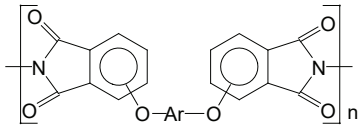
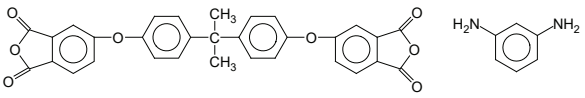
PEI poly(ether imide)

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	poly(ether imide)	
CAS name	-	1,3-isobenzofurandione, 5,5'-[(1-methylethylidene)bis(4,1-phenyleneoxy)]bis-, polymer with 1,3-benzenediamine	
Acronym	-	PEI	
CAS number	-	61128-46-9	
Linear formula			
HISTORY			
Person to discover	-	Wirth, J G; Heath, D R	Wirth, J G; Heath, D R, US Patent 3,787,364, General Electric, Jan. 22, 1974.
Date	-	1974	
Details	-	polymerization patented	
SYNTHESIS			
Monomer(s) structure	-		
Monomer(s) CAS number(s)	-	38103-06-9; 108-45-2	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	520.49; 108.14	
Method of synthesis	-	reaction of bis(chlorophthalimide) with alkalimetal salt of divalent carbocyclic aromatic radical in the presence of appropriate solvent (can be water)	Chiefari, J; Dao, B; Groth, A M; Hodgikin, J H, High Performance Polym., 15, 269-79, 2003.
Temperature of polymerization	°C	180	
Time of polymerization	h	3-4	
Number average molecular weight, M_n	dalton, g/mol, amu	10,000-42,000	
Mass average molecular weight, M_w	dalton, g/mol, amu	30,000-75,000	
Polydispersity, M_w/M_n	-	1.6	
STRUCTURE	-		
Crystallinity	%	amorphous	Rath, T; Kumar, S; Mahaling, R N; Mukherjee, M; Das, C K; Pandley, K N; Saxena, A K, Polym. Compos., 27, 533-38, 2006; Rath, T; Kumar, S; Mahaling, R N; Khatua, B B; Das, C K; Yadaw, S B, Mater. Sci. Eng., 490A, 198-207, 2008.
Entanglement molecular weight	dalton, g/mol, amu	1,850	Yi, J H; Won, H J; Dong, I Y, Polym. Bull., 39, 2, 257-63, 1997.
COMMERCIAL POLYMERS			
Some manufacturers	-	Nippon Polypenco; Sabic; Solvay	
Trade names	-	Ultem; Extem; Ultem	

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PHYSICAL PROPERTIES			
Density at 20°C	g cm^{-3}	1.27-1.31; 1.52 (30% glass fiber); 1.27 (amorphous)	
Color	-	white	
Refractive index, 20°C	-	1.630-1.687	
Transmittance	%	58	
Haze	%	2	
Odor	-	none	
Melting temperature, DSC	°C	229	
Thermal expansion coefficient, -40 to 150°C	$°C^{-1}$	1-5.6E-5	
Thermal conductivity, melt	W m^{-1} K^{-1}	0.17-0.26	
Glass transition temperature	°C	209-249	da Conceicao, T F; Scharnagl, N; Dietzel, W; Kainer, K U, Corrosion Sci., 53, 338-46, 2011.
Long term service temperature	°C	170	
Temperature index (50% tensile strength loss after 20,000 h/5000 h)	°C	170	Padey, D; Walling, J; Wood A, Polymers in Defence and Aerospace 2007, Rapra, 2007, paper 15.
Heat deflection temperature at 0.45 MPa	°C	210-250; 257 (30% glass fiber)	
Heat deflection temperature at 1.8 MPa	°C	190-235; 254 (30% glass fiber)	
Vicat temperature VST/B/50	°C	219-260; 267 (30% glass fiber)	
Hansen solubility parameters, δ_D, δ_P, δ_H	$MPa^{0.5}$	19.6, 7.6, 9.0	Hansen, C M; Just, L, Ind. Eng. Chem. Res., 40, 21-25, 2001.
Interaction radius		6.0	Hansen, C M; Just, L, Ind. Eng. Chem. Res., 40, 21-25, 2001.
Hildebrand solubility parameter	$MPa^{0.5}$	19.8	
Dielectric constant at 100 Hz/1 MHz	-	3.15	
Relative permittivity at 100 Hz	-	3.41	
Relative permittivity at 1 kHz	-	3.41	
Dissipation factor at 100 Hz		0.0015-0.025	
Dissipation factor at 1 MHz		0.0025-0.007	
Volume resistivity	ohm-m	1E13 to 1E15	
Electric strength K20/P50, d=0.60.8 mm	kV mm^{-1}	14-33	
Comparative tracking index, CTI, test liquid A	V	175	
Coefficient of friction	-	0.15-0.7 (against steel; depending on sliding speed, and applied pressure)	Mimaroglu, A; Unal, H; Arda, T, Wear, 262, 1407-13, 2007.
Permeability to nitrogen, 25°C	barrer	0.07	Lopez-Gonzalez, M M; Compan, V; Saiz, E; Riande, E; Guzman, J, J. Membrane Sci., 253, 175-81, 2005.
Permeability to oxygen, 25°C	barrer	0.5	Lopez-Gonzalez, M M; Compan, V; Saiz, E; Riande, E; Guzman, J, J. Membrane Sci., 253, 175-81, 2005.
Diffusion coefficient of nitrogen	cm^2 s^{-1} $x10^9$	1.9	Lopez-Gonzalez, M M; Compan, V; Saiz, E; Riande, E; Guzman, J, J. Membrane Sci., 253, 175-81, 2005.

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Diffusion coefficient of oxygen	$cm^2\ s^{-1}\ x10^9$	6.1	Lopez-Gonzalez, M M; Compan, V; Saiz, E; Riande, E; Guzman, J, J. Membrane Sci., 253, 175-81, 2005.
Contact angle of water, 20°C	degree	76.5	
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	53-124; 156 (30% glass fiber)	
Tensile modulus	MPa	3420-3,700; 10,230 (30% glass fiber)	
Tensile stress at yield	MPa	96-103; 156 (30% glass fiber)	
Elongation	%	14-50; 3 (30% glass fiber)	
Tensile yield strain	%	6-7; (30% glass fiber)	
Flexural strength	MPa	145-168; 206 (30% glass fiber)	
Flexural modulus	MPa	3,040-3,810; 8,960 (30% glass fiber)	
Elastic modulus	MPa	3,000-3,300	
Compressive strength	MPa	118	
Young's modulus	MPa	3,000	
Charpy impact strength, unnotched, 23°C	$kJ\ m^{-2}$	NB	
Charpy impact strength, unnotched, -30°C	$kJ\ m^{-2}$	NB	
Charpy impact strength, notched, 23°C	$kJ\ m^{-2}$	21; 24 (30% glass fiber)	
Izod impact strength, unnotched, 23°C	$J\ m^{-1}$	1,340-1870 to NB	
Izod impact strength, notched, 23°C	$J\ m^{-1}$	27-69; 89 (30% glass fiber)	
Izod impact strength, notched, -30°C	$J\ m^{-1}$	74	
Poisson's ratio	-	0.36	Ramani, K; Zhao, W, Antec, 1160-64, 1997.
Rockwell hardness	-	R127	
Shrinkage	%	0.5-1.2	
Melt viscosity, shear rate=1000 s^{-1}	Pa s	350	Lou, J; Shabazi, A; Harinath, V, Antec, 2193-7, 2003.
Melt volume flow rate (ISO 1133, procedure B), 360°C/5 kg	cm^3/10 min	8	
Melt index, 230°C/3.8 kg	g/10 min	14-18; 4 (30% glass fiber)	
Water absorption, equilibrium in water at 23°C	%	0.65 (24 h immersion); 1.75 (30 days immersion)	
Moisture absorption, equilibrium 23°C/50% RH	%	0.15 (24 h); 0.76 (30 days)	
CHEMICAL RESISTANCE			
Acid dilute/concentrated	-	very good	
Alcohols	-	good	
Alkalis	-	very good	
Aliphatic hydrocarbons	-	good	
Aromatic hydrocarbons	-	good	
Esters	-	good	
Greases & oils	-	very good	

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Halogenated hydrocarbons	-	very good	
Ketones	-	good	
Good solvent	-	N-methylpyrrolidone, dichloromethane	
FLAMMABILITY			
Autoignition temperature	°C	385	
Limiting oxygen index	% O_2	45-47	
NBS smoke chamber	Ds	50	Padey, D; Walling, J; Wood A, Polymers in Defence and Aerospace 2007, Rapra, 2007, paper 15.
Char at 500°C	%	49.2	Lyon, R E; Walters, R N, J. Anal. Appl. Pyrolysis, 71, 27-46, 2004.
Heat of combustion	J g^{-1}	29,060-35,220	Walters, R N; Hacket, S M; Lyon, R E, Fire Mater., 24, 5, 245-52, 2000.
UL 94 rating	-	V-0	
WEATHER STABILITY			
Spectral sensitivity	nm	293	
Excitation wavelengths	nm	350	
Emission wavelengths	nm	470; 550	
Products of degradation	-	acetophenone, phenyl acetic acid, phenols, benzoic acid, phthalic anhydride and phthalic acid end-groups; chain scission, photooxidative degradation of the isopropylidene bridge of BPA units, photooxidation of phthalimide units to phthalic anhydride end groups, hydrolysis of phthalic anhydride end groups	
Stabilizers	-	triphenyl; phosphate	
TOXICITY			
HMIS: Health, Flammability, Reactivity rating	-	0/1/0	
Carcinogenic effect	-	not listed by ACGIH, NIOSH, NTP	
Oral rat, LD_{50}	mg kg^{-1}	>5,000	
PROCESSING			
Typical processing methods	-	blow molding, extrusion, injection molding	
Preprocess drying: temperature/time/residual moisture	°C/h/%	150-175/4-6/0.02	
Processing temperature	°C	260-320 (molding)	
Processing pressure	MPa	0.3-0.7 (back pressure)	
Process time	min	5	
Additives used in final products	-	Fillers: calcium silicate, carbon fibers, glass fibers, graphite flakes, mica, multiwalled carbon nanotubes, titaniun dioxide; Plasticizers: pentaerythritotetrabenzoate ester; Antistatics: fatty quaternary ammonium compounds, potassium titanate whisker; Release: fatty acid amide, p-tallow toluenesulfonamide, pentaerythritol tetrastearate, polyolefin	
Applications	-	aircraft interiors, automotive engine sensors, bulb sockets, electronic connectors, microwaveable cookware, steam sterilizable surgical components thermally resistant film for copper laminated boards,231 vacuum pump vanes	

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BLENDS			
Suitable polymers	-	epoxy, LCP, PA (amorphous), PBT, PC, PET, PPT, silicone	
ANALYSIS			
FTIR (wavenumber-assignment)	cm^{-1}/-	C=O – 1725, 1779; Ar-O-Ar – 1200, 1300	da Conceicao, T F; Scharnagl, N; Dietzel, W; Kainer, K U, Corrosion Sci., 53, 338-46, 2011.