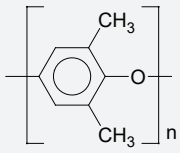
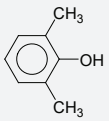
PPO poly(phenylene oxide)

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	poly(phenylene oxide); poly(2,6-dimethyl-1,4-phenyle oxide)	
IUPAC name	-	poly[oxy(2,6-dimethyl-1,4-phenylene)]	
CAS name	-	poly(oxyphenylene)	
Acronym	-	PPO, PPE	
CAS number	-	9041-80-9	
Linear formula			
HISTORY			
Person to discover	-	A S Hay	
Date	-	1956, 1960 (commercialization)	
Details	-	Hay discovered polymer and GE commercialized it	
SYNTHESIS			
Monomer(s) structure	-		
Monomer(s) CAS number(s)	-	526-26-1	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	122.17	
Formulation example	-	monomer, solvent, catalyst	
Method of synthesis	-	three methods are used for synthesis, including oxidative coupling, radical polymerization, and Ullmann reaction	Fink, J K, High Peformance Polymers, William Andrew, 2008.
Temperature of polymerization	°C	35-55	
Catalyst	-	Mn, Cu, or Co derivatives	
Number average molecular weight, M_n	dalton, g/mol, amu	15,000-164,000	
Mass average molecular weight, M_w	dalton, g/mol, amu	35,000-320,000	
Polydispersity, M_w/M_n	-	1.3-2.4	
Molar volume at 298K	cm^3 mol^{-1}	calc.=75.0; 92.0 (crystalline)	
Van der Waals volume	cm^3 mol^{-1}	49.42; 69.3 (crystalline)	
Molecular cross-sectional area, calculated	cm^2 x 10^{-16}	27.6	
STRUCTURE			
Crystallinity	%	40-58	
Cell type (lattice)	-	orthorhombic	
Cell dimensions	nm	a:b:c=0.807:0.554:1.026	
Unit cell angles	degree	α:β:γ=90:90:90	
Number of chains per unit cell	-	4	

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Chain conformation	-	2/1 helix	
Entanglement molecular weight, M_e	dalton, g/mol, amu	calc.=1461, 3620	
COMMERCIAL POLYMERS			
Some manufacturers	-	Aclo; Evonic; Sabic	
Trade names	-	Accuguard; Vestoran; Noryl	
PHYSICAL PROPERTIES			
Density at 25°C	g cm^{-3}	1.04-1.06; 0.96 (melt); 1.16 (crystalline)	
Refractive index, 20°C	-	calc.=1.608-1.6209; exp.=1.6400	
Melting temperature, DSC	°C	240-267	
Decomposition temperature	°C	300 (under vacuum and N_2)	
Thermal expansion coefficient, -30 to 30°C	$°C^{-1}$	2.5-5.2E-5	
Thermal conductivity, melt	W m^{-1} K^{-1}	calc.=0.2060	
Glass transition temperature	°C	calc.=85-115; exp.=205-215	
Heat of fusion	kJ mol^{-1}	7.8	
Heat deflection temperature at 0.45 MPa	°C	106	
Hansen solubility parameters, δ_D, δ_P, δ_H	$MPa^{0.5}$	16.9, 8.9, 2.7	
Interaction radius		11.7	
Hildebrand solubility parameter	$MPa^{0.5}$	19.3	
Surface tension	mN m^{-1}	calc.=44.5; exp.=42.8	Pozniak, G; Gancarz, I; Tylus, W, Desalination, 198, 215-224, 2006.
Dielectric constant at 100 Hz/1 MHz	-	4.6-4.7/4.5-4.8	
Dielectric loss factor at 1 kHz	-	0.0027	
Permeability to nitrogen, 25°C	cm^3 cm cm^{-2} s^{-1} Pa^{-1} x 10^{12}	0.286	
Permeability to oxygen, 25°C	cm^3 cm cm^{-2} s^{-1} Pa^{-1} x 10^{12}	0.119	
Permeability to water vapor, 25°C	cm^3 cm cm^{-2} s^{-1} Pa^{-1} x 10^{12}	304.5	
Surface free energy	mJ m^{-2}	91.3-93.9	Khayet, M; Villaluega, J P G; Godino, M P; Mengual J I; Seoane, B; Khulbe, K C; Matsuura, T, J. Colloid Interface Sci., 278, 410-422, 2004.
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile modulus	MPa	2,700	
Tensile stress at yield	MPa	98	

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Elongation	%	20-40	
Tensile yield strain	%	7	
Flexural strength	MPa	114-137	
Flexural modulus	MPa	5,880-10,000	
Izod impact strength, notched, 23°C	J m^{-1}	69	
Poisson's ratio	-	0.410-0.492	
Shrinkage	%	0.25-0.35	
Intrinsic viscosity, 25°C	dl g^{-1}	0.7-1.57	Khayet, M; Villaluega, J P G; Godino, M P; Mengual J I; Seoane, B; Khulbe, K C; Matsuura, T, J. Colloid Interface Sci., 278, 410-422, 2004.
CHEMICAL RESISTANCE			
Acid dilute/concentrated	-	very good	
Alcohols	-	good	
Alkalis	-	very good	
Aliphatic hydrocarbons	-	poor	
Aromatic hydrocarbons	-	poor	
Esters	-	poor	
Greases & oils	-	good	
Halogenated hydrocarbons	-	poor	
Ketones	-	poor	
Θ solvent, Θ-temp.=69°C	-	methylene chloride	
Good solvent	-	benzene, halogenated hydrocarbons, toluene	
Non-solvent	-	acetone, alcohols, THF	
FLAMMABILITY			
Char at 500°C	%	25.5	Lyon, R E; Walters, R N, J. Anal. Appl. Pyrolysis, 71, 27-46, 2004.
Heat of combustion	J g^{-1}	34,210	Walters, R N; Hacket, S M; Lyon, R E, Fire Mater., 24, 5, 245-52, 2000.
WEATHER STABILITY			
Spectral sensitivity	nm	320	
Depth of UV penetration	μm	20	
Important initiators and accelerators	-	products of thermal degradation, hydroperoxides, phenyl radicals, phenoxy radicals, benzyl radicals, hydroxyl groups	
Products of degradation	-	chain scission (oxygen atmosphere), crosslinking (under nitrogen)	
Stabilizers	-	UVA: 2,2'-methylenebis(6-(2H-benzotriazol-2-yl)-4-1,1,3,3-tetramethylbutyl)phenol; 2-(4,6-diphenyl-1,3,5-triazin-2-yl)-5-hexyloxy-phenol; HAS: 1,3,5-triazine-2,4,6-triamine, N,N'''[1,2-ethane-diyl-bis[[[4,6-bis[butyl(1,2,6,6-pentamethyl-4-piperidinyl) amino]-1,3,5-triazine-2-yl]imino]-3,1-propanediyl]bis[N',N''-dibutyl-N',N''-bis(1,2,2,6,6-pentamethyl-4-piperidinyl)-; Electron transfer quencher: 1,2,4-trimethoxybenzene	

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PROCESSING			
Typical processing methods	-	blow molding, casting, extrusion, injection molding, thermoforming	
Additives used in final products	-	Fillers: aluminum flake, calcium carbonate, carbon fiber, cellulose fiber, glass fiber, graphite fiber, nickel coated graphite fiber, PTFE, zinc borate, wood flour; Other: blowing agents (e.g., azodicarbonamide), flame retardants (e.g., antimony trioxide, brominated PS), impact modifiers (e.g., HIPS); Plasticizers: aromatic phosphates, diphenyl phthalate, pentaerythritol tetrabenzoate, polybutene, triphenyl trimellitate; Antistatics: carbon black (including supoerconductive), carbon fibers, lithium chloride, polyether ester amide, potassium titanate, sodium alkanesulfonate, stainless steel fiber; Release: fluororesin, stearic acid salt	Fink, J K, High Performance Polymers, William Andrew, 2008.
Applications	-	adhesives, air conditioner housings, automotive (instrument panels, interior and exterior trim, glove compartments, wheel covers, electric connectors, fuse boxes), electronics (computer and television housings, keyboard frames, interface boxes), hospital and office furniture, membranes, production of blends; UV dosimetry	
BLENDS			
Suitable polymers	-	epoxy, HIPS, PA6, PA66, PAE, PE, PP, PPS, PS, PVME, SI	Fink, J K, High Performance Polymers, William Andrew, 2008.
Compatibilizers	-	maleic anhydride, fumaric acid, methacrylic anhydride, epichlorohydrin, benzoyl chloride	Fink, J K, High Performance Polymers, William Andrew, 2008.
ANALYSIS			
x-ray diffraction peaks	degree	7.7, 13.0, 16.0, 21.7	Khayet, M; Villaluega, J P G; Godino, M P; Mengual J I; Seoane, B; Khulbe, K C; Matsuura, T, J. Colloid Interface Sci., 278, 410-422, 2004.