3M Science. Applied to Life.™

▶ 3M™ Dyneon™ Fluoropolymers

Additive Manufacturing with fully fluorinated polymers.

The technology at a glance.


3M

3M pioneers 3D printing with PTFE.

Additive Manufacturing is particularly exciting for PTFE (Polytetrafluoroethylene) applications and is aimed at the Automotive, Chemical Processing, Medical equipment as well as Energy and Aerospace markets.

The new development, which complements fluoropolymer processing, allows 3D printing as an additional and differentiated way of processing PTFE. 3M has selected stereolithography, also known as Vat Polymerization, as the Additive Manufacturing process method.

Stereolithography involves the curing of a photosensitive material by selectively delivering energy to specific regions. The printed parts show many properties similar to those produced by traditional processing techniques. Some properties may be even superior.

Benefits of 3D printing

New design capabilities

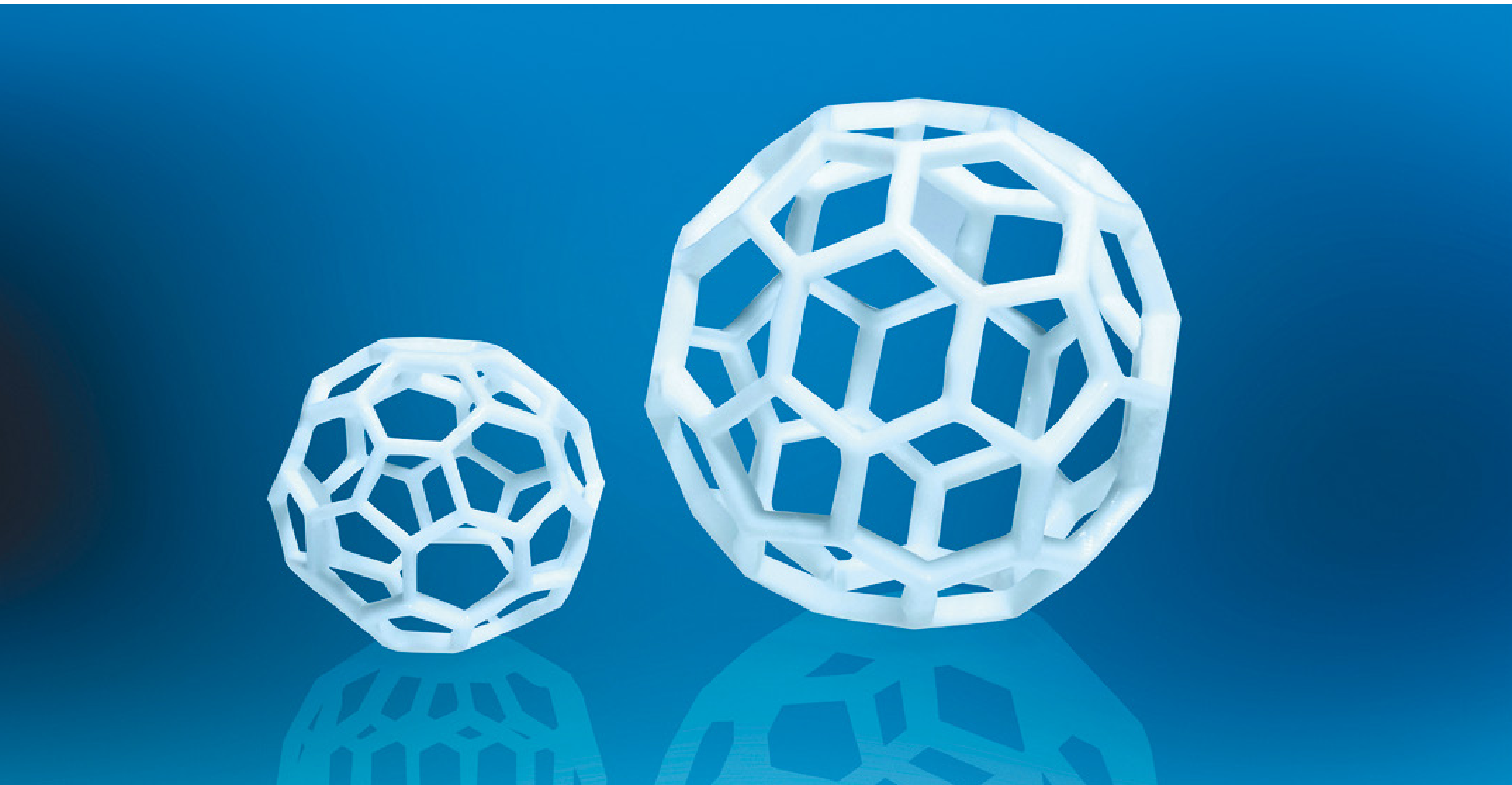
- New geometric flexibility can lead to improved designs and potential weight reduction
- Adds function to design
- Faster response to customer inquiries
- Enables on demand supply of customized products

Enhanced product development cycle

- Accelerates and improves design iteration
- Eliminates the need for prototype tooling
- Reduces unit cost and lead time of small lot sizes

Cost savings opportunities

- Eliminates initial tooling and tooling maintenance costs
- Reduces assembly steps via printing integrated assemblies
- Generates less waste
- Reduces inventories by printing spare parts on demand

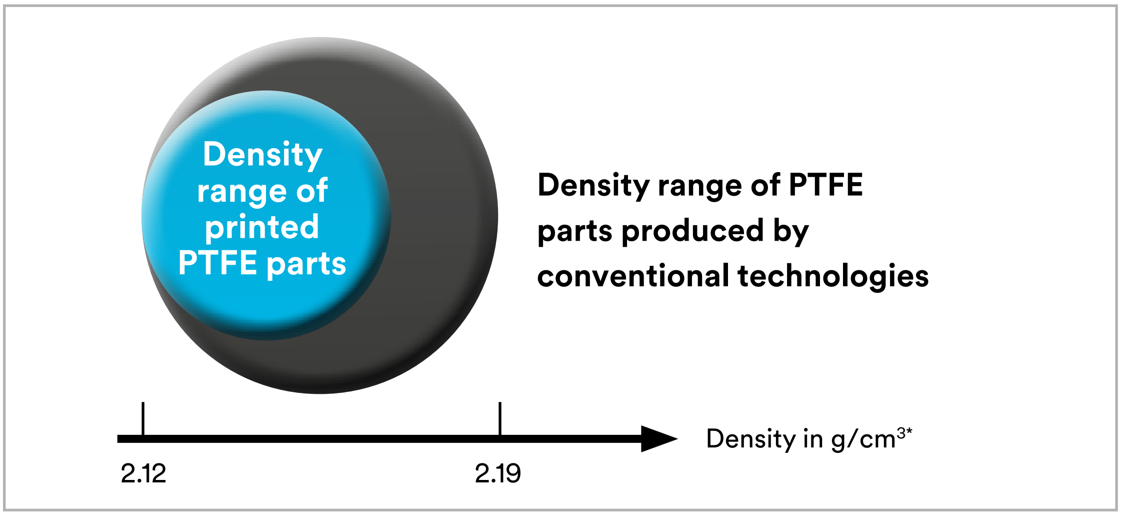


Density of 3D printed PTFE parts

Stereolithography is the selected Additive Manufacturing process method for PTFE and other fully fluorinated polymers.

Density may be regarded as one of the most significant PTFE properties. Density data allows for conclusions about processing conditions, like cooling rate after sintering, and about certain properties, like flex life or permeability, which all affect the quality of a PTFE part.

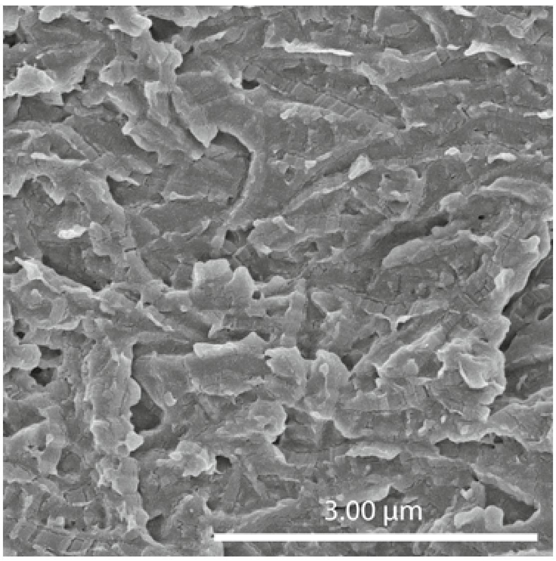
3M printed PTFE parts up to approximately 1.4 mm thickness. The samples show density values of 2.12 to 2.17g/cm³ which is within the typical range of conventionally processed material.



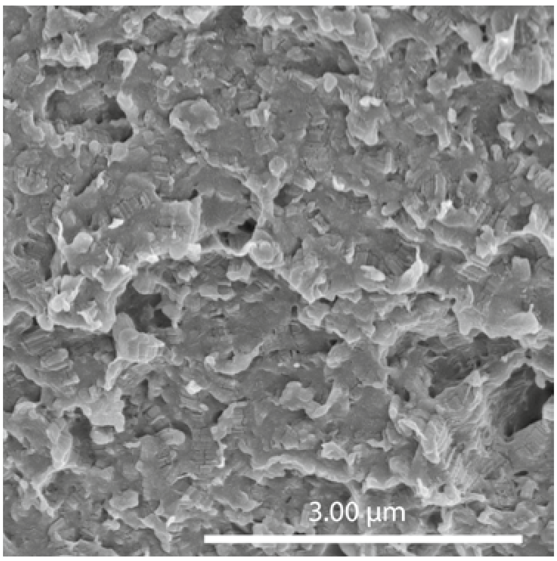
*Density measurements were performed by teh displacement method referring to ASTM D792-13

Visualization under the microscope

The PTFE parts printed by 3M were analyzed by SEM. No voids are visible in either cross sectional SEM picture, printed or machined.



Cross section of a 3D printed PTFE part (freeze fractured)



Cross section of a machined PTFE part (freeze fractured)

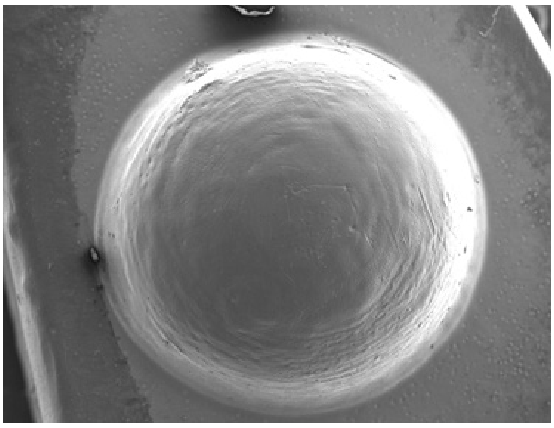
Surface finish of printed PTFE parts

Additive Manufacturing (AM) is a process that creates three-dimensional objects directly from digital information, avoiding the use of tooling. Typical tool marks generated during machining are replaced by layered steps using this technology. As a result, parts produced by certain AM techniques can show smooth surfaces.

This difference is demonstrated by a microscopical comparison of printed and machined PTFE parts with dome-shaped features. Microscopy of the 2mm dome-shape example below illustrates a superior surface finish produced with stereolithography, using tailor-made PTFE formulations. It further shows minimal ‘layer step’ formations that can be noticeable in many additive manufactured articles.

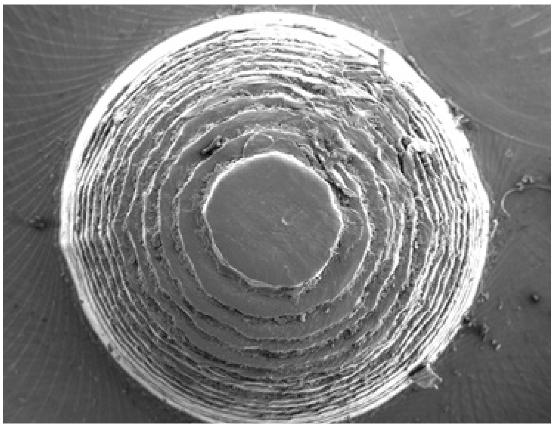
Certain applications in the food and pharmaceutical as well as semiconductor industries may benefit from this technology. Those requiring low roughness and low surface adhesion are of specific interest. This is because cross-contamination and microbial growth may be minimized and subsequent cleaning processes may be streamlined. This may translate into increased efficiency and service life of the PTFE part.

Visualization under the microscope



Top view of a printed PTFE part* with dome-shaped features.

*(as produced in 3M labs)



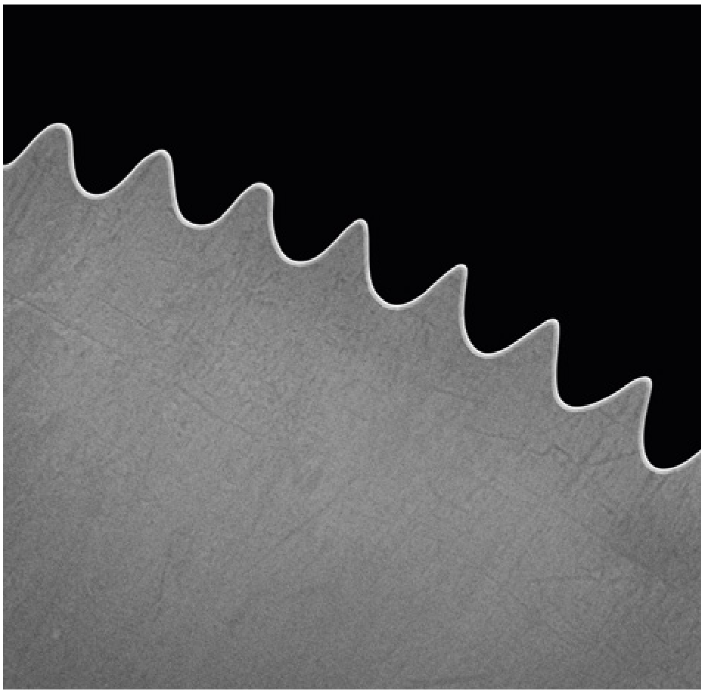
Top view of a machined PTFE part* with dome-shaped features.

*(as produced by an external machine shop)

Surface finish of printed PTFE parts

These parts printed by stereolithography not only provide a good surface finish, but also have high dimensional resolution. Therefore, fine PTFE structures of less than 1 mm in dimension can be achieved.

Furthermore, the design flexibility offered by AM techniques can be maximized, particularly benefitting miniaturized technical parts, lightweight structures and applications requiring parts with a high level of detail.



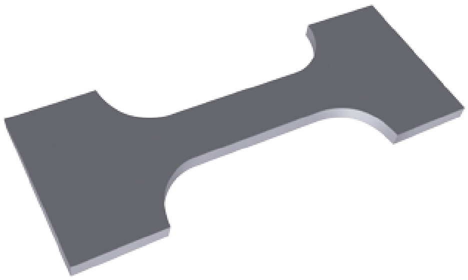
Top view of a small printed PTFE cogwheel*.
*(as produced in 3M labs)

Mechanical Properties

In order to meet the demands of an application, the design of the part must consider both material and processing to ensure reliability. Selection of material and processing method involves comparison of many parameters including mechanical strength. Two characteristics related to the material's mechanical strength are tensile strength and elongation at break, which are often part of the initial screening for specific applications.

Average tensile and elongation values of 3D printed PTFE structures are shown in the figure below. The 3D printed part simulated a sintered die cut PTFE specimen. The part was then tested in build plane (parallel to printed layers).

Data is not for specification. Tensile specimen based on ASTM D1708 (thickness: 1.5 mm) tested at 12.7 mm per minute extension at room temperature.



Tensile testing. Measurement based on a dog-bone, punched from horizontal printed sheet (ASTM D1708)

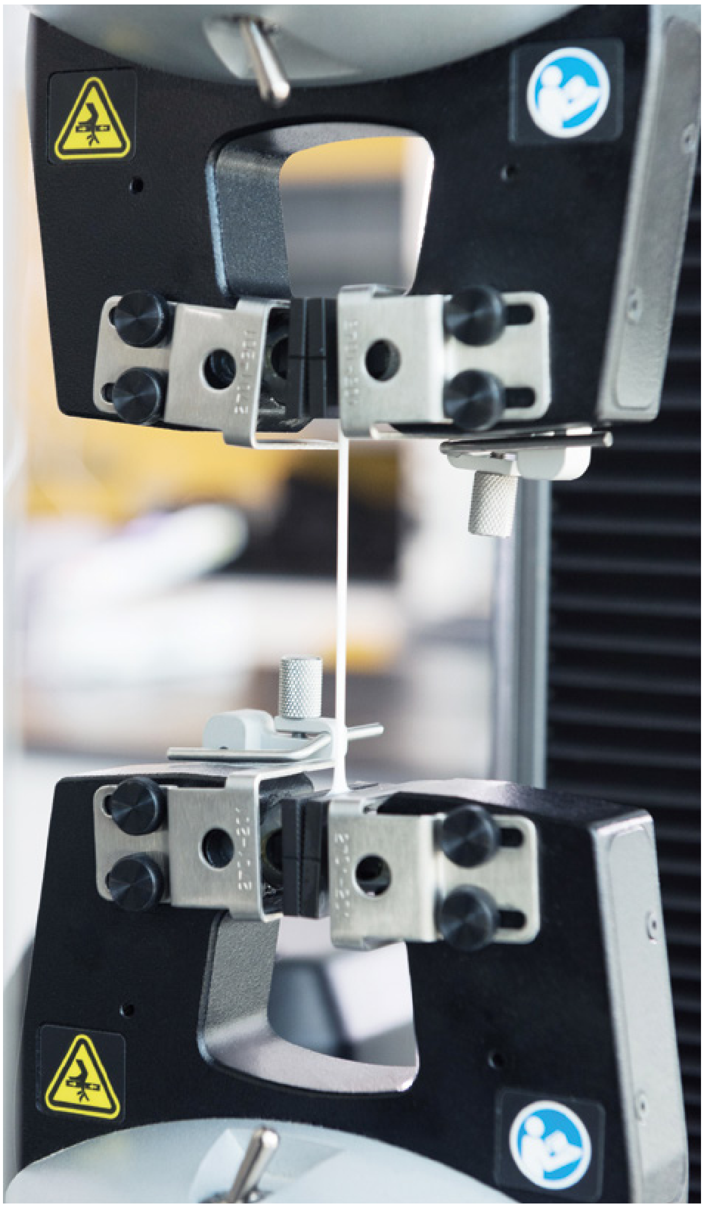
Tensile and elongation properties are influenced by the polymer, process conditions, and to the degree to which the part is optimally formed. Due to its unique nature, PTFE is not melt processible, which is why PTFE is not injection molded or extruded. A critical step to achieve mechanical integrity in the finished part is fusion of the PTFE particles.

While not intended to exactly replicate existing PTFE processing technology, 3D printed part test results show that this process can be a viable option for a wide range of applications. The next step is to print some parts to benchmark and evaluate potential uses. Processing and performance from this benchmarking will help optimize the process and performance of this emerging technology.

Mechanical Properties

In order to meet the demands of an application, both material and processing methods must be taken into consideration when designing a part. Selection of material and processing methods involves comparison of many parameters including yield strength.

The yield strength is significant as once the part is stressed beyond its yield point it becomes permanently deformed. Many plastic parts need to operate below their yield point to maintain elasticity and to retain their original shape. The yield point can be approximated by defining an offset yield strength, which is the stress at which a specific plastic deformation occurs. For PTFE, the stress at which 10% permanent deformation occurs (also called the “offset”) is often used, as no clear yield point appears for PTFE over the course of the stress-strain curve.

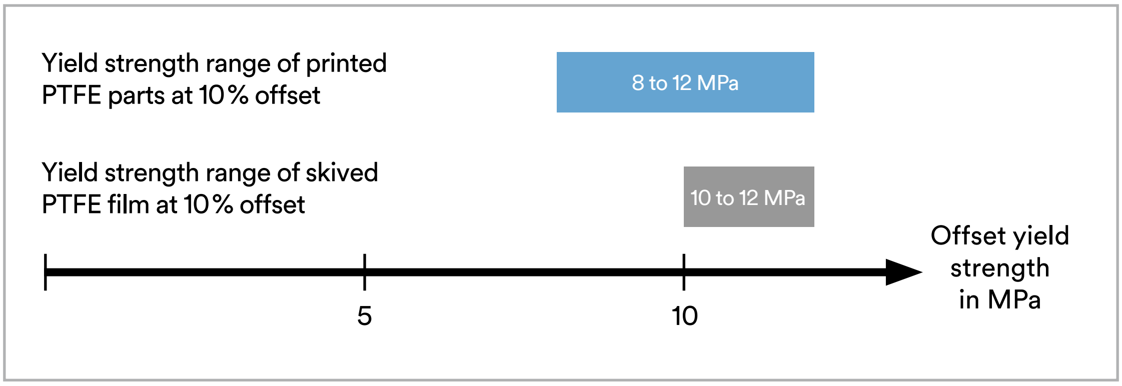


Tensile testing.
Measurement based on a dog-bone, punched from horizontal printed sheet (ASTM D1708)

Mechanical Properties

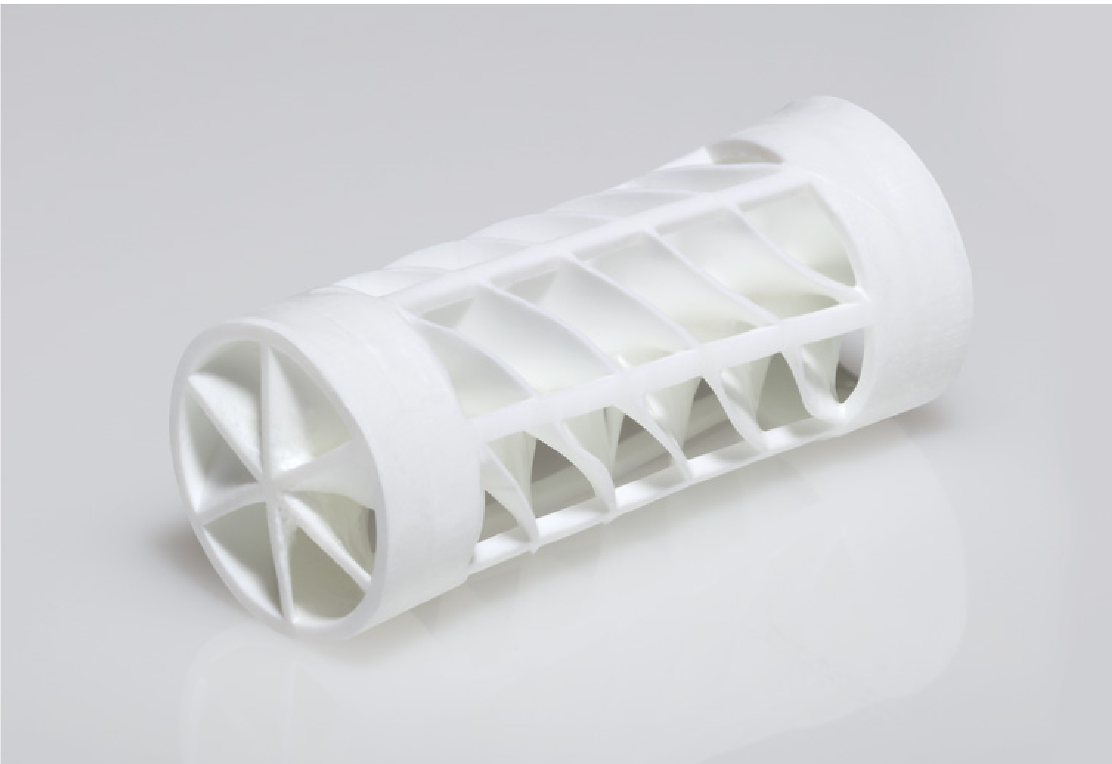
In the figure below, the average offset yield strength of a sintered 3D printed PTFE structure simulating a test specimen is compared to a sintered die cut PTFE test specimen, which is manufactured using traditional PTFE processing. The 3D printed part was tested in the build plane (parallel to printed layers).

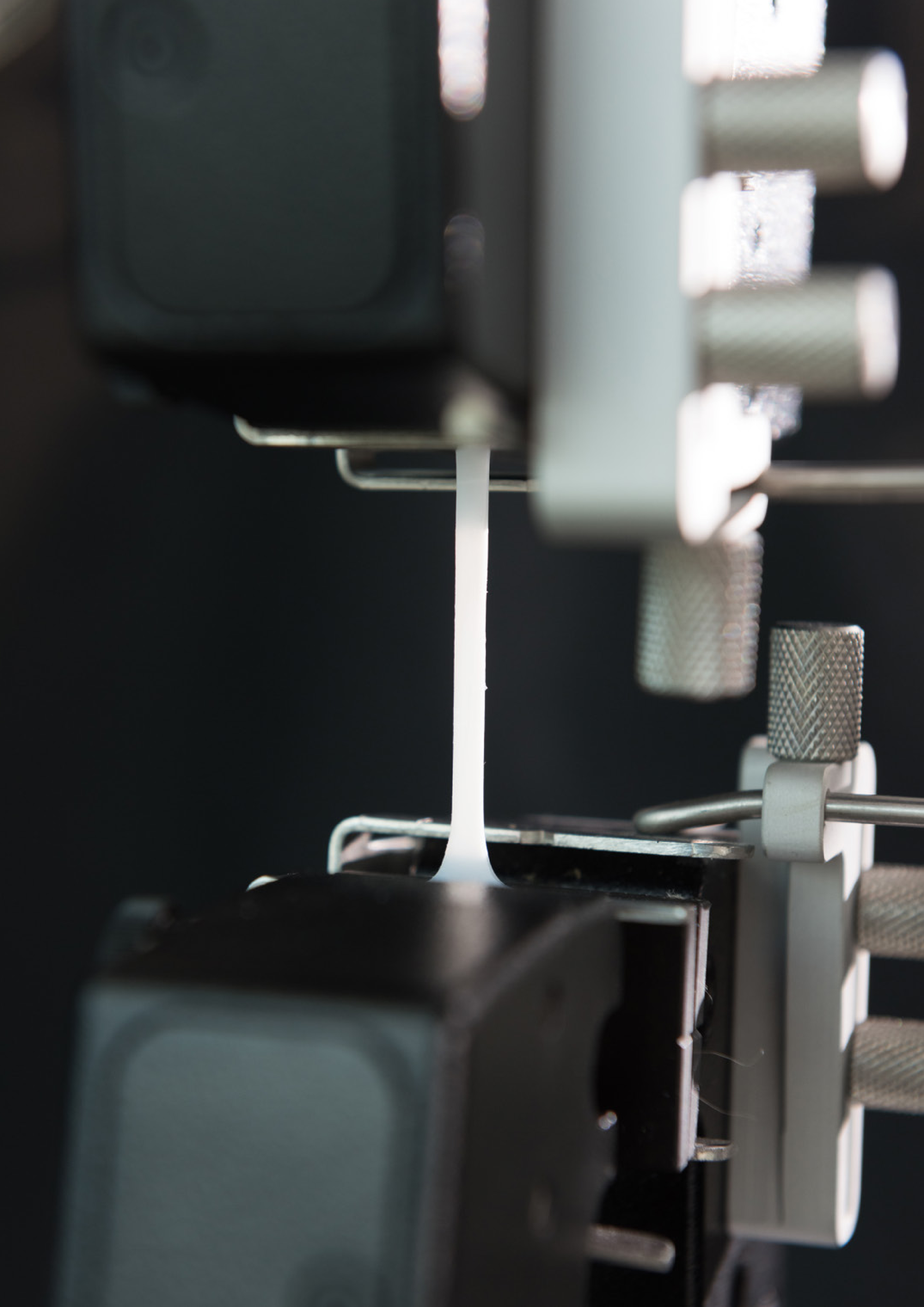
Offset yield strength of 3D printed structures:



Data is not for specification. Tensile specimen based on ASTM D1708 (thickness: 1.5 mm) tested at 12.7 mm per minute extension at room temperature.

While not intended to exactly replicate existing PTFE processing technology, comparing this 3D printed specimen against the traditionally produced specimen demonstrates similar performance in the direction parallel to the printed layers. This further supports that this process can be a viable option for a wide range of applications. The next step is to print some parts to benchmark and evaluate potential uses. This benchmarking will help optimize the process and performance of this emerging technology.





Technical Information and Test Data

Technical information, test data, and advice provided by Dyneon personnel are based on information and tests we believe are reliable and are intended for persons with knowledge and technical skills sufficient to analyse test types and conditions, and to handle and use raw polymers and related compounding ingredients. No license under any Dyneon or third party intellectual rights is granted or implied by virtue of this information.

General recommendations on health and safety in processing, on work hygiene and on measures to be taken in the event of accident are detailed in our material safety data sheets.

You will find further notes on the safe handling of fluoropolymers in the brochure "Guide for the safe handling of Fluoropolymers Resins" by PlasticsEurope, Box 3, B-1160 Brussels, Tel. +32 (2) 676 17 32.

The present edition replaces all previous versions. Please make sure and inquire if in doubt whether you have the latest edition.

Important Notice

All Information which is presented here is based on our current best knowledge and is intended to present general notes and data for 3D printed PTFE articles. All data relate to the current formulation and current processing technique. The formulation and process to print 3D printed PTFE articles is under development and is not commercial yet.

Thus, product properties, features and processing technology are not standardized yet, may change during development and cannot be warranted.

Please note that 3M does not make a statement about the commercial availability of this product.

Where to go for more information?

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