EVERFLON™ FEP

Properties Handbook

Fluorinated ethylene propylene

EVERFLON ACADEMIC

Introduction

Everflon™ FEP (fluorinated ethylene propylene) is chemically a copolymer of hexafluoropropylene and tetrafluoroethylene. It differs from PTFE (polytetrafluoroethylene) resins, in that it is meltprocessible using conventional injection molding and screw extrusion techniques.

Everflon™ FEP can be made into articles having a combination of mechanical, chemical, electrical, temperature, and friction-resisting properties unmatched by articles made of any other material.

The design and engineering data presented in this publication are intended to assist end users in determining where and how Everflon™ FEP may best be used.As with other products, it is recommended that design engineers work closely with an experienced fabricator, since the method of fabrication may markedly affect not only production costs, but also the properties of the finished article.

All properties presented in this handbook should be considered typical values and are not to be used for specification purposes.

Commercially Available Everflon™ FEP Fluoropolymers

Everflon™ FEP	Resin Characteristics	Applications
4601/4603	Good viscosity, highest degree of stress crack resistance	Extruded or molded parts for chemical industries Jackets for wire and cable applications
4608/4610	General- purpose resin with medium melt flow rate	Wire and cable insulation Small tubing Injection-molded parts
4622/4630	High productivity grade	Small diameter, thin wire, and cable insulations Injection-molded intricate/thin wall parts
4603X	Modifed low MFI with high working temperature and stress crack resistance	Extruded or molded parts for chemical industries Jackets for wire and cable applications
4610X	High degree of stress crack resistance	Jacketing resin for a wide range of wire sizes and wall thicknesses
4622X	Medium melt flow resin with improved adhesion to copper wire under specific wireline process conditions	Small diameter, thin wall wire and cable insulation Industrial film Injection-molded intricate/thin wall parts
4630X	Best-in-class dissipation factor at high frequencies (>10 GHz). Significant plateout resistance in melt extrusion	Small diameter, thin wall wire and cable insulation Industrial film Injection-molded intricate/thin wall parts
PF/CF 4610	Foamable resin	Coaxial cables
PF/CF 4622	Foamable resin with increased production speed	Medium to large coaxial cables
PF/CF 4630	High MFR foamable resin offering superior attenuation and high production speeds	Thin wall wire insulation
CC46	Color Concentrate with FEP virgin resin	Cables, tubing, linings, and molded parts with various colors requirement
JP46	Powder for specialty applications	Ideal for compounding and compression molding
D50	50% Solid content dispersion	Coating

General Properties of Everflon™ FEP Fluoropolymers

Thermal stability

Superior reliability and retention of its properties in a wide thermal range from cryogenic temperature to high temperature.(–200~+200°C)

Chemical inertness

Most exposure conditions including heat, weather, light and moisture.

Non-sticking property

The lowest critical surface energy of any plastics; an excellent water and oil repellent for non-stick and mold release use.

Electrical reliability

A low dielectric constant and dissipation factor and high dielectric strength over a wide range of frequencies and temperatures.

Long-term weather resistance

Excellent resistance to ozone, sunlight and weather.

High transparency

Transparent with good transmittance of ultraviolet rays and visible rays; the lowest refractive index of any plastics; characterized by very low light reflection.

Flame resistance

Will not burn in atmosphere. (Oxygen index > 95%)

Material properties of Everflon™ FEP

	Property	Unit	ASTM standard	4601/4603	4608/4610	4622/4630
Physical	Melting point	℃	--		260-270	
	MFR	g/10min		1-4	6-12	20-30
	Specific gravity	--	D792		2.12-2.17	
Mechanical	Tensile strength23 ℃	MPa	D2116	28	24	22
	Elongation 23 ℃	%	D2116	380	330	300
	Impact strength(Izod)	kg-cm	D256A		No Break	
	Hardness(Dorometer)	--	D2240		D56	
	Flexural modulus	Mpa	D790	550	620	650
	Compressive Strength at 5% Strain 23 ℃	Mpa	D695		15.2	
	Coefficient of Friction	--	D1894		0.25	
	Deformation Under Load	%	D621		0.5	
Thermal	Thermal conductivity	W/m·°C	C177		0.2	
	Specific heat	cal/℃.g	DSC		0.25	
	Thermal expansion	1/°C	D696		(8~15)×10-5	
	Heat of Fusion	kJ/kg	DSC	9.8	10	11.6
	Max service temp.	℃			200	
Electrical	Volume resistivity	Ω-cm	D257		$>10^{17}$	
	Surface resistivity	Ω	D257		$>10^{17}$	
	Dielectric constant	1 MHz	D150		< 2.1	
		1 GHz				
	Dielectric factor	1 MHz	D150		0.00061	
		1 GHz			0.00094	
	Dielectric strength	kV/mm	D149		78	
	Ark resistance	sec	D495		165	
	Flammability	--	UL94		V-0	
Others	Oxygen index	--	D2863		>95	
	Solvent resistance		D543		Excellent	
	Chemical resistance	--			Excellent	
	Water absorption	%	D570		< 0.03	

Mechanical Properties

Fabricated shapes of Everflon™FEP fluoropolymer resins are tough, flexible in thin sections, and fairly rigid in thick sections. With increasing temperature, rigidity (as measured by flexural modulus) decreases significantly up to the maximum continuous-use temperature of 204°C. Surfaces of fabricated parts have a very low coefficient of friction, although slightly higher than that of Everflon™ PTFE. Very little sticks to Everflon™ FEP, but the surfaces can be specially treated to accept conventional industrial adhesives.

Tensile Properties

Everflon™ FEP is an engineering material whose performance in any particular application may be predicted by calculation in the same manner as for other engineering materials. From the data presented in this handbook, values can be selected which, with appropriate safety factors, will allow standard engineering formulas to be used in designing parts.

Stress/strain curves for temperatures in the usual design range for Everflon™ FEP 4610 show that yield occurs at relatively low deformations. Elastic response begins to deviate from linearity at strains of only a few percent, as with most plastics. Therefore in designing with Everflon, it is often best to work with acceptable strain and determine the corresponding stress. Typical stress/strain curves that show ultimate tensile strengths at –52°C , 23°C, 100°C, and 200°C for Everflon™ FEP 4610 4603, and 4601 are given in Figures. Test specimen preparation, geometry, and test conditions affect test results, so these variables must be kept constant when making comparisons.

The effects of temperature on tensile strength and ultimate elongation are summarized in Figures. Of more practical importance is yield strength. With Everflon™ FEP, elastic response begins to deviate from linearity at strains of only a few percent. This is referred to as yield strength.

Flexural Modulus

Flexural modulus is a measure of stiffness and is among the properties included in Table Everflon™ FEP retains flexibility to very low temperatures and is useful at cryogenic temperatures. The effect of temperature on flexural modulus is shown in Figure.

Compressive Stress

Stress/strain curves for compression are similar to those for tension at low values of strain. Typical compression curves for Everflon™ FEP 4610 at three temperatures at low levels of strain are shown in Figure

Creep and Cold Flow

A plastic material subjected to continuous load experiences a continued deformation with time that is called creep or “cold flow.” A similar phenomenon occurs with metals at elevated temperatures. With most plastics, however, deformation can be significant even at room temperature or below, thus the name “cold flow.”

Creep is the total deformation under stress after a specified time in a given environment beyond that instantaneous strain that occurs immediately upon loading. Independent variables that affect creep are load or stress level, time under load, and temperature. Initial strain or deformation occurs instantaneously as a load is applied to Everflon™ FEP or any other plastic.

Following this initial strain is a period during which the part continues to deform but at a decreasing rate. Data can be obtained over a wide range of temperatures using tensile, compressive, or flexural creep. Flexural measurements are more easily made and are the most common. However, tensile and compressive creep data are frequently more useful in designing parts. Typical data for tensile loadings for Everflon™ FEP 4610 at four temperatures are shown graphically in Figures

Typical curves for total deformation versus time under compressive load are shown at two temperatures for Everflon™ FEP 4610 in Figures

Stress Relaxation

When materials that creep or cold-flow are used as gaskets in flanged joints, the phenomenon of stress relaxation is generally encountered. With Everflon™ FEP fluoropolymer resin, an application where this is important is in lined valves or tees where an extension of the lining is generally used as the flange gasket. In flanged, bolted connections, parts of Everflon will cold-flow between the flange faces with a resultant decrease in bolt pressure. Such relaxation in gasket stock may result in a leaky joint. Tightening the flange bolts during the first day after installation will usually maintain bolting pressure and prevent leakage; thereafter, stress relaxation will be negligible. Typical curves for tensile stress relaxation, Figures illustrate the rates at which tensile stress decays when the specimen is maintained at constant strain

Fatigue Resistance

Typical fatigue data for Everflon™ FEP 4610 fluoropolymer resin, the grade most commonly used for injection molding, are given in Table . Everflon™ FEP 4603 and 4601 are higher molecular weight resins and would be expected to require a higher number of cycles to cause failure at any given stress level.

Friction

Everflon™ FEP has a smooth surface and a slippery feel. Because of the low coefficient of friction, there have been many practical nonlubricated and minimallylubricated mechanical systems developed.

Everflon™FEP resins exhibit very low friction in nonlubricated applications, especially at low surface velocities and pressures higher than 34 kPa (5 psi). The coefficient of friction increases rapidly with sliding speeds up to about 30 m/min (100 ft/min), under all pressure conditions.

This pattern of behavior prevents “stick-slip” tendencies. Moreover, no “squeaking” or noise occurs, even at the slowest speeds. Above about 45 m/min (150 ft/min), sliding velocity has relatively little effect at combinations of pressure and velocity below the PV limit.

Figure indicates that static friction of Everflon™ FEP decreases with increases in pressure. The incorporation of fillers does not appreciably alter the coefficient of friction.

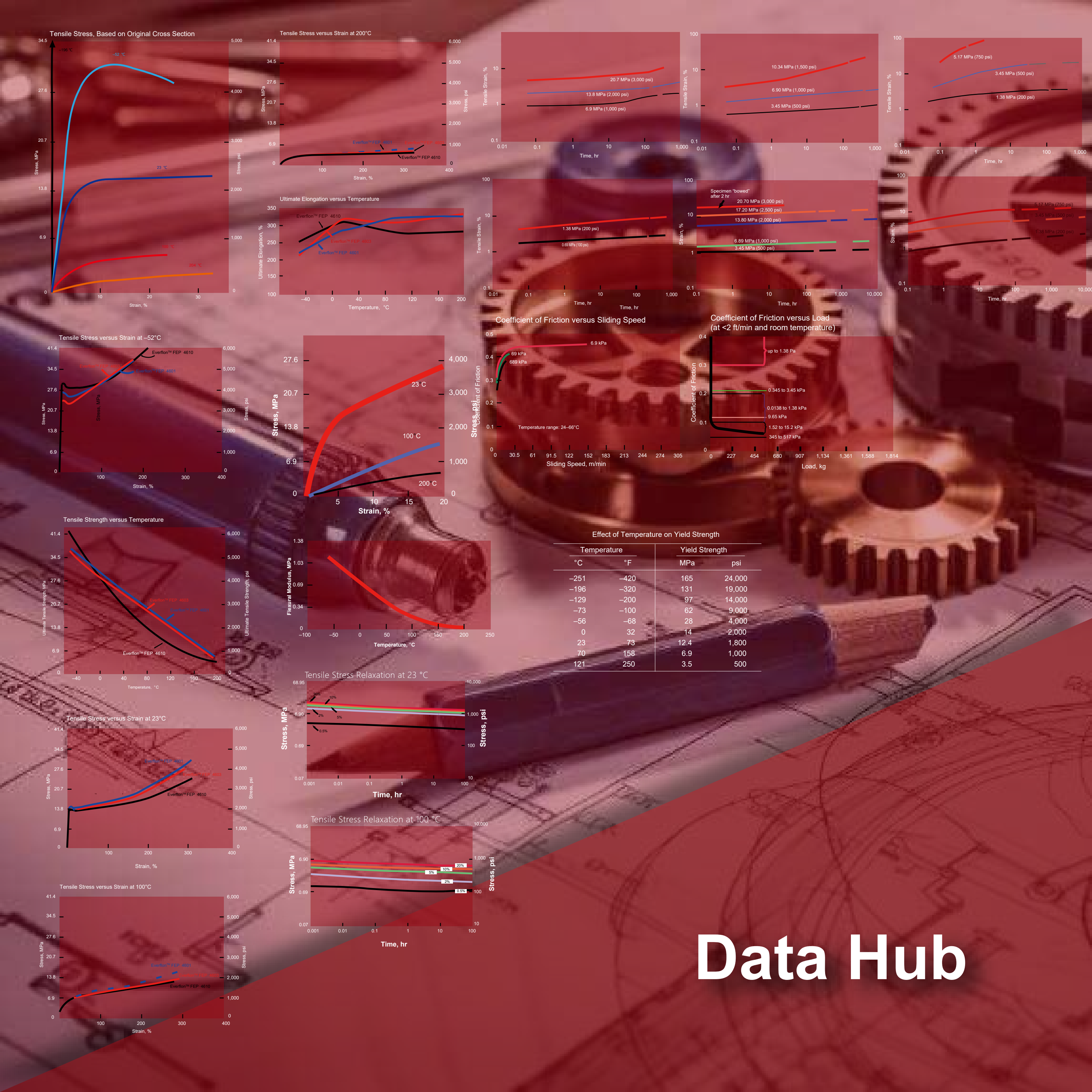
PV limits presented in Table define the maximum combinations of pressure at which these materials will operate continuously without lubrication. PV limit does not necessarily define useful combinations of pressure and velocity since wear is not considered in its determination.

The useful PV limit of a material cannot exceed the PV limit and must take into account the composition’s wear characteristics and the allowable wear for the application. The melting point of the resin is an additional limiting factor.

The coefficient of friction versus sliding speed for Everflon™ FEP 4610 and coefficient of friction versus load at low rates of speed are shown in Figures.

Impact Resistance

Everflon™ FEP has excellent impact strength over a wide range of temperatures. In the notched Izod impact test, no breaks are incurred with Everflon™ FEP 4610, 4603, or 4601 at temperatures as low as –60°C.



Effect of Temperature on Yield Strength

Temperature		Yield Strength	
°C	°F	MPa	psi
–251	–420	165	24,000
–196	–320	131	19,000
–129	–200	97	14,000
–73	–100	62	9,000
–56	–68	28	4,000
0	32	14	2,000
23	73	12.4	1,800
70	158	6.9	1,000
121	250	3.5	500

Data Hub

Chemical Properties

Everflon™ FEP fluoropolymer resins are essentially chemically inert. Up to the highest use temperature of 200°C (392°F), very few chemicals are known to react chemically with these resins.

Those that do include molten alkali metals, fluorine, and a few fluorochemicals such as chlorine trifluoride, CIF3, or oxygen difluoride, OF2, which readily liberate free fluorine at elevated temperatures.

The unique degree of inertness of Everflon™ fluoropolymer resin reflects its chemical structure. Molecules of Everflon™ FEP fluoropolymer resins are formed simply from strong carbon-carbon and super-strong carbon-fluorine interatomic bonds; moreover, the fluorine atoms form a protective sheath around the carbon core of each molecule.

This structure also produces other special properties, suchas insolubility and low surface tension (which imparts nonwettability to many solvents), low coefficient of friction, and excellent nonstick characteristics. For example, sheeting or components of Everflon™PTFE resins may be bonded to metal with molten Everflon™FEP.

Absorption

Everflon™ FEP has unusually low absorption compared with other thermoplastics. It absorbs practically no common acids or bases at temperatures as high as 200°C and exposures of one year. Even the absorption of solvents is very small. Weight increases are generally less than 1% when exposed at elevated temperatures for long periods. Aqueous solutions are absorbed very little by Everflon™ FEP. Moisture absorption is typically less than 0.01% at ambient temperature and pressure.

Weathering

Everflon™ FEP is essentially unchanged after 25 years of outdoor weathering . The tensile strength is unaffected although there seems to be some loss in ultimate elongation. However, the value remains quite high.

Cryogenic Service

Everflon™ FEP has performed satisfactorily in cryogenic service at temperatures below that of liquid nitrogen.
When carefully cleaned of any organic substances, Everflon™ FEP is inert to LOX and is frequently used in LOX applications.

Mildew Resistance

Everflon™ FEP has been shown to be completely resistant to mildew growth by testing in humidity chamber, while inoculated with a spore suspension, and, in a soil burial test for three months.

Permeability

Many gases and vapors permeate Everflon™ FEP at a much lower rate than for other thermoplastics. In general, permeation increases with temperature, pressure, and surface contact area and decreases with increased thickness. Table lists rates at which various gases are transmitted through Everflon™ FEP E4610 film while typicalvapor transmission rates of Everflon™ FEP are shown in Table. Note that the pressure for each material is its vapor pressure at the indicated temperature.
Figure shows water vapor transmission rate of Everflon™ FEP film at 40°Cas a function of thickness.

FDA Compliance

Everflon™ FEP may be used as articles or components of articles intended to contact food in compliance with FDA regulation 21 CFR 177.1550.

Optical Properties

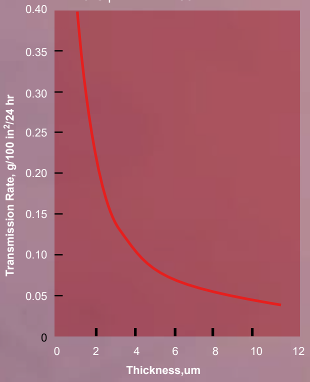
In thin sections or films, Everflon™ FEP transmits a high percentage of ultraviolet and visible light. The solar transmission of Everflon™ FEP in thin-film form is approximately 96%. Everflon™ FEP is much more transparent in the infrared region of the spectrum than is glass.

Typical Vapor Transmission Rates

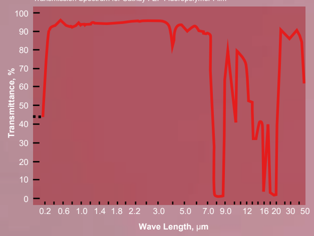
(1 mil film, ASTM E96 modified test)

	Temperature		Vapor Transmission Rate	
Vapor	°C	°F	g/m².d	g/100 in².d
Acetic acid	35	95	6.3	0.41
Acetone	35	95	14.7	0.95
Benzene	35	95	9.9	0.64
Carbon tetrachloride	35	95	4.8	0.31
Ethyl acetate	35	95	11.7	0.76
Ethyl alcohol	35	95	10.7	0.69
F-12	23	73	372	24
Hexane	35	95	8.7	0.56
Hydrochloric acid	25	77	<0.2	<0.01
Nitric acid (red fuming)	25	77	160	10.5
Sodium hydroxide, 50%	25	77	<0.2	<0.01
Sulfuric acid, 98%	25	77	2×10^{-4}	1×10^{-5}
Water	39.5	103	7.0	0.40

Water Vapor Transmission Rate of Cathay FEP Film at 40°C per ASTM E96



Transmission Spectrum for Cathay FEP Fluoropolymer Film



Data Hub

Thermal Properties

Everflon™ FEP is a copolymer of hexafluoropropylene and tetrafluoroethylene and, as such, has a melting range rather than a sharp melting point. The melting peak derived from differential thermal analysis (DTA) is 257–263°C.

The heat of combustion of Everflon™ FEP is extremely low. This property in combination with its very high oxygen index makes this product very useful in areas where fire hazards must be kept to a minimum.

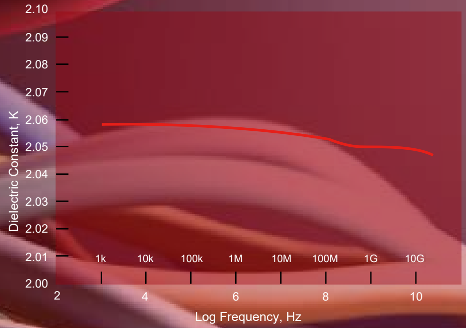
Property	Test method	Everflon™ FEP	PTFE
Melt viscosity at 380°C		$(1.5\sim60)\times10^{4}$	$10^{11}\sim10^{12}$
Specific heat (J/kg·°C)		1.2×10^{3}	1.0×10^{3}
Melting point (°C)		265~275	327
Thermal conductivity (W/m·°C)	ASTM C 177	0.2	0.23
Thermal expansion (1/°C)	ASTM D 696 (-50°C~+100°C)	$(8\sim15)\times10^{-5}$	$(11\sim14)\times10^{-5}$

Property	FEP	ETFE	PVDF
Oxygen index (vol.%)	>95	31	43
UL 94 flame class	V-0	V-0	V-0
Heat of combustion (J/g)	7,700	15,620	18,300

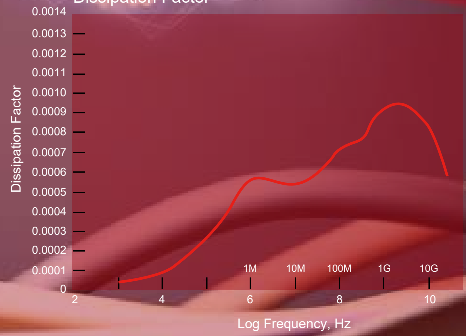
Electrical Properties

Everflon™ FEP has a dielectric constant of 2.04–2.05 over a wide range of frequencies from 1 kHz to 13 GHz. The dissipation factor increases slowly from 0.00006 at 1 kHz to 0.0006 at 30 MHz and peaks out at 0.001 at 1 GHz. These relationships are shown graphically in Figures. The effects of temperature on these properties are shown in Figures. A glance at the figures will show that temperature has a significant effect on the dissipation factor, but the shapes of the curves are similar. The data were obtained from measurements made on Everflon™ FEP 4610 but the values for EverflonTM FEP 4603 and 4601 should be similar.

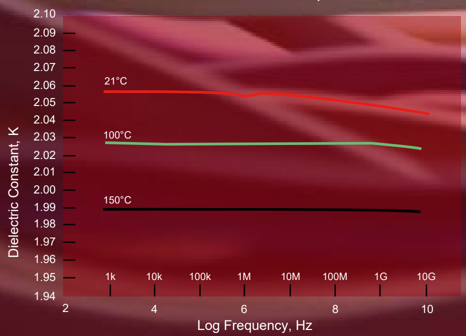
Dielectric Constant



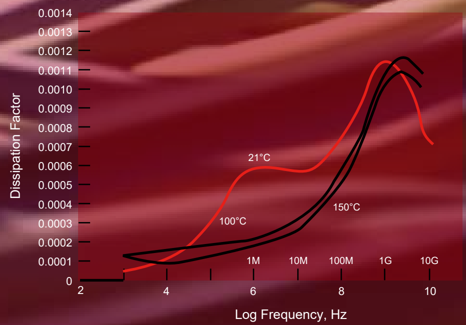
Dissipation Factor



Dielectric Constant—Elevated Temperature,



Dissipation Factor—Elevated Temperature,



Fabrication Guide

Everflon™ FEP, as a thermoplastic polymer, can be processed by most techniques applicable to the type of resin. Depending upon the grade, and hence the melt viscosity (melt flow number),Everflon™ FEP can be processed by injection, compression, transfer, or rotational molding.

It can be extruded into a variety of complex shapes including rod, tubing, and film and can be coatedonto wire as a primary insulation or for jacketing purposes. Everflon™FEP 4601 is usually the preferred material for transfer molding of liners, tubing, etc., where a high degree of stress crack resistance is required.

However, the very high melt viscosity of this product results in considerably slower production rates and limits its use for some types of processing.

Everflon™ FEP 4610, being of lower viscosity and hence more easily processible, is the preferred resin for injection molding and general extrusion applications. Everflon™ FEP 4603 is of intermediate viscosity and usually used where a modest improvement in stress crack resistance is required but where some degree of production rate reduction can be tolerated.

One property of Everflon™ FEP fluoropolymer resin is the exceptionally low thermal conductivity. It does not rapidly absorb and dissipate heat generated at a cutting edge.

If too much generated heat is retained in the cutting zone, it will tend to dull the tool and overheat the resin. Coolants, then, are desirable during machining operations, particularly above a surface speed of 150 m/min.

Coupled with low conductivity, the high thermal expansion of Everflon™ FEP fluoropolymer resins (nearly ten times that of metals) could pose supplemental problems. Any generation and localization of excess heat will cause expansion of the fluoropolymer material at that point.Depending on the thickness of the section and the operation being performed, localized expansion may result in overcuts or undercuts and drilling a tapered hole.

Machining procedures, then, especially at working speeds, must take conductivity and expansion effects into account. Surface speeds from 60 to 150 m/min are most satisfactory for fine finish turning operations; at these speeds, flood coolants are not needed. Higher speeds can be used with very low feeds or for rougher cuts, but coolants become a necessity for removing excess generated heat. A good coolant consists of water plus water-soluble oil in a ratio of 10:1 to 20:1.

Feeds for the 60 to 150 m/min speed range should run between 0.05–0.25 mm/revolution. If a finishing cut is the object of a highspeed operation (e.g., an automatic screw-machine running at 240 m/min), then feed must be dropped to a correspondingly lower value. Recommended depth of cut varies from 0.005 to 6.3 mm.

Selection Guide for Everflon™ FEP Materials

Processing	Grade 4630/4622	4610/4608	4603	4601
Extrusion molding				
Wires and cable coating				
Thin wall type(0.1~0.17mm)	Y			
Thin wall type(0.17~0.3mm)		Y		
Thin wall type(0.3~0.5mm)			Y	Y
Jacket			Y	
Tubing and pipes				
Spaghetti tubes	Y	Y		
General purpose tubes		Y	Y	
Heat shrinkable tubes			Y	Y
Lined pipes				Y
Films and sheets				
< 250 um thickness	Y			
250~2400 um thickness				
Rod				Y
Mono-filaments	Y	Y		Y
Transfer molding				
Pipe linings				Y
Valve linings				Y
Injection molding	Y			
Compression molding			Y	Y

Fabrication Guide

Extrusion

If the shear rate exceeds the critical shear rate while Everflon™ FEP is being processed, melt fracture will result thus making the molding surface rough.Therefore, the molding method used must have a shear rate lower than theabove mentioned critical shear rates.

Critical Shear Rate of Everflon™ FEP
(360~400°C)

Grade	Critical shear rate (sec^{-1})
4622/4630	60-130
4608/4610	20-40
4603	10-15
4601	1-5

Everflon™ FEP Processing Conditions for Wire and Cable Coating

	4622	4610	4603
Insulated wire size (mm)	0.51*0.86	0.7*1.4	1.0*2.4
Extruder			
Barrel dia.(mm)	50	30	40
Screw L/D	32	22	20
Compression ratio	2.7	2.74	3.0
Aperture of die (mm)	4.7×7.9	7×13	11×24
Temperature (°C)			
Z1	330	330	320
Z2	360	360	340
Z3	380	380	340
Adapter	380	380	340
Die	380	380	370
Screw speed (rpm)	25	30	12
Draw-down ratio (DDR)	100	82	95.5
Insulating speed (m/min)	200	40	14

Everflon™ FEP Processing Conditions for Tubing

	4610	4603	4601
Tubing size (outside dia. × inside dia.)	8×10mm	16×19mm	16×19mm
Extruder			
Screw L/D	20	20	20
Compression ratio	2.85	2.85	2.85
Aperture of die	4.5×8.5	13×17	13×17
Temperature			
Z1	320	320	320
Z2	350	340	360
Z3	350	340	360
Die head	360	360	380
Die	370	370	370
Screw speed (rpm)	12	12	12
Tubing speed (m/min)	4	2	1

Fabrication Guide
Injection Molding

Everflon™ FEP has a high melt viscosity and requires a higher processing temperature compared to general thermoplastics. It is necessary to use a screw type injection molding machine with the shortest possible distance between the sprue and runner gate, and the temperature of the mold must reach 200~230°C.

For compression molding of Everflon™ FEP pellets, the recommended wall thickness are:
Grade Everflon™ 4603, 22 10mm or less
Grade Everflon™4601, 40 10mm or more
Grades 4610, 4603 and 4601 can be processed at 330~350°C. If the temperature reaches higher than 350°C, it is difficult to remove moldings, or the surface of the mold becomes corroded. Desirable molding pressure is 4.9 to 7.8 MPa. During cooling, this pressure should be maintained until the temperature of the mold decreases to approximately 200°C; otherwise, sink marks or voids may remain in the moldings.

Temperature of cylinder	
Z1	300°C
Z2	320~340 °C
Z3	340~360 °C
nozzle	360~380 °C
Temperature of mold	200°C
Extrusion speed of screw	180rpm
Injection pressure	29.4~68.6 MPa
Back pressure	2.9 MPa
Holding time	20 s
Injection rate	9.5(scale)
Period of cooling	60 s
Cycle time	120 s/cycle

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