ETFE poly(ethylene-co-tetrafluoroethylene)

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	poly(ethylene-co-tetrafluoroethylene)	
ACS name	-	ethene, 1,1,2,2-tetrafluoro-, polymer with ethene	
Acronym	-	ETFE	
CAS number	-	25038-71-5	
HISTORY			
Person to discover	-	Hanford, W E, Roland, J R; Joyce, R M; Sauer, J C	Ebnesajjad, S, Fluoroplastics. Vol. 2. Melt Processible Fluoroplastics, William Andrew, 2003.
Date	-	1949 (first patents); 1970 (commercialization)	
SYNTHESIS			
Monomer(s) structure	-	CH_2=CH_2; CF_2=CF_2	
Monomer(s) CAS number(s)	-	74-85-1; 116-14-3	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	28.05; 100.02	
Monomer ratio	-	1	
Tetrafluoroethylene contents	%	39-71	Arai, K; Funaki, A; Phongtamrug, S; Tashiro, K, Polymer, 51, 4831-35, 2010.
Method of synthesis	-	suspension or emulsion polymerization	
Mass average molecular weight, M_w	dalton, g/mol, amu	500,000-1,200,000	
STRUCTURE			
Crystallinity	%	32.8-44.6 (depending on orientation)	Pieper, T; Heise, B; Wilke, W, Polymer, 30, 1768-75, 1989.
Cell type (lattice)	-	orthorhombic, monoclinic	
Cell dimensions	nm	a:b:c=0.96:0.925:0.5	
Unit cell angles	degree	γ=96	
Chain conformation	-	zig-zag	
COMMERCIAL POLYMERS			
Some manufacturers	-	3M; Asahi; Daikin; DuPont	
Trade names	-	Dyneon; Luon; Neoflon; Tefzel	
PHYSICAL PROPERTIES			
Density at 20°C	g cm^{-3}	1.67-1.78; 1.9 (crystalline)	
Bulk density at 20°C	g cm^{-3}	0.55-1	
Color	-	clear	
Refractive index, 25°C	-	1.403	
Transmittance	%	90-97 (visible); 92 (300 nm); 93 (350 nm); 94 (400-600 nm); 95 (700-800 nm)	Ebnesajjad, S, Fluoroplastics. Vol. 2. Melt Processible Fluoroplastics, William Andrew, 2003.
Odor	-	odorless	
Melting temperature, DSC	°C	225-280	Spencer, P, Polymers in Defence and Aerospace 2007, Rapra, 2007, paper 16.
Softening point	°C	200-300	

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PARAMETER	UNIT	VALUE	REFERENCES
Decomposition temperature	^oC	>270; 356.5 (1%)	
Thermal expansion coefficient, 23-80^oC	$^oC^{-1}$	1.3-2.6E-4	
Thermal conductivity, melt	W m^{-1} K^{-1}	0.24	
Glass transition temperature	^oC	60-110	
Specific heat capacity	J K^{-1} kg^{-1}	250-380	
Maximum service temperature	^oC	150	Charbonneau, L; Polak, M A; Pendilis, A, Construction Bld. Mater., 60, 63-72, 2014.
Long term service temperature	^oC	-200 to 165	
Heat deflection temperature at 0.45 MPa	^oC	81-88	
Heat deflection temperature at 1.8 MPa	^oC	50-74; 204 (20% glass fiber)	
Surface tension	mN m^{-1}	25.5	Becker, K, Int. Biodet. Biodeg., 41, 93-100, 1998.
Dielectric constant at 100 Hz/1 MHz	-	2.5-2.7/2.5-2.6	
Dissipation factor at 1000 Hz	E-4	8	
Volume resistivity	ohm-m	1E13 to 1E15	
Surface resistivity	ohm	1E15	
Electric strength K20/P50, d=0.60.8 mm	kV mm^{-1}	15-150	
Coefficient of friction	-	0.23 (ETFE/steel); 0.19-0.20 (20% glass fiber)	
Permeability to nitrogen, 25^oC	cm^3 mm m^{-2} day^{-1} atm^{-1}	11.8	
Permeability to oxygen, 25^oC	cm^3 mm m^{-2} day^{-1} atm^{-1}	39.4	
Contact angle of water, 20^oC	degree	93-94; 106; 108 (adv) and 84 (rec)	Kwok, D Y; Neuman, A W, Colloid Surf. A, 161, 49-62, 2000; Lee, S; Park, J-S; Lee, T R, Langmuir, 24, 4817-26, 2008.
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	33-64	
Tensile modulus	MPa	300-1,100	
Tensile stress at yield	MPa	25	
Elongation	%	150-650	
Tensile yield strain	%	4.5-23	
Flexural strength	MPa	38	
Flexural modulus	MPa	880-1380; 5,170 (20% glass fiber)	
Compressive strength	MPa	11-17.2	
Izod impact strength, unnotched, 23^oC	J m^{-1}	480	
Poisson's ratio	-	0.43-0.45	Galliot, C; Luchsinger, R H, Polym. Testing, 30, 356-65, 2011; Hu, J; Chen, W; Zhao, B; Wang, K, Construction Bld. Mater., 75, 200-7, 2015.
Shore D hardness	-	63-75	

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PARAMETER	UNIT	VALUE	REFERENCES
Shrinkage	%	0.2-4	
Melt index, 230°C/3.8 kg	g/10 min	2-50	Spencer, P, Polymers in Defence and Aerospace 2007, Rapra, 2007, paper 16.
Water absorption, 24h at 23°C	%	0.005-0.007	
CHEMICAL RESISTANCE			
Acid dilute/concentrated	-	very good	
Alcohols	-	very good	
Alkalis	-	very good	
Aliphatic hydrocarbons	-	very good	
Aromatic hydrocarbons	-	very good	
Esters	-	very good	
Greases & oils	-	very good	
Halogenated hydrocarbons	-	very good	
Ketones	-	very good	
Non-solvent	-	not soluble in any solvent below 100°C	
FLAMMABILITY			
Ignition temperature	°C	470	
Autoignition temperature	°C	510-515	
Limiting oxygen index	% O_2	30-31	
Heat release	kW m^{-2}	16	
Heat of combustion	J g^{-1}	13,700	
Volatile products of combustion	-	HF, CO, CO_2, toxic fluorinated compounds	
UL 94 rating	-	V-0	
WEATHER STABILITY			
Spectral sensitivity	nm	92-94% radiation in the range of 300-400 is transmitted	
Important initiators and accelerators	-	glass fibers decrease stability	
Stabilizers	-	not used	
Low earth orbit erosion yield	cm^3 $atom^{-1}$ x 10^{-24}	0.961	Waters, D L; Banks, B A; De Groh, K K; Miller, S K R; Thorson, S D, High Performance Polym., 20, 512-22, 2008.
TOXICITY			
NFPA: Health, Flammability, Reactivity rating	-	0/1/0 (HMIS)	
Carcinogenic effect	-	not listed by ACGIH, NIOSH, NTP	
PROCESSING			
Typical processing methods	-	extrusion, injection molding, wire coating	
Processing temperature	°C	<380	
Additives used in final products	-	Fillers: graphite, glass fiber, bronze powder	
Applications	-	aircraft insulated wires, components of valves and pumps, data transmission cable, filler in PTFE to reduce wear, lined pipes, wire coating	

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PARAMETER	UNIT	VALUE	REFERENCES
Outstanding properties	-	mechanical toughness, chemical resistance, radiation resistance	
BLENDS			
Suitable polymers	-	PA, PE, PMMA, PVDF	
ANALYSIS			
FTIR (wavenumber-assignment)	cm^{-1}/-	CH_2 – 2976; C=C – 1750, CH – 1454; CF_2 – 1000-1300	Chen, J; Asano, M; Yamaki, T; Yoshida, M, J. Membrane Sci., 269, 194-204, 2006.