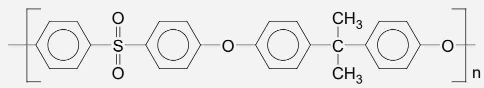
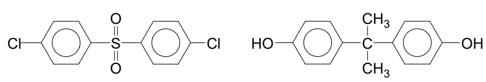
PSU polysulfone

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	polysulfone	
IUPAC name	-	poly[oxy-1,4-phenylenesulfonyl-1,4-phenyleneoxy-1,4-phenylene(dimethylmethylene)-1,4-phenylene]	
CAS name	-	poly[oxy-1,4-phenylenesulfonyl-1,4-phenyleneoxy-1,4-phenylene(1-methylethylidene)-1,4-phenylene]	
Acronym	-	PSU, PSF	
CAS number	-	25135-51-7	
Formula			
Releveant literature			Processing Guide for Injection Molding and Extrusion; Udel Polysulfone, Design Guide, Solvay Advanced Polymers.
HISTORY			
Person to discover	-	Shechter, L	Shechter, L, US Patent 3,282,893, Union Carbide, Nov. 1, 1966.
Date	-	1965, 1966 (filled in 1961)	
Details	-	introduced by Union Carbide in 1965 (patented in 1966)	
SYNTHESIS			
Monomer(s) structure	-		
Monomer(s) CAS number(s)	-	80-07-9; 80-05-7	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	287.16; 228.29	
Monomer ratio	-	1.26:1	
Method of synthesis	-	polysulfone is produced by the reaction of a bisphenol A and bis(4-chlorophenyl)sulfone	
Number average molecular weight, M_n	dalton, g/mol, amu	39,000-41,000	
Mass average molecular weight, M_w	dalton, g/mol, amu	20,000-96,000	
Polydispersity, M_w/M_n	-	1.6	
Molecular cross-sectional area, calculated	$cm^2 \times 10^{-16}$	20.1	
Radius of gyration	nm	7.2	Koriyama, H; Oyama, H T; Ougizawa, T; Inoue, T; Weber, M; Koch, E, Polymer, 40, 6381-93, 1999.
End-to-end distance of unperturbed polymer chain	nm	12.4	Koriyama, H; Oyama, H T; Ougizawa, T; Inoue, T; Weber, M; Koch, E, Polymer, 40, 6381-93, 1999.
Chain-end groups	-	OH; modifications: methacrylate functionality; COOH functionality	Dizman, C; Ates, S; Torun, L; Yagci, Y, Bielstein J. Org. Chem., 6, 56, 1-7, 2010; Hoffmann, T; Pospiech, D; Kretzschmar, B; Reuter, U; Haussler, L; Eckert, F; Perez-Graterol, R; Sandler, J K W; Altstadt, V, High Performance Polym., 19, 48-61, 2007.

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PARAMETER	UNIT	VALUE	REFERENCES
STRUCTURE			
Crystallinity	%	amorphous	
Entanglement molecular weight	dalton, g/mol, amu	calc.=2,250	
COMMERCIAL POLYMERS			
Some manufacturers	-	BASF; Solvay	
Trade names	-	Ultrason S; Udel	
PHYSICAL PROPERTIES			
Density at 20°C	g cm^{-3}	1.23-1.24; 1.33-1.49 (10-30% glass fiber)	
Color	-	amber to beige	
Refractive index, 20°C	-	1.6330	
Transmittance	%	84-86	
Haze	%	1.5-2.5	
Odor	-	odorless	
Melting temperature, DSC	°C	185	
Decomposition temperature	°C	550	
Thermal expansion coefficient, 23-80°C	°C^{-1}	5.3-5.7E-5; 1.9-4.9E-5	
Thermal conductivity, melt	W m^{-1} K^{-1}	0.26; 0.19-0.22 (10-30% glass fiber)	
Glass transition temperature	°C	185-190; 187 (20-30% glass fiber)	
Specific heat capacity	J K^{-1} kg^{-1}	2,300 (400°C)	
Maximum service temperature	°C	140-160	
Long term service temperature	°C	150 (glass fiber reinforced)	
Heat deflection temperature at 0.45 MPa	°C	183; 187-188 (20-30% glass fiber)	
Heat deflection temperature at 1.8 MPa	°C	174-175; 179-183 (10-30% glass fiber)	
Vicat temperature VST/A/50	°C	183-188; 187-192 (10-30% glass fiber)	
Hansen solubility parameters, δ_D, δ_P, δ_H	MPa$^{0.5}$	18.5, 8.5, 7.0; 19.03, 0, 6.96	
Interaction radius		9.4	
Hildebrand solubility parameter	MPa$^{0.5}$	20.26; 21.5	
Surface tension	mN m^{-1}	46.11	Ioan, S; Ffilimon, A; Avram, E; Ioanid, G, e-Polymers, 031, 1-13, 2007.
Dielectric constant at 60 Hz/1 MHz	-	3.03/3.02; 3.18-3.48/3.15-3.47 (10-30% glass fiber)	
Dielectric loss factor at 1 kHz	-	3.02; 3.47 (30% glass fiber)	
Relative permittivity at 100 Hz	-	3.1-3.5; 3.5-3.7 (20-30% glass fiber)	
Relative permittivity at 1 MHz	-	3.1-3.5; 3.5-3.7 (20-30% glass fiber)	
Dissipation factor at 60 Hz		0.0007-0.0011; 0.0007-0.001 (10-30% glass fiber)	
Dissipation factor at 1 MHz		0.006-0.0071; 0.005-0.006 (10-30% glass fiber)	
Volume resistivity	ohm-m	3E14; 1-3E14 (10-30% glass fiber)	
Surface resistivity	ohm	4E15; 1-6E15 (10-30% glass fiber)	

PARAMETER	UNIT	VALUE	REFERENCES
Electric strength K20/P50, d=0.60.8 mm	kV mm^{-1}	17-37; 19-46 (10-30% glass fiber)	
Comparative tracking index, CTI	-	125-135; 165 (10-30% glass fiber)	
Coefficient of friction	-	0.48 (air); 0.4 (water)	Duan, Y; Cong, P; Liu, X; Li, T, J. Macromol. Sci. B, 48, 604-16, 2009.
Permeability to nitrogen, 25°C	mm^3 m m^{-2} MPa^{-1} day^{-1}	155	
Permeability to oxygen, 25°C	mm^3 m m^{-2} MPa^{-1} day^{-1}	894	
Permeability to water vapor, 25°C	g m^{-1} s^{-1} Pa^{-1} x 10^9	0.146	Vidotti, S E; Pessan L A, J. Appl. Polym. Sci., 101, 2, 825-32, 2006.
Contact angle of water, 20°C	degree	66-79	
Surface free energy	mJ m^{-2}	44.9	
Speed of sound	m s^{-1}	37.33	
Acoustic impedance		2.78	
Attenuation	dB cm^{-1}, 5 MHz	4.25	
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	70-77; 77.9-120 (10-30% glass fiber)	
Tensile modulus	MPa	2,480-2,600; 3,720-9,400 (10-30% glass fiber)	
Tensile stress at yield	MPa	75	
Tensile creep modulus, 1000 h, elongation 0.5 max	MPa	2,500; 6,000-8,300 (20-30% glass fiber)	
Elongation	%	50-100, 1.7-4 (10-30% glass fiber)	
Tensile yield strain	%	5.7; 2.2 (20-30% glass fiber)	
Flexural strength	MPa	106; 128-154 (10-30% glass fiber)	
Flexural modulus	MPa	2690; 3,790-7580 (10-30% glass fiber)	
Compressive modulus	MPa	2,580; 4,070-8,000 (10-30% glass fiber)	
Charpy impact strength, unnotched, 23°C	kJ m^{-2}	no break; 5.9-45 (20-30% glass fiber)	
Charpy impact strength, unnotched, -30°C	kJ m^{-2}	no break; 45 (20-30% glass fiber)	
Charpy impact strength, notched, 23°C	kJ m^{-2}	5.5-6; 7 (20-30% glass fiber)	
Charpy impact strength, notched, -30°C	kJ m^{-2}	6; 7 (20-30% glass fiber)	
Izod impact strength, unnotched, 23°C	J m^{-1}	no break; 477 (20% glass fiber)	
Izod impact strength, notched, 23°C	J m^{-1}	69; 48-69 (10-30% glass fiber)	
Izod impact strength, notched, -30°C	J m^{-1}	41-62; 59 (30% glass fiber)	

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PARAMETER	UNIT	VALUE	REFERENCES
Poisson's ratio	-	0.37; 0.41-0.43 (10-30% glass fiber)	
Rockwell hardness	M	69; 80-86 (10-30% glass fiber)	
Shrinkage	%	0.68-0.77; 0.2-0.52 (10-30% glass fiber)	
Viscosity number	ml g^{-1}	72-81; 63 (20-30% glass fiber)	
Intrinsic viscosity, 25°C	dl g^{-1}	0.36-0.60	
Melt viscosity, shear rate=1000 s^{-1}	Pa s	400-600; 530-550 (20-30% glass fiber)	
Melt volume flow rate (ISO 1133, procedure B), 360°C/10 kg	cm^3/10 min	30-90; 30-40 (20-30% glass fiber)	
Melt index, 343°C/3.8 kg	g/10 min	3.4-17.5; 6.5 (10-30% glass fiber)	
Water absorption, 24h at 23°C	%	0.22-0.3; 0.22-0.29 (10-30% glass fiber)	
Moisture absorption, equilibrium 23°C/50% RH	%	0.3; 0.2 (20-30% glass fiber)	
CHEMICAL RESISTANCE			
Acid dilute/concentrated	-	excellent	
Alcohols	-	excellent	
Alkalis	-	good to excellent	
Aliphatic hydrocarbons	-	excellent	
Aromatic hydrocarbons	-	good to poor	
Esters	-	poor	
Halogenated hydrocarbons	-	poor	
Ketones	-	poor	
FLAMMABILITY			
Ignition temperature	°C	490; 875 (20-30% glass fiber)	
Autoignition temperature	°C	550-590	
Limiting oxygen index	% O_2	26-32 ; 31-40 (10-30% glass fiber)	
NBS smoke chamber (max optical density)	4 min.	16-65	
Char at 500°C	%	28.1-29	Perng, L H, J. Polym. Sci. A, 38, 583-93, 2000; Lyon, R E; Walters, R N, J. Anal. Appl. Pyrolysis, 71, 27-46, 2004.
Heat of combustion	J g^{-1}	30,280-30,630	Walters, R N; Hacket, S M; Lyon, R E, Fire Mater., 24, 5, 245-52, 2000.
Volatile products of combustion	-	CO, CO_2, oxides of sulfur; and more	Perng, L H, J. Polym. Sci. A, 38, 583-93, 2000.
UL 94 rating	-	HB to V-0; HB to V-1 to V-0 (10-30% glass fiber)	
WEATHER STABILITY			
Spectral sensitivity	nm	<320, 365; 193 (photolithography)	Chen, L; Goh, Y-K; Lawrie, K; Chuang, Y; Piscani, E; Zimmerman, P; Blakey, I; Whittaker, A K, Radiation Phys. Chem., 80, 242-47, 2011.
Excitation wavelengths	nm	245-255, 270, 320,	
Emission wavelengths	nm	310, 360, 450	
Retention of tensile strength and impact after exposure to 50-100 kGy of gamma radiation	%	93-100	

PARAMETER	UNIT	VALUE	REFERENCES
Depth of UV penetration	μm	50	
Important initiators and accelerators	-	residual monomer, copper stearate	
Products of degradation	-	products of photooxidation: chain scissions, free radicals, carbonyl groups, acetic acid, sulfoacetic acid, benzoic acid, crosslinks, unsaturations, hydroxyl groups, sulfonic acid, SO_2	
BIODEGRADATION			
Typical biodegradants	-	Gram-positive and Gram-negative bacteria	Filimon, A; Avram, E; Dunca, S; toica, I; Ioan, S, J. Appl. Polym. Sci., 112, 18088-16, 2009.
Stabilizers	-	quaternization	Filimon, A; Avram, E; Dunca, S; toica, I; Ioan, S, J. Appl. Polym. Sci., 112, 18088-16, 2009.
TOXICITY			
Carcinogenic effect	-	not listed by ACGIH, NIOSH, NTP	
PROCESSING			
Typical processing methods	-	compression molding, electrospinning, extrusion, extrusion blow molding, injection molding, photolithography, thermoforming	
Preprocess drying: temperature/time/residual moisture	°C/h/%	163/3 or 140-150/4 or 135/5; residual moisture for injection molding is 0.05% and for extrusion 0.01%	
Processing temperature	°C	350-390; 360-390 (10-30% glass fiber)	
Processing pressure	MPa	0.7-2.1 (back pressure)	
Process time	min	10-20 (residence time)	
Regrind	%	25	
Additives used in final products	-	Fillers: activated carbon, glass fiber, carbon fiber, aramid fiber, montmorillonite, PTFE, silica, titanium dioxide; Plasticizers: benzyl butyl phthalate, diethyl phthalate, methyl phthalyl ethyl glycolate, tricresyl phosphate; Release: silicone oil, zinc stearate	
Applications	-	battery separator, faucet components, fibers, hot water fittings, medical applications which require resistance to hot water and sterilization, membranes (hemodialysis, water treatment, bioprocessing, food and beverage, and gas separation), microwave cookware, plumbing manifolds, printed circuit boards, tubing, solar hot water applications, utrafiltration membrane	
Outstanding properties	-	high heat deflection temperature, high strength	
BLENDS			
Suitable polymers	-	epoxy, PA6, PC, PDMS, PEG, PEI, PEO, PI, PPS, PPSU, PTFE, PVOH, PVDF	
ANALYSIS			
FTIR (wavenumber-assignment)	cm^{-1}/-	sulfone – 1302, 1143; Ar-SO_2-Ar – 1151; Ar-O-Ar – 1242	Chen, L; Goh, Y-K; Lawrie, K; Chuang, Y; Piscani, E; Zimmerman, P; Blakey, I; Whittaker, A K, Radiation Phys. Chem., 80, 242-47, 2011; Dahe, G J; Teotia, R S; Kadam, S S; Bellare, J R, Biomaterials, 32, 352-65, 2011.

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PARAMETER	UNIT	VALUE	REFERENCES
NMR (chemical shifts)	ppm	phenyl ring – 4.52; sulfonyl group – 7.85	Yilmaz, G; Toiserkani, H; Demirkol, D O; Sakarya, S; Timur, S; Torun, L; Yagci, Y, Mater. Sci., Eng., C31, 1091-97, 2011.