LABORATORY EQUIPMENT

Fluoroplastics
Properties and production

Fluoroplastics
PTFE –the engineering material with potential

Polytetrafluorethylene, PTFE, is a state-of-the-art, high performance plastic, which is used in a broad range of industries. This plastic is also known by trade names such as Teflon® Dyneon™ or Fluon®.
Berghof produces digestions vessels for sample preparation in trace-analysis and inliner for high pressure reactors in R&D.

Convincing properties
The special technical properties of PTFE plastic are crucial for its success.

PTFE characteristics
- → Broad temperature range from -200 °C to +260 °C
- → Universal resistance to chemicals, even against aggressive acids such as aqua regia
- → Excellent dielectric properties
- → A high degree of hydrophobicity
- → Extremely non-adhesive
- → Low refractive index at ~1.38
- → Physiologically harmless
- → Excellent for mechanical processing

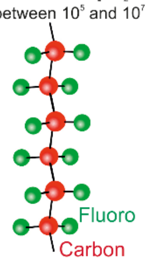
TFM™ PTFE a second-generation PTFE
Dyneon the manufacturer is offering a so-called second-generation PTFE under the brand name TFM™ PTFE. At Dyneon small quantities of a modifier have been built-into the linear chain of the polymer. This modified variant is processed with conventional PTFE, but shows a significantly improved properties profile. The resistance to chemicals, thermal stability and the broad range of temperatures at which it can be used are comparable to that if Standard PTFE However, the modified PTFE possesses a significantly reduced melting viscosity, a

BERGHOF

considerably reduced microporosity and a lower Stretch-Void-Index (SVI). The outcome is non-porous components with a low degree of permeability. The permeation rate of gases is significantly lower than for unmodified PTFE and is only a little above the PFA. Modification results in further positive properties. For example, the capacity for welding and the quality of the surface are much improved compared to conventional PTFE.

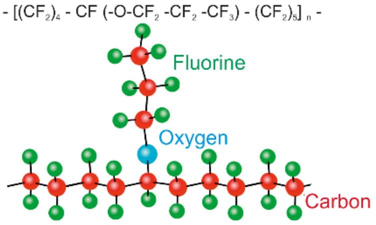
PTFE structure

Polytetrafluorethylene (PTFE) is a linear polymer with the formula: - $[CF_2 - CF_2]_n$ and a molecular weight between 10^5 and 10^7



Modified TFM™ PTFE

Polytetrafluorethylene (PTFE) is a branched polymer with the formula:
- $[(CF_2)_4$ - CF (-O-CF_2 -CF_2 -CF_3) - $(CF_2)_5]_n$ -



PTFE und modifiziertes PTFE (TFM™-PTFE)

Processing competence

Berghof process both base materials, PTFE and TFM™PTFE, including their compounds, to produce numerous semi-finished products and prefabricated components. Besides the conventional production and processing techniques special knowledge and skills in isostatic compression molding and in the manufacture of porous PTFE is present. Semi-finished PTFE products are manufactured by means of extrusion or by compression-molding. In compression-molding as a rule two different techniques are applied. In single-axis compression molding the PTFE powder is compressed in one direction; in isostatic compression molding it is compressed evenly from all sides.

Processing of PTFE and TFM™PTFE by compression molding takes place in the process steps: compress.- sinter - cool down. Processing has a significant effect on molecular weight, crystallinity and pore content of the molded components and hence also their quality. Compression molding becomes of central importance as the first step of the process. Faults that occur here cannot be put right in the subsequent steps of the process. To obtain optimal compression and therefore the optimal materials properties, we have decided on the isostatic compression molding method; a method, which Berghof already developed over 40 years ago.

PTFE before sinter process

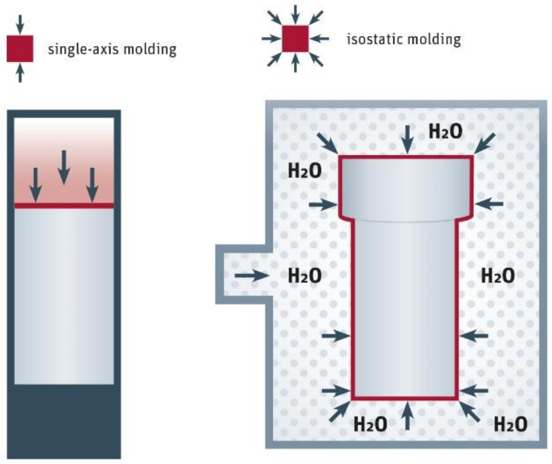
Isostatic compression-molding permits components to be manufactured in a sophisticated, geometric shape, which is unattainable with the conventional methods.

There is one variant of isostatic compression molding, which Berghof uses to manufacture high-purity vessels, such as those required in trace analysis. Here the TFM™PTFE powder is pressed onto an appropriate plastic mandrel. This method dispenses with the final mechanical reworking of the vessels, and contamination of the vessels from the abrasion of the metal-working tools.

Isostatic compression molding

When conventional, single-axis compression molding methods are applied, as a rule the material is compressed vertically in a mold with a force plug. An inhomogeneous compression is obtained due to unilateral pressurization and inner friction.

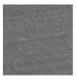
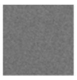
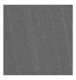
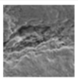
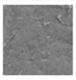
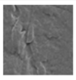
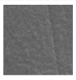
By contrast, in the isostatic compression-molding process the force is applied to the material evenly and simultaneously from all directions in space via a hydraulic medium and compresses it homogeneously. Hence optimal compression is achieved, resulting in minimal porosity, a better surface structure and maximum tensile and compressive strength. No preferred directions are created and isotropic material properties are retained. Particularly the tensile and compressive strength of the material is consistent in all directions in space.
In practice a rubber mold filled with PTFE- or TFM™PTFE powder and then sealed watertight is conveyed into the pressure vessel of a compression-
molding plant. The pressure exerted on all sides of the rubber mold via the fluid in the pressure vessel compresses the sealed-in PTFE powder evenly. After being compression-molded, the PTFE compression-molded part is removed from the rubber mold and subjected to a sintering cycle in the furnace.
compression-molded part is removed from the rubber mold and subjected to a sintering cycle in the furnace.



Comparison of molding technologies

Quality advantages thanks to isostatic compression molding

The advantages of isostatic compression molding can be illustrated by means of appropriately enlarged REM images.
When magnified 100 times the granulate particles of the original material can still be identified in PTFE if it has been subjected to single-axis compression molding.
By contrast, isostatically compression-molded PTFE shows a significantly more consistent surface structure. It is roughly equivalent to single-axis compression-molded TFM™PTFE. However isostatically compression-molded TFM™PTFE achieves a much finer and smoother structure.
Furthermore, when magnified 2,500 times, in single-axis compression-molded material flaws become visible, which no longer occur in isostaticaly compression-molded TFM™PTFE.

Comparison of PTFE vs TFM™-PTFE				
Material	**PTFE**		**TFM™-PTFE**	
Compression-molding technique	Single axis	Isostatic	Single axis	Isostatic
Density (g/cm³)		2.15	2.16	2.16
Tensile strength (N/mm²)	38.9	41.3	44.0	45.1
Elongation at rupture	289	333	484	489
REM image 100-fold magnification				
REM image 2500-fold magnification				

Comparison of PTFE and TFM™-PTFE

Pressure vessels made from fluoropolymers:

A special core competence of Berghof is the manufacture of pressure vessels from or in combination with fluoropolymers. Isostatic compression-molding is the fundamental prerequisite to be able to produce pressure vessels from high-purity TFM™PTFE without a supportive shell. The vessels manufactured according to this method are distinguished by the high purity of the materials and an at least 3-year service life.

Blank values of Berghof digestion vessel (Blank digestion with 10mL HNO_3, 200°C, 15 min)	
Element	**Concentration [µg/L] (ppb)**
Ag	<0.025
Al	<0.1
As	<0.025
Ba	<0.05
Be	<0.25
Bi	<0.025
Ca	<0.2
Cd	<0.025
Co	<0.025
Cr	<0.05
Cu	<0.025
Hg	<0.25
Fe	<0.1
K	<0.5
Li	<0.025
Mg	<0.1
Mn	<0.05
Na	<0.1
Ni	<0.025
Pb	<0.05
Sr	<0.025
U	<0.001
V	<0.025
Zn	<0.1