

FEP fluorinated ethylene-propylene copolymer

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	fluorinated ethylene-propylene copolymer	
CAS name	-	1-propene, 1,1,2,3,3,3-hexafluoro-, polymer with 1,1,2,2-tetrafluoroethene	
Acronym	-	FEP	
CAS number	-	25067-11-2	
HISTORY			
Person to discover	-	Bro, M I and Sandt B W	
Date	-	1960 (commercialization)	
Details	-	polymerization in aqueous medium	
SYNTHESIS			
Monomer(s) structure	-	$\text{F}_2\text{C}=\text{CF}_2 \quad \begin{array}{c} \text{CF}_2 \\ \\ \text{CF}_3\text{CF} \end{array}$	
Monomer(s) CAS number(s)	-	116-14-3; 116-15-4	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	100.02; 150.03	
Tetrafluoroethylene content	%	15-50	Steward, C W; Wheland, R C; Anolick, C; Tattersall, T L, J. Vinyl Addit. Technol., 4, 4, 229-32, 1998.
Formulation example	-	water, monomers, surfactant, initiator, solvent	
Temperature of polymerization	°C	110-120; 350-380 (thermal polymerization)	Ebnesajjad, S, Fluoroplastics. Vol. 2. Melt Processible Fluoroplastics, William Andrew, 2003; Guerrero, G R; Sevilla, L; Soriano, C, Appl. Surf. Sci., 353, 686-92, 2015.
Pressure of polymerization	MPa	3.97-4.14	Ebnesajjad, S, Fluoroplastics. Vol. 2. Melt Processible Fluoroplastics, William Andrew, 2003.
Mass average molecular weight, M_w	dalton, g/mol, amu	76,000-603,000	Kazatchkov, I B; Rosenbaum, E E; Hatzikiriakos, S G; Steward, C W, Antec, 2120-24, 1996.
Polydispersity, M_w/M_n	-	2.28-3.57	
STRUCTURE			
Crystallinity	%	40-70	
Cell type (lattice)	-	pseudo-hexagonal	
Cell dimensions	nm	a:c=0.644:4.15	
Chain conformation	-	helical	
COMMERCIAL POLYMERS			
Some manufacturers	-	3M; DuPont	
Trade names	-	Dyneon	
PHYSICAL PROPERTIES			
Density at 20°C	g cm ⁻³	2.12-2.17	
Color	-	transparent	
Refractive index, 20°C	-	1.3380-1.344	
Odor	-	odorless	

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Melting temperature, DSC	°C	250-280	
Thermal degradation	°C	230	
Decomposition temperature	°C	380	
Thermal expansion coefficient, 23-80°C	°C ⁻¹	0.8-2.8E-4	
Thermal conductivity, melt	W m ⁻¹ K ⁻¹	0.19-0.24	
Glass transition temperature	°C	80	
Specific heat capacity	J K ⁻¹ kg ⁻¹	1100-1200	
Maximum service temperature	°C	-267 to 205	
Long term service temperature	°C	150-200	
Heat deflection temperature at 0.45 MPa	°C	50-79	
Heat deflection temperature at 1.8 MPa	°C	48-70; 91 (20% glass fiber)	
Molar volume	kmol m ⁻³	19.0, 4.0, 3.0	
Interaction radius		4.0	
Hildebrand solubility parameter	MPa ^{0.5}	19.6	
Surface tension	mN m ⁻¹	20.5	Becker, K, Int. Biodet. Biodeg., 41, 93-100, 1998.
Dielectric constant at 100 Hz/1 MHz	-	2.1/2.1	
Dielectric loss factor at 1 kHz	-	0.0002	
Relative permittivity at 100 Hz	-	0.0002	
Dissipation factor at 1000 Hz	E-4	3-8	
Dissipation factor at 1 MHz	E-4	7	
Volume resistivity	ohm-m	1E15-1E18	
Surface resistivity	ohm	1E15-1E16	
Electric strength K20/P50, d=0.608 mm	kV mm ⁻¹	19.7-20	
Surface arc resistance	s	165	
Coefficient of friction	-	0.05-0.67 (itself, static); 0.3 (FEP/steel); 0.11-0.12 (20% glass fiber)	
Permeability to nitrogen, 25°C	cm ³ m ⁻² day ⁻¹ atm ⁻¹	5,000	
Permeability to oxygen, 25°C	cm ³ m ⁻² day ⁻¹ atm ⁻¹	1,600	
Diffusion coefficient of water vapor	cm ² s ⁻¹ x10 ⁷	7.56 (20°C); 4.42 (90°C)	Hansen, C M, Prog. Org. Coat., 42, 167-78, 2001.
Contact angle of water, 20°C	degree	102-120; 118 (adv) and 98 (rec)	Lee, S; Park, J-S; Lee, T R, Langmuir, 24, 4817-26, 2008.
Surface free energy	mJ m ⁻²	18.5	
Surface tension	mN m ⁻¹	16 (lower than PTFE – 18)	Guerrero, G R; Sevilla, L; Soriano, C, Appl. Surf. Sci., 353, 686-92, 2015.
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	14-30; 12 (20% glass fiber)	

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Tensile modulus	MPa	345-1,010	
Tensile stress at yield	MPa	20	
Elongation	%	150-300; 6 (20% glass fiber)	
Tensile yield strain	%	10	
Flexural strength	MPa	19-21	
Flexural modulus	MPa	600-797	
Compressive strength	MPa	15.2	
Izod impact strength, unnotched, 23°C	J m ⁻¹	980 to NB	
Izod impact strength, notched, 23°C	J m ⁻¹	570-680	
Abrasion resistance (ASTM D1044)	mg/1000 cycles	5-15	
Poisson's ratio	-	0.36 (100°C); 0.48 (23°C)	
Shore D hardness	-	55-66	
Rockwell hardness	-	R25-45	
Shrinkage	%	3.5-6.0	
Brittleness temperature (ASTM D746)	°C	-73	
Melt index, 200°C/15 kg	g/10 min	0.17-20	
Water absorption, equilibrium in water at 23°C	%	<0.01 to <0.03	
CHEMICAL RESISTANCE			
Acid dilute/concentrated	-	resistant	
Alcohols	-	resistant	
Alkalis	-	resistant	
Aliphatic hydrocarbons	-	resistant	
Aromatic hydrocarbons	-	resistant	
Esters	-	resistant	
Greases & oils	-	resistant	
Halogenated hydrocarbons	-	resistant	
Ketones	-	resistant	
Other	-	fluorine, molten alkali metals, and molten NaOH react with FEP	
FLAMMABILITY			
Ignition temperature	°C	530-550	
Autoignition temperature	°C	>500	
Limiting oxygen index	% O ₂	>95	
Heat of combustion	J g ⁻¹	5,114-10,460	
Volatile products of combustion	-	carbonyl fluoride, CO, CO ₂ , HF, perfluoroisobutylene, toxic vapor	
UL 94 rating	-	V-0	
WEATHER STABILITY			
Spectral sensitivity	nm	113-180	Dever, J A; McCracken, C A, High Performance Polym., 16, 289-301, 2004.

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PARAMETER	UNIT	VALUE	REFERENCES
Stabilizers	-	not known to be used	
Crack growth rate in space	μm/year	30	De Groh, K K; Banks, B A; Dever, J A; Hodermarsky, J C, High Performance Polym., 16, 319-37, 2004.
Exposure in Florida		no change in tensile strength during 20 years of exposure	
TOXICITY			
NFPA: Health, Flammability, Reactivity rating	-	1/0/0	
Carcinogenic effect	-	not listed by ACGIH, NIOSH, NTP	
OSHA	mg m ⁻³	5 (respirable), 15 (total dust)	
Oral rat, LD₅₀	mg kg ⁻¹	>4,900 (inhalation of dust)	
PROCESSING			
Typical processing methods	-	extrusion	
Preprocess drying: temperature/time/residual moisture	°C/h/%	121-149/4/	
Processing temperature	°C	350-370; 310-330 (injection)	
Processing pressure	MPa	6.7-10.1; 0.17-0.34 (back)	
BLENDS			
Suitable polymers	-	FEP, PANI, PF, PTFE	
ANALYSIS			
FTIR (wavenumber-assignment)	cm ⁻¹ /-	COF – 1883, COOH – 1814, COOH (DIMER) – 1781, CF+CF ₂ -1793, COOCH ₃ – 1795, CONH ₂ – 1768, CH ₂ OH – 3648	Ebnesajjad, S, Fluoroplastics. Vol. 2. Melt Processible Fluoroplastics, William Andrew, 2003.