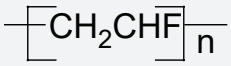
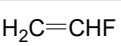
PVF poly(vinyl fluoride)

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	poly(vinyl fluoride)	
IUPAC name	-	poly(vinyl fluoride)	
CAS name	-	ethene, fluoro-, homopolymer	
Acronym	-	PVF	
CAS number	-	24981-14-4	
Formula			
HISTORY			
Person to discover	-	Coffman, D D; Ford, T A	Coffman, D D; Ford, T A, US Patent 2,419,008 and 2,419,010, DuPont, Apr. 15, 1947.
Date	-	1947 (patent); 1961 (commercialization)	
SYNTHESIS			
Monomer(s) structure	-		
Monomer(s) CAS number(s)	-	75-02-5	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	46.04	
Monomer ratio	-	100%	
Formulation example	-	water 200, monomer 100, perfluorinated carboxylic acid 0.6, ammonium persulfate 0.2, water glass 3	Ebnesajjad, S, Fluoroplastics. Vol. 2. Melt Processible Fluoroplastics, William Andrew, 2003.
Method of synthesis	-	emulsion polymerization	
Temperature of polymerization	°C	46	
Time of polymerization	h	8	
Pressure of polymerization	MPa	4.3	
Yield	%	95	
Number average molecular weight, M_n	dalton, g/mol, amu	80,000-790,000	Wang, J; Lu, Y; Li, H; Yuan, H, J. Appl. Polym. Sci., 102, 1780-86, 2006.
Mass average molecular weight, M_w	dalton, g/mol, amu	126,000-150,000	
Polydispersity, M_w/M_n	-	2.5-5.6	
Molar volume at 298K	$cm^3 mol^{-1}$	calc.=35.0; 32.0 (crystalline)	
Van der Waals volume	$cm^3 mol^{-1}$	23.12; 22.8 (crystalline)	
Concentration of head-to-head and tail-to-tail units	%	10-12	
Degree of branching	%	0.45-1.35	Aronson, M T; Bergeer, L L; Honsberg, U S, Polymer, 34, 12, 2546-53, 1993.

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STRUCTURE			
Crystallinity	%	52-68	Ebnesajjad, S, Fluoroplastics. Vol. 2. Melt Processible Fluoroplastics, William Andrew, 2003; Wang, J; Lu, Y; Li, H; Yuan, H, J. Appl. Polym. Sci., 102, 1780-86, 2006; Alchikh, M; Fond, C; Frere, Y, Polym. Deg. Stab., 95, 440-44, 2010.
Cell type (lattice)	-	hexagonal, orthorhombic, monoclinic	
Cell dimensions	nm	a:b:c=0.493:0.493:0.253 (hexagonal); 0.857:0.495:0.252 (orthorhombic); 0.494:0.494:0.252 (monoclinic)	
Unit cell angles	degree	2	
Crystallite size	nm	100,000	Alchikh, M; Fond, C; Frere, Y, Polym. Deg. Stab., 95, 440-44, 2010.
Polymorphs	-	α, β (*trans*), γ, δ	Alchikh, M; Fond, C; Frere, Y, Polym. Deg. Stab., 95, 440-44, 2010.
Tacticity	%	atactic	
Chain conformation	-	planar zig-zag (c-spacing=0.252 nm)	
Entanglement molecular weight	dalton, g/mol, amu	calc.=2,400; 2,546	
COMMERCIAL POLYMERS			
Some manufacturers	-	DuPont, Daikin	
Trade names	-	Tedlar	
PHYSICAL PROPERTIES			
Density at 20°C	g cm^{-3}	1.37-1.38	
Color	-	white	
Refractive index, 20°C	-	calc.=1.452-1.4926; exp.=1.45-1.46	
Transmittance	%	92	
Odor		odorless	
Melting temperature, DSC	°C	178-206	
Softening point	°C	125-130	
Decomposition temperature	°C	379-421	Wang, J; Lu, Y; Li, H; Yuan, H, J. Appl. Polym. Sci., 102, 1780-86, 2006.
Thermal expansion coefficient, 23-80°C	$°C^{-1}$	7.1-9E-5	
Thermal conductivity, melt	W m^{-1} K^{-1}	calc.=0.1566	
Glass transition temperature	°C	calc.=1-65; exp.=40-64	
Specific heat capacity	J K^{-1} kg^{-1}	1,000-1,760	
Maximum service temperature	°C	204	
Long term service temperature	°C	-73 to 107	
Hansen solubility parameters, δ_D, δ_P, δ_H	$MPa^{0.5}$	17.2, 12.3, 9.2	
Hildebrand solubility parameter	$MPa^{0.5}$	calc.=22.67; exp.=23.2	
Surface tension	mN m^{-1}	calc.=31.0-43.3; exp.=28-38.4	
Dielectric constant at 100 Hz/1 MHz	-	8.5/4.8	

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Dissipation factor at 100 Hz	E-4	20	
Dissipation factor at 1 MHz	E-4	70	
Volume resistivity	ohm-m	6.9E11 to 1.8E12	
Surface resistivity	ohm	1.6-6.1E15	
Electric strength K20/P50, d=0.60.8 mm	kV mm^{-1}	120-140	
Coefficient of friction	-	0.13 (PVF/steel); 0.24 (PVF/PVF)	
Permeability to nitrogen, 25°C	cm^3 cm cm^{-2} s^{-1} Pa^{-1} x 10^{12}	0.00012-0.00167	
Permeability to oxygen, 25°C	cm^3 cm cm^{-2} s^{-1} Pa^{-1} x 10^{12}	0.00139-0.0062	
Permeability to water vapor, 25°C	cm^3 cm cm^{-2} s^{-1} Pa^{-1} x 10^{12}	1.01	
Contact angle of water, 20°C	degree	74-89	
Surface free energy	mJ m^{-2}	36.4	
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	69-103	
Tensile modulus	MPa	2,075-2,138	
Elongation	%	95	
Tear strength	N m^{-1}	6,600-7,400	
Poisson's ratio	-	calc.=0.5	
Shrinkage	%	6 (150°C)	
Water absorption, equilibrium in water at 23°C	%	<0.5	
CHEMICAL RESISTANCE			
Acid dilute/concentrated	-	resistant	
Alcohols	-	poor	Alchikh, M; Fond, C; Frere, Y, Polym. Deg. Stab., 95, 440-44, 2010.
Alkalis	-	resistant	
Aliphatic hydrocarbons	-	resistant	
Aromatic hydrocarbons	-	resistant	
Esters	-	resistant	
Greases & oils	-	resistant	
Halogenated hydrocarbons	-	resistant	
Ketones	-	resistant	
Good solvent	-	cyclohexanone (hot), dinitrile, DMA (hot), DMF, DMSO	
Non-solvent	-	aliphatic, cycloaliphatic, and aromatic hydrocarbons	
FLAMMABILITY			
Ignition temperature	°C	420	

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Autoignition temperature	°C	480	
Limiting oxygen index	% O_2	22.6	
Volatile products of combustion	-	CO, HF	
WEATHER STABILITY			
Exposure result		5 years in Florida without change	
Important initiators and accelerators	-	aluminum	Drobny, J, Fluoroplastics, Rapra, 2006.
Stabilizers	-	UV absorbers in laminating films to protect substrate behind the film	
Results of exposure		82% tensile strength retention after 6 years of Florida exposure	
Low earth orbit erosion yield	cm^3 $atom^{-1}$ x 10^{-24}	3.19	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			
Carcinogenic effect	-	not listed by ACGIH, NIOSH, NTP	
PROCESSING			
Typical processing methods	-	coating, film extrusion, vacuum deposition	
Additives used in final products	-	Plasticizer: dimethyl phthalate; Stabilizer: pentaerythritol	Wang, J; Lu, Y; Yuan, H, Polym.-Plast. Technol. Eng., 46, 461-68, 2007.
Applications	-	aircraft interiors, architectural panels, awnings, coatings, glazing, molding, signs, wallcovering	
BLENDS			
Suitable polymers	-	PAC, PLA, PVDF	
ANALYSIS			
FTIR (wavenumber-assignment)	cm^{-1}/-	CH_2 – 2970, 2932, 2861, 1446, 1427, 1410, 1295, 831, 763; C-C – 1189, 1092; CF - 1033, 888, 465, 394	Aronson, M T; Bergeer, L L; Honsberg, U S, Polymer, 34, 12, 2546-53, 1993.
Raman (wavenumber-assignment)	cm^{-1}/-	CH_2 – 2932, 2859, 1436, 1302, 834; C-C – 1194, 1095; CF – 1150, 1032, 890, 454, 395	Aronson, M T; Bergeer, L L; Honsberg, U S, Polymer, 34, 12, 2546-53, 1993.
NMR (chemical shifts)	ppm	F NMR: head-to-tail monomer units – 178-182; head-to-head monomer units – 189, 197; CH_2F end groups – 220, 162, 147	Aronson, M T; Bergeer, L L; Honsberg, U S, Polymer, 34, 12, 2546-53, 1993.