Description

Image

Caption

1. Personal computer casing made of polycarbonate. © Chris Lefteri 2. Polycarbonate is tough and impact-resistant: hence its use in hard hats and helmets, transparent roofing and riot shields.

The material

PC is one of the 'engineering' thermoplastics, meaning that they have better mechanical properties than the cheaper 'commodity' polymers. The family includes the plastics polyamide (PA), polyoxymethylene (POM) and polytetrafluorethylene (PTFE). The benzene ring and the -OCOO- carbonate group combine in pure PC to give it its unique characteristics of optical transparency and good toughness and rigidity, even at relatively high temperatures. These properties make PC a good choice for applications such as compact disks, safety hard hats and housings for power tools. To enhance the properties of PC even further, it is possible to co-polymerize the molecule with other monomers (improves the flame retardancy, refractive index and resistance to softening), or to reinforce the PC with glass fibers (giving better mechanical properties at high temperatures).

Composition (summary)

(O-(C6H4)-C(CH3)2-(C6H4)-CO)n

General properties

Density		71.2	-	75.5	lb/ft^3
Price	*	1.54	-	1.65	USD/lb
Date first used		1958			

Mechanical properties

Young's modulus		0.29	-	0.354	10^6 psi
Shear modulus		0.114	-	0.126	10^6 psi
Bulk modulus		0.537	-	0.566	10^6 psi
Poisson's ratio		0.391	-	0.408	
Yield strength (elastic limit)		8.56	-	10.2	ksi
Tensile strength		8.7	-	10.5	ksi
Compressive strength		10	-	12.6	ksi
Elongation		70	-	150	% strain

Hardness - Vickers	17.7	-	21.7	HV
Fatigue strength at 10^7 cycles	3.21	-	4.47	ksi
Fracture toughness	1.91	-	4.19	ksi.in^0.5
Mechanical loss coefficient (tan delta)	0.0164	-	0.0181	

Thermal properties

Glass temperature	287	-	401	°F
Maximum service temperature	214	-	291	°F
Minimum service temperature	-190	-	-99.7	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.109	-	0.126	BTU.ft/h.ft^2.F
Specific heat capacity	0.367	-	0.39	BTU/lb.°F
Thermal expansion coefficient	66.7	-	76	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e20	-	1e21	µohm.cm
Dielectric constant (relative permittivity)	3.1	-	3.3	
Dissipation factor (dielectric loss tangent)	8e-4	-	0.0011	
Dielectric strength (dielectric breakdown)	399	-	487	V/mil

Optical properties

Transparency	Optical Quality		
Refractive index	1.54	-	1.59

Critical Materials Risk

High critical material risk?	No

Processability

Castability	1	-	2
Moldability	4	-	5
Machinability	3	-	4
Weldability	5		

Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Excellent
Soils, acidic (peat)	Excellent
Soils, alkaline (clay)	Excellent
Wine	Excellent

Durability: acids

Acetic acid (10%)	Excellent
Acetic acid (glacial)	Excellent
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent
Hydrochloric acid (36%)	Excellent
Hydrofluoric acid (40%)	Acceptable
Nitric acid (10%)	Excellent
Nitric acid (70%)	Excellent
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Excellent

Durability: alkalis

Sodium hydroxide (10%)	Excellent
Sodium hydroxide (60%)	Limited use

Durability: fuels, oils and solvents

Amyl acetate	Excellent
Benzene	Unacceptable
Carbon tetrachloride	Excellent
Chloroform	Unacceptable
Crude oil	Limited use
Diesel oil	Acceptable
Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
Silicone fluids	Excellent
Toluene	Unacceptable
Turpentine	Excellent
Vegetable oils (general)	Excellent
White spirit	Excellent

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Unacceptable
Acetone	Unacceptable
Ethyl alcohol (ethanol)	Excellent
Ethylene glycol	Excellent
Formaldehyde (40%)	Excellent
Glycerol	Excellent
Methyl alcohol (methanol)	Excellent

Durability: halogens and gases

Chlorine gas (dry)	Unacceptable
Fluorine (gas)	Unacceptable
O2 (oxygen gas)	Unacceptable
Sulfur dioxide (gas)	Limited use

Durability: built environments

Industrial atmosphere	Acceptable
Rural atmosphere	Acceptable
Marine atmosphere	Acceptable
UV radiation (sunlight)	Fair

Durability: flammability

Flammability	Slow-burning

Durability: thermal environments

Tolerance to cryogenic temperatures	Unacceptable
Tolerance up to 150 C (302 F)	Acceptable
Tolerance up to 250 C (482 F)	Unacceptable
Tolerance up to 450 C (842 F)	Unacceptable
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	1.12e4	-	1.24e4	kcal/lb
CO2 footprint, primary production	*	5.74	-	6.35	lb/lb
Water usage	*	19.8	-	21.8	gal(US)/lb
Eco-indicator 95		510			millipoints/kg
Eco-indicator 99		463			millipoints/kg

Material processing: energy

Polymer extrusion energy	*	626	-	692	kcal/lb
Polymer molding energy	*	1.91e3	-	2.11e3	kcal/lb
Coarse machining energy (per unit wt removed)	*	118	-	130	kcal/lb
Fine machining energy (per unit wt removed)	*	713	-	788	kcal/lb
Grinding energy (per unit wt removed)	*	1.38e3	-	1.52e3	kcal/lb

Material processing: CO2 footprint

Polymer extrusion CO2	*	0.434	-	0.48	lb/lb
Polymer molding CO2	*	1.32	-	1.46	lb/lb
Coarse machining CO2 (per unit wt removed)	*	0.0814	-	0.09	lb/lb

Fine machining CO2 (per unit wt removed)	* 0.494	-	0.546	lb/lb
Grinding CO2 (per unit wt removed)	* 0.951	-	1.05	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 4.38e3	-	4.84e3	kcal/lb
CO2 footprint, recycling	* 3.18	-	3.51	lb/lb
Recycle fraction in current supply	* 0.5	-	1	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 3.28e3	-	3.45e3	kcal/lb
Combustion CO2	* 2.7	-	2.84	lb/lb
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

The processing of engineering thermoplastics requires a higher energy input than that of commodity plastics, but otherwise there are no particular environmental penalties. PC can be recycled if unreinforced.

Recycle mark

Supporting information

Design guidelines

The optical transparency and high impact resistance of PC make it suitable for bullet-resistant or shatter-resistant glass applications. It is readily colored. PC is usually processed by extrusion or thermoforming (techniques that impose constraints on design), although injection molding is possible. When designing for extrusion with thermoplastics, the wall thickness should be as uniform as possible to prevent warping, and projections and sharp corners avoided- features like hollows and lone unsupported die sections greatly increase the mold cost. The stiffness of the final part can be improved by the incorporation of corrugations or embossed ribs. PC can be reinforced using glass fibers to reduce shrinkage problems on cooling and to improve the mechanical performance at high temperatures.

Technical notes

The combination of the benzene ring and carbonate structures in the PC molecular structure give the polymer its unique characteristics of high strength and outstanding toughness. It can be easily blended with ABS or polyurethane. ABS/PC gets its flame retardance and UV resistance from polycarbonate at a lower cost than that of ABS. PU/PC gets its rigidity from polycarbonate and flexibility and ease of coating from polyurethane.

Typical uses

Safety shields and goggles, lenses, glazing panels, business machine housing, instrument casings, lighting fittings, safety helmets, electrical switchgear, laminated sheet for bullet-proof glazing, twin-walled sheets for glazing, kitchenware and tableware, microwave cookware, medical (sterilizable) components.

Tradenames

Calibre, FR-PC, Latilon, Lexan, Lupilon, Makrolon, Naxell, Nyloy, Panlite, Sinvet, Star-C, Starglas, Triex, Xantar

Links

Reference

ProcessUniverse

Producers