and other chemically pure fluids used in the Microelectronic industry.

While some commonly known perfluorinated polymers (eg. PTFE) have a chemical resistance to a wider range of aggressive environments, their mechanical properties are inferior to those of PVDF. PVDF embodies an excellent compromise among general properties, combined with very easy processing and an advantageous quality-price ratio. PVDF resin is characterized by a melting temperature which is significantly lower than that of perfluorinated polymers. However, the mechanical properties (in particular creep strength) of PVDF are superior in the temperature range between –20 and 150 °C.

Solvay Specialty Polymers has developed a wide range of VF2-HFP copolymers, and as a result of its manufacturing flexibility, PVDF can be tailored to meet a wide range of property and processing requirements.

Solef® PVDF AM filament MSC NT 1 is obtained from a base resin optimized for FFF processing allowing improved flexibility, dimensional stability and color stability.

Typical Properties of Finished Parts

(For information regarding the general properties of Solef® PVDF, please refer to the online document Solef® PVDF Design and Processing Guide)

Solef® PVDF is a versatile material that is commonly melt processed by injection molding, extrusion and compression molding. Items accurately 3D printed using FFF with Solvay AM-ready Solef® PVDF AM filament MSC NT1 offer properties that are close to those of parts manufactured by extrusion or molding.

The results of mechanical property testing on Solef® PVDF AM parts are shown in Figure 1 and Table 1. The properties show that functional parts can be made using FFF with Solef® PVDF AM filament MSC NT1.

Figure 1: Difference in mechanical properties between compression molded and 3D printed parts using Fused Filament Fabrication

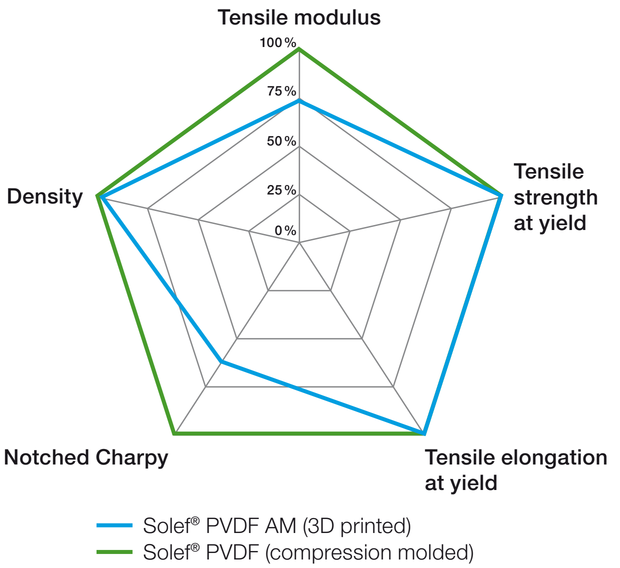


Table 1: Typical properties of parts printed using Solef® PVDF AM filaments

Typical Property	Solef® PVDF AM	Unit	Test Method
General			
Filament diameter	2.85	mm	
Density	1.72	g/cm³	ISO 1183
Mechanical			
Tensile modulus*	0.8	GPa	ASTM D638
Tensile strength at break*	25	MPa	ASTM D638
Tensile strength at yield*	30	MPa	ASTM D638
Tensile elongation at break*	50–250	%	ASTM D638
Tensile elongation at yield*	10	%	ASTM D638
Notched Charpy Impact	6.5	kJ/m²	ISO 179
Thermal			
Melting temperature	148	°C	ASTM D3418
Printing conditions			
Filament drying conditions	Not needed		
Extruder temperature	225–235	°C	
Bed temperature	100	°C	
Printing tool path	Cross hatching XY plane		
Test specimen parameters	Layer: 0.2 mm thick, 100 % infill, 3 shells, printing speed: 25 mm/s		

* Type V bars

Equipment Requirements

Solef® PVDF AM filament MSC NT1 can be printed on a wide range of 3D printers as it is extruded at temperatures ranging from 200–250 °C (recommended extruder temperature of 225–235 °C). A heated bed at temperatures of 100–130 °C is required for warpage prevention.

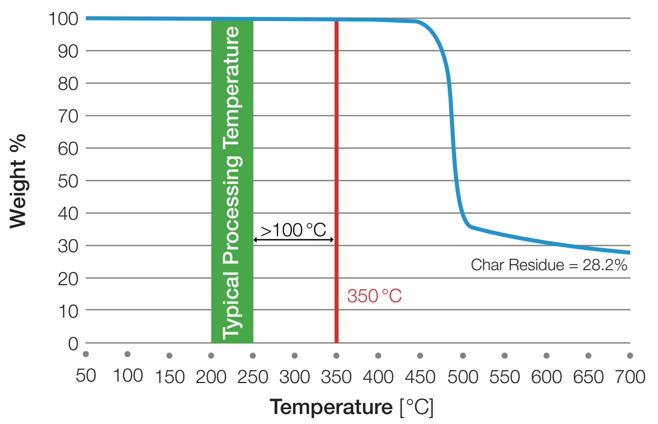
Safety

PVDF resins are relatively non-toxic resins which are not hazardous under typical handling or processing conditions. But, as with all polymer materials exposed to high temperatures, good safety practice requires the use of adequate ventilation when processing. Ventilation should be provided to prevent exposure to any fumes and gases which could be generated. Excessive heating may produce fumes and gases which are irritating or toxic.

Certain additives such as mica, glass fibers, light metals such as titanium, boron, aluminum, may catalyze thermal decomposition rates and need to be avoided.

Solef® PVDF AM filament MSC NT1 must be processed safely below 250 °C and more preferably at 235 °C with proper ventilation. Decomposition usually doesn't take place below 350 °C and a safety margin of roughly 100 °C is observed. In the unlikely event of thermal decomposition please refer to the SDS or the Solef® PVDF Design and Processing Guide pages 55 & 57.

Figure 2: Solef® AM filaments processing safety margin



Handling and Storage (Drying)

Drying is unnecessary, as the polymer does not absorb water due to its inherent non-hygroscopic nature. The low water absorption inhibits the dissipation of frictional static charges; consequently, the bag containing the spool should be kept closed until printing to prevent the deposition of contaminants on the filament. When bringing the filament from a colder room, the closed packing should not be opened until the material has gained the temperature of the processing room. This avoids condensing atmospheric moisture on the filament.

Recommended Processing Conditions

Table 2: Melt processing parameters for Solef® PVDF AM filaments

Temperatures	Solef® PVDF AM Filament MSC NT1	Unit
Nozzle temperature	225–235	°C
Build plate temperature	100	°C

Bed Adhesion

Adhesion to the base can be achieved by printing directly onto the heated glass substrate using an adhesive spray. In addition, a brim is useful for establishing stability of the part and maintaining adhesion of the part to the build plate.

Printing Speed

Should be around 25–30 mm/s. A lower speed is suggested while printing the brim (15 mm/s).

Cooling Fan

Low fan speed: 0–20%, except for small areas.

Tips for small areas:

- Print multiple copies in order to displace the hot nozzle from the printed part, providing extra time for the part to cool down.
- Tune the cooling fan parameters:
  - Regular fan speed: 20 %
  - Maximum fan speed: 100 %
  - Minimum layer time: 10 s

Support Material

Use support for overhangs larger than 70 °.

Solef® PVDF AM filament MSC NT1 is PVA compatible. When PVA support structures touch the build plate, a lower bed temperature (80 °C) prevents PVA detachment. Z distance in the case of PVA can be set to 0. Solef® PVDF AM filament is also compatible with breakaway.

For both the support materials, a speed reduction, obtainable through the activation of the option: “overhang speed reduction”, is beneficial in improving the adhesion between the two materials. Flatter surfaces will be obtained by reducing the speed to 30–40% of the standard value.

Solef® PVDF AM filament MSC NT1 itself can be used as auto- support material. In the latter case, the Z distance should be set to 1–2 times the layer height. An increase in fan speed can result in an easier detachment of the support structure.

Startup

It is important to follow good practice guidelines when setting up a part print. Preparation activities should include:

- installing the build plate into the printer and ensuring that it is clean
- properly installing the printing heads
- calibrating the distance between the printing head and the build plate and leveling the build plate
- checking that the filament unrolls easily as tangles can cause the feed to stop

Part Removal

It is necessary to cool the print bed to room temperature prior to attempting to remove the part. In doing so, the dimensional stability of the part will be preserved and the removal will be facilitated.

Cleaning

At the end of a printing program (or if degradation problems occur), purge with a thermo-stable, highly viscous, pure polymer whose processing is compatible with Solef® PVDF AM filament MSC NT1 (e.g. PE, PP). Never burn Solef® PVDF AM filament MSC NT1 wastes.

Do not clean pieces (e.g. printing nozzle) in a salt bath. Metal parts must be physically cleaned (it is advisable to use brass tooling). Physically cleaned metal parts used for 3D printing Solef® PVDF AM filament MSC NT1 can be put into an ultrasonic bath, filled with dimethylacetamide and heated to 60 °C (immersion time: 1 hour) under sufficient venting (due to toxicity of solvent).

Table 3: Troubleshooting printing problems with Solef® PVDF AM filament

Problem	Cause	Solution
Warpage	Insufficient adhesion to build plate	• Adjust build plate temperature or adhesion surface • Use wider brim (15 mm) • Decrease initial layer speed to 10–15 mm/s • Increase initial layer width
	Non uniform cooling	• Increase build plate temperature • Use enclosure cell
Layer separation	Previous layer too cold	• Increase nozzle temperature • Reduce/remove fan cooling
Overheating in small areas	Printing too fast	• Decrease printing speed for smaller layers (requiring less than 10 seconds)
	Insufficient cooling	• Enable fan cooling for smaller layers
Stringing		• Increase retraction distance (up to 10 mm) and/or retraction speed (up to 40 mm/s)
Overhang		• Activate the overhang speed reduction option from Cura: – Reduce the speed up to 30–40% – Select 0 for overhang angle to reduce the speed for all the overhangs

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