LCP liquid crystalline polymers

PARAMETER	UNIT	VALUE	REFERENCES
GENERAL			
Common name	-	liquid crystalline polymers	
Acronym	-	LCP	
CAS number	-	31072-56-7 (Xydar); 144114-03-4 (Vectra C)	
HISTORY			
Person to discover	-	George-Luis LeClerc, Comte de Buffon; Friedrich Reinitze	
Date	-	1707-1788; 1888	
Details	-	first observation by LeClerc; Reinitzer described properties based on observations of cholesterol benzoate	
SYNTHESIS			
Monomer(s) structure	-	three groups of monomers are involved: stiff units (e.g, phenyl, biphenyl, or naphthoic units), linking units (e.g., ether, ester, amide, etc.), and flexible spacer units (e.g., aliphatic or polyether chains); these monomers are used in Xydar: terephthalic acid; benzoic acid; p,p'-biphenol	Fink, J K, High Performance Polymers, William Andrew, 2008.
Monomer(s) CAS number(s)	-	100-21-0; 99-96-7; 92-88-6	
Monomer(s) molecular weight(s)	dalton, g/mol, amu	166.1308; 138.1207; 186.2066	
Method of synthesis	-	various routes can be used to link the three types of monomers involved, but polycondensation (transesterification) to form copolyesters and polyester amides is the most frequently used	Fink, J K, High Performance Polymers, William Andrew, 2008.
Temperature of polymerization	°C	80-100	Ji, L; Wu, Y; Ma, L; Yang, X, Composites: Part A, 72, 32-9, 2015.
Time of polymerization	h	12-24	Ji, L; Wu, Y; Ma, L; Yang, X, Composites: Part A, 72, 32-9, 2015.
Yield	%	24.2-60	Ji, L; Wu, Y; Ma, L; Yang, X, Composites: Part A, 72, 32-9, 2015.
Number average molecular weight, M_n	dalton, g/mol, amu	10,600-24,200	
Mass average molecular weight, M_w	dalton, g/mol, amu	12,000-47,400	
Polydispersity, M_w/M_n	-	1.8-2	
STRUCTURE			
Crystallinity	%	18-38	Kim, J Y; Kim, S H, Antec, 2942-46, 2004.
Crystallite size	nm	1-3.5 (spun fiber)	Kim, J Y; Kim, S H, Antec, 2942-46, 2004.
COMMERCIAL POLYMERS			
Some manufacturers	-	America Quantum Leap Packaging; Eastman; Kuraray; Solvay; Sumitomo; Ticona	
Trade names	-	LCPh; Titan, X7G; Vecstar; Xydar; Ekonol, Sumicasuper; Vectra, Zenite	
PHYSICAL PROPERTIES			
Density at 20°C	g cm^{-3}	1.34-1.4; 1.5-1.81 (15-50% glass fiber)	
Bulk density at 20°C	g cm^{-3}	0.6	
Birefringence	-	0.03-0.07	Kim, J Y; Kim, S H, Antec, 2942-46, 2004.

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PARAMETER	UNIT	VALUE	REFERENCES
Melting temperature, DSC	°C	221-370; 280-350 (15-50% glass fiber)	
Decomposition temperature	°C	350-400	
Thermal expansion coefficient, 23-80°C	$^oC^{-1}$	3.6-7.6E-6; 2-10E-6 (20-45% glass fiber)	Long, V K, Antec, 1570-76, 1998.
Thermal conductivity, melt	$W\ m^{-1}\ K^{-1}$	0.05-0.2	
Glass transition temperature	°C	95-136; 164-181 (crosslinked)	Hakemi, H, Polymer, 41, 6145-50, 2000; Igbal, M; Knijnenberg, A; Poulis, H; Dingemans, T J, Intl. J. Adhesion Adhesives, 30, 682-88, 2010.
Specific heat capacity	$J\ K^{-1}\ kg^{-1}$	1,000	
Heat of fusion	$J\ g^{-1}$	1.3-6.5	Sauer, B B; Kampert, W G; McLean, R S, Polymer, 44, 2721-38, 2003.
Maximum service temperature	°C	340-400	
Long term service temperature	°C	240	
Temperature index (50% tensile strength loss after 20,000 h/5000 h)	°C	130	
Heat deflection temperature at 0.45 MPa	°C	210; 273 (15-50% glass fiber)	
Heat deflection temperature at 1.8 MPa	°C	108-187; 230-340 (15-50% glass fiber)	
Vicat temperature VST/A/50	°C	128	
Vicat temperature VST/B/50	°C	145; 160-200 (15-50% glass fiber)	
Surface tension	$mN\ m^{-1}$	20-43	Gomes, L S; Demarquette, N R; Shimizu, R N; Kamal, M R, Antec, 3589-93, 2003.
Dielectric constant at 60 Hz/1 MHz	-	4.2/3.9-5	
Relative permittivity at 1 MHz	-	3	
Dissipation factor at 1 MHz	E-4	20	
Volume resistivity	ohm-m	1E13-1E14; 1E14 (15-50% glass fiber)	
Surface resistivity	ohm	1E14; 1E16 (15-50% glass fiber)	
Electric strength K20/P50, d=0.60.8 mm	$kV\ mm^{-1}$	39-47; 28-42 (15-50% glass fiber)	
Comparative tracking index	-	150-185	
Arc resistance	MV/m	3.9	
MECHANICAL & RHEOLOGICAL PROPERTIES			
Tensile strength	MPa	117-200; 430 (oriented); 125-200 (15-50% glass fiber)	Lusignea, R; Perdikoulias, J, Antec, 28-35, 1997.
Tensile modulus	MPa	7,500-13,200; 41,000 (oriented); 12,00-17,500 (15-50% glass fiber)	Lusignea, R; Perdikoulias, J, Antec, 28-35, 1997.
Tensile stress at yield	MPa	176; 140-155 (15-50% glass fiber)	
Elongation	%	1.3-4.4; 1.0-3.1 (15-50% glass fiber)	
Flexural strength	MPa	158-180; 200-280 (15-50% glass fiber)	
Flexural modulus	MPa	9,100-13,400; 12,400-20,000 (15-50% glass fiber)	
Compressive strength	MPa	70; 85-125 (15-50% glass fiber)	
Charpy impact strength, unnotched, 23°C	$kJ\ m^{-2}$	60-270; 19-48 (15-50% glass fiber)	

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Charpy impact strength, notched, 23°C	kJ m^{-2}	46-95; 9-42 (15-50% glass fiber)	
Izod impact strength, unnotched, 23°C	J m^{-1}	250-430; 14-61 (15-50% glass fiber)	
Izod impact strength, notched, 23°C	J m^{-1}	60-96; 14-45 (15-50% glass fiber)	
Shear strength	MPa	8-13	Igbal, M; Knijnenberg, A; Poulis, H; Dingemans, T J, Intl. J. Adhesion Adhesives, 30, 682-88, 2010.
Rockwell hardness	-	M66-85 (15-50% glass fiber)	
Shrinkage	%	0.1-0.4; 0.1-0.6 (15-50% glass fiber)	
Melt viscosity, shear rate=1000 s^{-1}	Pa s	30-40	Guo, T; Harrison, G M; Ogale, A A, Antec, 1154-58, 2001.
Melt index, 230°C/3.8 kg	g/10 min	2	
Water absorption, equilibrium in water at 23°C	%	0.01; 0.005-0.02 (15-50% glass fiber)	
Moisture absorption, equilibrium 23°C/50% RH	%	0.03-0.04; 0.006-0.04 (15-50% glass fiber)	
CHEMICAL RESISTANCE			
Alcohols	-	resistant	
Aromatic hydrocarbons	-	resistant	
Esters	-	resistant	
Greases & oils	-	resistant	
Halogenated hydrocarbons	-	resistant	
FLAMMABILITY			
Ignition temperature	°C	93	
Autoignition temperature	°C	>540	
Char at 500°C	%	40.6	Lyon, R E; Walters, R N, J. Anal. Appl. Pyrolysis, 71, 27-46, 2004.
Volatile products of combustion	-	CO, CO_2, phenol	
UL 94 rating	-	V-2 to V-0	
WEATHER STABILITY			
Absorption wavelengths	nm	285-298, 309-310, 350-355	Marin, L; Perju, E; Damaceanu, M D, Eur. Polym. J., 47, 1284-99, 2011.
TOXICITY			
NFPA: Health, Flammability, Reactivity rating	-	1/1/0	
Carcinogenic effect	-	not listed by ACGIH, NIOSH, NTP	
TLV, ACGIH	mg m^{-3}	3 (respirable), 10 (total)	
OSHA	mg m^{-3}	5 (respirable), 15 (total)	
Oral rat, LD_{50}	mg kg^{-1}	>2,000	

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PROCESSING			
Typical processing methods	-	extrusion, fiber spinning, injection molding, micromolding, rotational molding	
Preprocess drying: temperature/ time/residual moisture	°C/h/%	140-160/4-8/0.01	
Processing temperature	°C	270-360; 330-340 (injection molding)	
Processing pressure	MPa	35-70 (injection); 0.35 (back)	
Additives used in final products	-	Fillers: calcium carbonate, carbon black, glass fiber, graphene oxide, graphite, magnesium carbonate, mica, synthetic graphite, wollastonite	
Applications	-	adhesives, aerospace structures, audiovisual equipment, barrier films, bobbins, cameras, capsules for electronic devices, coatings, composites, connectors and sockets, electric motor components, fiber optic connectors, fuel cells bipolar plates, information storage devices, lamp sockets, LED, microwave cookware, precision molded components, printers and copiers parts, SMT components, sporting goods, under-bonnet automotive components, watches	
Outstanding properties	-	flow, heat deflection temperature, stiffness, strength, weather resistance	
BLENDS			
Suitable polymers	-	acrylics, fluorocarbon elastomers, PA6, PA6,6, PBT, PC, PDMS, PEEK, PE, PEI, PEN, PET, PP, PPO, PPS, PS; PSF, PVC, SEBS	Fink, J K, High Performance Polymers, William Andrew, 2008; DeMeuse, M T; Kiss, G, High Temperature Polymer Blends, Elsevier, 2014, 141-64.
Compatibilizers	-	maleic anhydride grafted PP, SEBS, epoxy	Fink, J K, High Performance Polymers, William Andrew, 2008.