MASTCO INC.

Material Science & Technology Company

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Imaginative design is as important as technical know-how

PTFE's intrinsic qualities enable reproduction of fine detail

PTFE components begin life as compounds of premium grade granular resin with or without various additional organic fillers. In this way the quality of the finished component can be determined at a very early stage by taking care in controlling the processes involved in converting the resin to a finished component. The pure material produced can be made in complex shapes without concern regarding grain structures, voids, stresses, etc.

Mastco's success in developing and extending its core client base in fluoropolymer products results primarily from the ability to identify and resolve complex material problems.

All Mastco products begin life as high-grade granular resin and are not manufactured from stock extrusions. This insures full control over the material, reduce waste and the component can be accurately and consistently reproduced.

The ability to apply imaginative, intuitive and creative thinking in solving complex design problems with materials such as PTFE makes Mastco unique in the business of plastics engineering. Our personnel have extended experience in high-grade fluoropolymer products developed over two decades and resulting in the rapid growth of the core business and significant penetration into a number of scientific and technology based market sectors.

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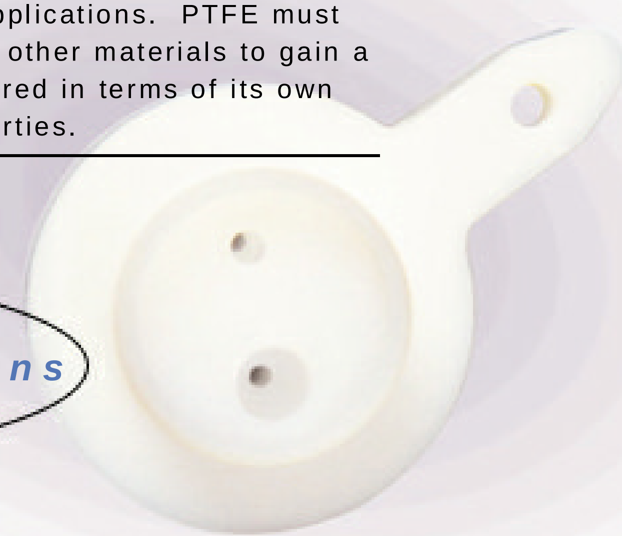
The unique mechanical properties of PTFE enables the material to be specified for an extremely wide diversity of applications. PTFE must not simply be regarded as a straight swap for other materials to gain a few chemical advantages but must be considered in terms of its own complete advanced package of material properties.



Porous PTFE for filtration and gas dispersion applications

PTFE..."miracle material of the age"

In the spring of 1938 at the Jackson laboratory in New Jersey, DuPont Chemist, Dr. Roy Plunkett was working on refrigeration gases related to Freon®. Upon cleaning a frozen, compressed sample of tetrafluoroethylene, he and his associates discovered that the sample had polymerized spontaneously into a waxy, white substance to form, **P**oly**T**etra**F**luoro**E**thylene or PTFE. The sample was numbered 2491-52-1 and by 1946 sold commercially under the trademark Teflon® (**TE**trafluoroethylene **FL**uorocarb**ON**). PTFE has been heralded as a fortunate discovery, lucky accident, mark of genius, or even a combination of all three. Whatever the case, PTFE is truly the "miracle material of the age"

PTFE has many outstanding properties as it belongs to a group of materials consisting almost entirely of Carbon and Fluorine. The structure is essentially a Carbon core shielded by a layer of Fluorine atoms held together by a super-strong Carbon-Fluorine inter-atomic bond. The effect makes the material almost totally chemically inert. The same molecular structure also makes the material almost insoluble and the extreme rigidity of the fluorocarbon chain yields a high melting point.

PTFE can be turned, milled, drilled, pierced, broached, punched, ground and polished. By special processes it can be compression molded, isostatically molded, rolled and even thermal formed.

In general, parts can be designed in the same manner as parts made of other materials such as metals, iron, etc. Even the same formula may be applied if careful attention is paid to the special characteristics of the resin.

... one the most versatile engineering materials known

Extended performance from modified variants of PTFE

Two modified variants of PTFE were developed in the 1960's to give the material extended performance in manufacture and use. Modification with two co-monomers, hexafluoropropylene (HFP) and perfluoropropyl vinyl ether (PPVE) produce principally these forms. Once incorporated into the PTFE chain, materials are produced with thermoplastic properties - FluoroEthylene Perfluoropylene (FEP) and PerFluoro Alkoxy (PFA).

An enhanced form of PTFE namely TFM™ uses a very low addition of PPVE (<0.1%) which increases the coalescence of the resin particles during the sintering process. The resulting material has exceptional surface properties resistant to contamination and is especially suited to the manufacture of components for semiconductor applications.

PTFE resin can be tailored to a wide variety of applications by the addition of fillers.

Such modifications permit resin/filler compositions to fit the exact requirements of a range of mechanical, electrical, and chemical applications.

In general, PTFE resins can be compounded to increase:

– Resistance to initial deformation under load by approximately 25%
– Resistance to rotating shaft wear by as much as 500 times
– Stiffness by a factor of 5
– Thermal conductivity by a factor of 5
– Resistance to creep by approximately a factor of 2
– Thermal dimensional stability by a factor of 2
– Hardness by approximately 10%

three stages to the perfect PTFE component

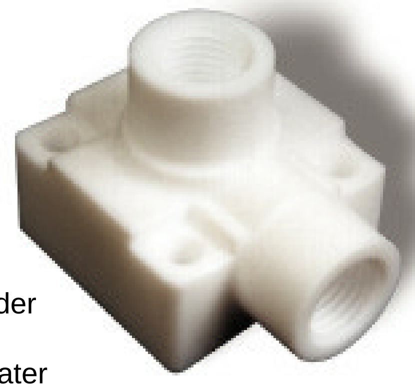
Stage 1 - Resin in granular form

PTFE resins are supplied in granular form of uniform density, particle distribution and grade. This ensures continuity from batch-to-batch for all materials.

Resin is stored in protective containers right up to the point of use and only the required volume of material is handled at any one time. The grade of material is checked at point of receipt and on any material movement thereafter.

Mastco can supply traceability information for any batch of material when requested at the ordering stage.

Stage 2 - Conformal Molding and Sintering



Resins are compressed into basic shapes prior to machining. In many cases this is the final product since PTFE readily molds to shape and may only require final sintering and polishing.

Why Isostatic Molding?

Many times we are asked, why is isostatic molding superior to compression molding?

Isostatic molding is a cold molding process in which the resin powder is compressed in a high pressure device that insures pressure is distributed equally in all directions. This provides substantially greater evenness in pressure distribution that leads to superior quality and improved reproducibility. Isostatic molding can produce hollow shapes, undercuts, profiles and solid components. Since fluoropolymers carry a premium cost the isostatic method also leads to reduced material use and reduced finishing times.

For these reasons, isostatic molding is a very cost effective and desired process of manufacturing both PTFE and TFM™ resins.

Encapsulation

Total encapsulation without seals or joints is used wherever total chemical protection or electrical insulation is essential. This opens up a new world for design and application possibilities often with dramatic improvements in performance and cost savings.

Discuss your needs with our technical team!

The compressed molding is now sintered using a controlled thermal process to create a solid mass - homogeneous component. Controlled variations in the sintering process can alter the final characteristics of the material to suit the application.

Stage 3 - Final Machining

Moldings can now be converted to the finished product by almost any known technique available for metal machining (spark erosion and flame techniques etc. excluded). In particular PTFE is readily ground and polished to an extremely fine finish.

At Mastco we are fully conversant with all applicable machining techniques and methods specific to the production of PTFE parts to meet cleanliness and high purity requirements of the semiconductor industry.

Machining Techniques
are determined by complexity and volume

Although there are a wide number of options for machining techniques on PTFE the more common among them are milling and turning. These operations are covered by a variety of proprietary CNC machines capable of extreme accuracy and repeatability.

Components manufactured by Mastco may be machined on a multiplicity of CNC machines with capabilities to operate in multiple axes. The one-time programming of these machines has a marked effect on the volume costs and these savings are passed on directly to the client.

Grinding and Polishing

A great number of products manufactured by Mastco are ground and polished in their final stages of production. For components specifically made for the semiconductor industry, the surface finish to some extent determines the degree of contamination. Mastco can supply certification of surface finish measurements on request if notified at the ordering stage.

PTFE's Molecular Chain - Purity, Chemical Inertness and More

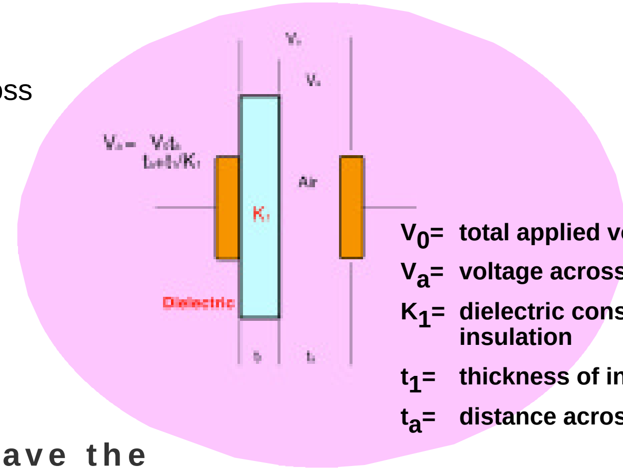
PTFE's molecular chain consists of extremely long, linear carbon chains surrounded entirely by fluorine atoms, which makes PTFE almost totally chemically inert and one of the purest materials known.

The unique degree of high-energy carbon-fluorine bond ensures the shielding effect is retained, even under the harshest conditions. In addition to chemical inertness and high purity, this molecule bond also produces special properties such as low-surface adherability, insolubility, and friction.

PTFE is truly one of the wonder materials of the twentieth century!

Voltage stress distribution

If dielectric materials are subjected to a voltage across their surfaces the stresses distribute unevenly. The area of lower dielectric constant is the area of highest voltage stress. With air, the higher the stress the greater the chances of ionization producing corona discharge. Corona discharge impacts on the dielectric material causing electrical breakdown.



PTFE fluorocarbon resins have the lowest dielectric constant of all solids and minimize the stress in the air more than any other dielectric

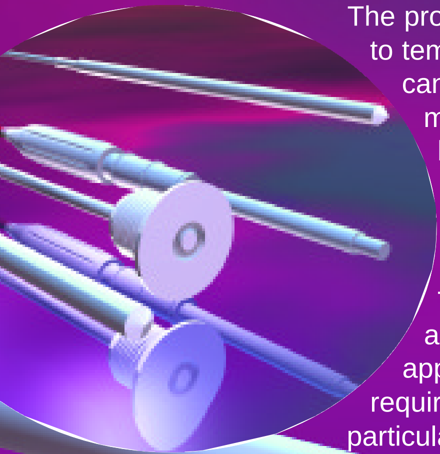
Surface arc resistance

PTFE has an extremely high surface arc resistance which is not affected by heat-aging. PTFE resins will never track or produce carbonizing conducting paths. In fact the surface nature of the resin reduces the chance of arcing by not retaining contamination.

Polymer Types

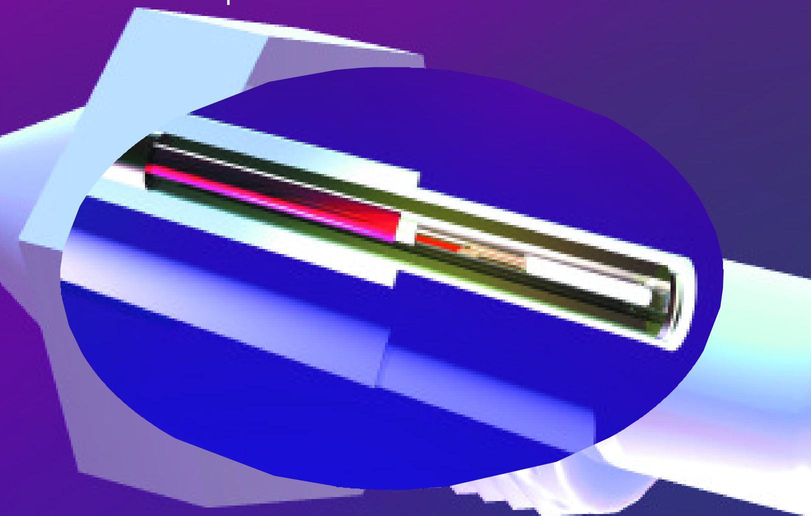
Polymer	Generic Polymer/Chemical Name	Maximum Service Temperature
PTFE	**P**oly**T**etra**F**luoro**E**thylene	260˚C
TFM™	(Poly)**T**etra**F**luoroethylene - **M**odified	260˚C
PFA	**P**er**F**luoro **A**lkoxy	260˚C
FEP	**F**luoro**E**thylene **P**erfluoropropylene	204˚C
CTFE	(Poly)**C**hloro**T**ri**F**luoro**E**thylene, also called **PCTFE**	204˚C
ECTFE	**E**thylene **C**hloro**T**ri**F**luoro **E**thylene	149˚C
ETFE	**E**thylene **T**etra**F**luoro**E**thylene	150˚C
HDPE	**H**igh **D**ensity **P**oly**E**thylene	82˚C
PVDF	**P**oly**V**inyli**D**ene **F**luoride	149˚C
UHMW PE	**U**ltra **H**igh **M**olecular **W**eight **P**oly**E**thylene	82˚C

Temperature is the single most measured Physical Quantity throughout Science



The properties of PTFE present an astonishing number of creative solutions that can be applied to temperature measurement problems. The material does not contaminate the media and it cannot be contaminated by it. This allows PTFE solutions to be specified where no other material will do. A number of technologies can be applied to temperature measurement but generally they are confined to thermocouples and resistance thermometers. The Resistance Thermometer is usually a Pt100 or Pt1000 device to European specification EN 60751 but other specifications can be accommodated.

Mastco also supplies probes that use thermistors or other types of sensors. Thermistors vary so widely between manufacturers that they do not have internationally accepted standards. Mastco has supplied integrated circuit based sensors for special applications in the past (such as the Dallas DS 1820 which gives a digital output). These require special considerations in manufacture but can produce advanced solutions to particular problems.



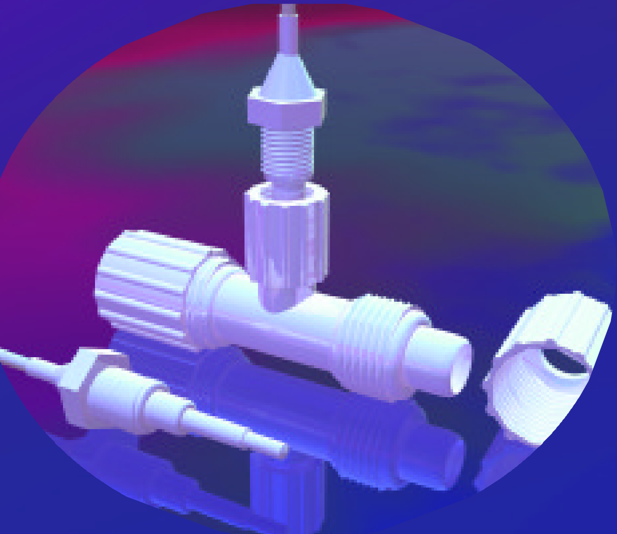
Mastco has manufactured and supplied a wide range of PTFE temperature probes for use in:

Semiconductor Industry
Process Industry
Food Processing
Biotechnology
Combinatorial Chemistry
Chemical Storage
Tissue Storage
Cryogenic Storage
Batteries
Plating
Instrumentation
Clean Rooms

Probe construction is basically similar for thermocouples or Resistance Thermometers. Initial differences are that thermocouples use the lead-in wire to create the sensor whereas Resistance Thermometers require a separate detector (illustration above shows construction of a Pt100 probe). The sensor is soldered or welded onto the ends of the PTFE lead-in wire. Connection can be two, three or four wire, depending on the required accuracy. The wire may or may not be shielded to prevent unwanted RF radiation interference. The soldered/welded connection is insulated using PTFE (insulation not shown for clarity).

In order to give the probe some rigidity and mechanical protection the sensor and wire may be enclosed in a stainless steel tube. To ensure good thermal transfer a Heat Transfer Paste surrounds the sensor and is in thermal contact with the steel tube (paste not shown for clarity). The assembly is then encapsulated in PTFE to complete the probe. The PTFE body and the PTFE lead-in cable are molecularly bonded to form a leak-proof seal.

The outer dimensions of the probe can be modified for a number of reasons. This is carried out using molding and basic machining techniques as described in the PTFE section. Quick response times are absolutely necessary for many applications. Contact Mastco for information and design criteria on obtaining better response times when using our PTFE encapsulated temperature probes.



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PTFE has more outstanding properties than any other known material

In many circumstances the choice of PTFE is not entirely parametric. The good looks and clean lines of Mastco's probes and comparable cost to a metallic construction often mean that clients prefer PTFE even in non-critical applications.

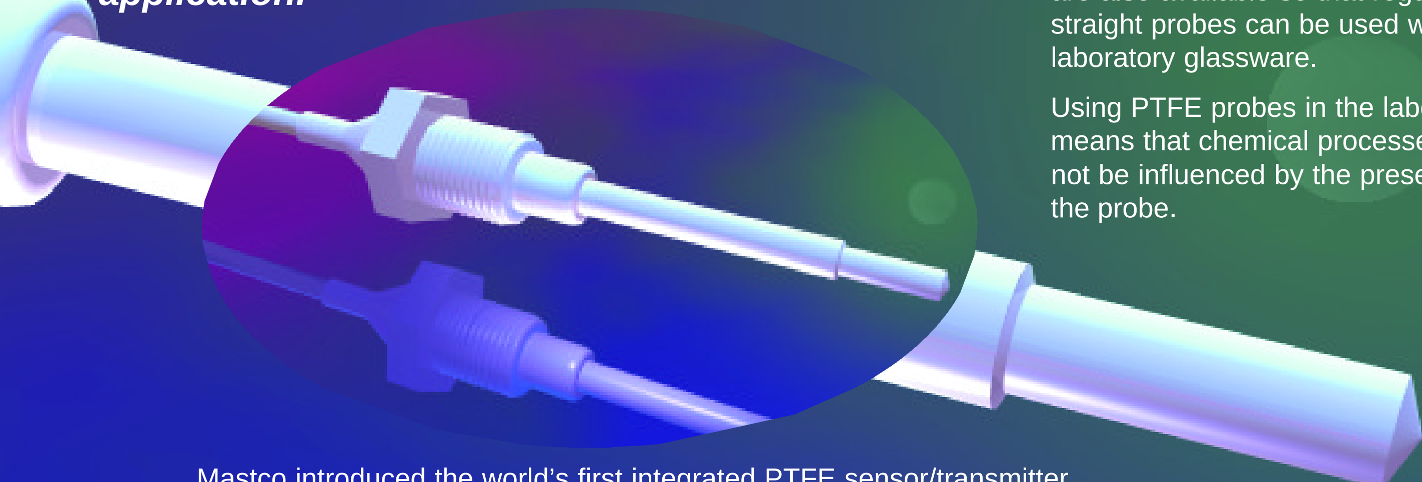
For critical chemical/moisture proof applications the superior seal between the body of the probe and the lead-in cable is the deciding factor. No other sealing method (resins, silicones, cements or other adhesives) produces such a superior seal. The upper temperature limit for total immersion is 250˚C, which rules out resins and silicones for long-term use.

Apart from the specialized laboratory probes there is no such thing as a 'Standard Probe'. Mastco manufactures probes to order and will discuss your requirements prior to manufacture.

We have a wealth of experience in temperature measurement and can confidently recommend and help you design probes for your particular application.

Sensors for use in laboratory situations are designed to integrate into regular glassware. Probes can be designed with different tapers and different shaft lengths. Adapters are also available so that regular straight probes can be used with laboratory glassware.

Using PTFE probes in the laboratory means that chemical processes will not be influenced by the presence of the probe.



Mastco introduced the world's first integrated PTFE sensor/transmitter probe for the semiconductor industry. This single unit allows the measurement of ultra-clean chemicals by means of a wire wound sensor with signal conditioning built right into the probe body. The probe screws into the wall of the delivery system with no need for thermowells or immersion tubes.

The accuracy and thermal response characteristics of the probe are designed to match the system requirements.

PTFE in Temperature Probes

The advanced fluoropolymer PTFE is one of a group of materials consisting almost entirely of Carbon and Fluorine. High molecular weight and long chain molecules characterize these polymers. The structure is essentially a central Carbon core shielded by a layer of Fluorine atoms held together by a high strength Carbon-Fluorine bond. This formulates a material that is almost totally chemically inert. The same molecular structure makes PTFE almost totally insoluble. The extreme rigidity of the fluorocarbon chain is responsible for PTFE's high melting point and the retention of order in the melt explains the high melt viscosity.

PTFE material has an extremely high intrinsic purity, which is due to the use of a free radical initiation process without the need for additives such as plasticizers, extenders or stabilizers. Like all materials the degree of contamination by inclusion of foreign material, either in the forming process or by surface contamination, determines the practical limitations of the form.

The processes used to manufacture PTFE components from raw resins differ between the modified forms. Pure PTFE is processed by cold processing using pressure in a mold followed by a sintering regime where modified resins are formed by melting and molding processes. Sintering pure PTFE alone produces a material with a small proportion of microscopic voids controlled by the pressure and depth of sintering. Isostatic pressure prior to sintering greatly reduces the proportion of microscopic voids giving a higher density material.

An enhanced form of PTFE namely TFM™‘ uses a very low addition of < 0.1% perfluoropropyl vinyl ether (PPVE), which increases the coalescence of the resin particles during the sintering process. The resulting material has excellent surface properties resistant to contamination and is especially suited to the manufacture of PTFE temperature probes for semiconductor and chemical applications.

PTFE is an excellent material to use in the construction of temperature probes. It has a dielectric strength of 48KV/mm and volume resistance of 10^{18} Wcm making it an exceptional insulator.

PTFE probes significantly differ from their metallic counterparts in that the outer surface is non-conducting. This can be a beneficial feature for electrical insulation but may pose a problem regarding thermal insulation. Ideally a temperature-sensing device will not interfere with the environment into which it is introduced but conversely must extract some of the energy of the system in order to measure the temperature. A PTFE probe will not draw as much heat away from the medium as a steel probe and therefore will take longer to absorb the necessary energy.

Our design and construction of probes is critical in producing a product that will give an accurate representation of the real temperature in as short a time as possible. The controlling factor is the

Effective Thermal Diffusivity = k/(c x p).

Where ***k*** is the effective thermal conductivity, ***c*** is the effective specific heat and ***p*** is the density. This function represents the rate at which a temperature change will be propagated through a material. An ideal material has a high conductivity, a low specific heat and a low density. It is not simply the PTFE that needs to be taken into consideration for temperature probe construction. Since the probe is made up of over-lapping layers of media of different thickness from the sensing element outwards, each layer will diffuse heat energy at a different rate. This includes platinum, air, ceramic material, heat transfer material, steel then the PTFE. In fact the proportion of PTFE actually makes it less significant than the other insulators. In addition, the rate of thermal diffusivity longitudinally through the body of the probe reduces the radial transfer of energy towards the sensor. This loss of energy is lessened with PTFE probes.

Mastco's temperature probes are designed to limit the Net Thermal Diffusivity. We introduce a low mass thermal transfer medium into the diffusion path, reducing the mass of the sensing element. This eliminates the air gap and by reducing the mass of the PTFE at the sensing tip will increase response times. The choice of sensor technology for use in PTFE probes also contributes to the increased speed without affecting the probe accuracy or stability.

...outstanding capabilities in physical properties

Property	Unit of Measure	Test Method/ Test Specimen	PTFE	TFM™
Physical Properties				
Specific Gravity	g/cm^3	ASTM D792	2.16	2.16
Melting Point	˚C	ASTM D4591	327˚C	327˚C
Service Temperature				
Minimum	˚C		-200˚C	-200˚C
Maximum	˚C		260˚C	260˚C
Mechanical Properties		ISO 12086 50mm/min at 23˚C		
Tensile Strength at Break	MPa	@23˚C / 100˚C	33 / 22	34 / 25
Elongation at Break	%	@23˚C / 100˚C	360 / 520	580 / 590
Tensile Modulus	MPa	@23˚C / 100˚C	540 / 210	630 / 255
Yield Strength	MPa	@23˚C / 100˚C	12.4 / 7.5	13.2 / 8.2
Flexural Modulus	MPa	ASTM D790 3pt bend	n/a*	n/a*
Deformation Under Load		ASTM D621		
(100h stress & 24h recovery)	%	@23˚C / 15 MPa	11	4
	%	@150˚C / 8.8 MPa	34.5	20
	%	@205˚C / 5.2 MPa	18.5	5.5
Hardness	ShD	ASTM D2240/DIN 53505	56	59
Surface Roughness			0.9[3]	0.3[3]
Electrical Properties				
Dielectric Constant		ASTM D150 @ 1MHZ	2.1	2.1
Dissipation Factor	10^4	ASTM D150 @ 1MHZ	0.7	0.7
Dielectric Strength	kv/mm	ASTM D149	60	70
			(0.20mm film)	(0.20mm film)
Permeation Properties				
HCI	$(cm^3*1000\mu m)/(m^2*d*bar)$	DIN 53380 Part 4.1.2	630 / 1600	445 / 1150
		@23˚C / 100˚C		
Water Vapor	$(g*1000\mu m)/(m^2*d)$	DIN 53122 Part 2	0.02 / 3.5	0.017 / 2.43
		@23˚C / 100˚C		
Flame Resistance				
Limiting Oxygen Index	%	ASTM D2863	96	96
Flammability Rating		UL 94	V-O	V-O

* Information not available

Note: Roughness measured on machined parts without polishing.