Polylactide (PLA)

Description

Image

Caption

Polylactide food packaging. © Cargill Dow

The material

Polylactide, PLA, is a biodegradable thermoplastic derived from natural lactic acid from corn, maize or milk. It resembles clear polystyrene, provides good aesthetics (gloss and clarity), but it is stiff and brittle and needs modification using plasticizers for most practical applications. It can be processed like most thermoplastics into fibers, films, thermoformed or injection molded.

General properties

Density		77.4			lb/ft^3
Price	*	0.998	-	1.2	USD/lb
Date first used		1993			

Mechanical properties

Young's modulus		0.479	-	0.522	10^6 psi
Shear modulus	*	0.174	-	0.187	10^6 psi
Bulk modulus	*	0.827	-	0.914	10^6 psi
Poisson's ratio	*	0.38	-	0.4	
Yield strength (elastic limit)		7.98	-	10.4	ksi
Tensile strength		6.82	-	10.2	ksi
Compressive strength		9.57	-	12.5	ksi
Elongation		3	-	6	% strain
Hardness - Vickers	*	17	-	22	HV
Fatigue strength at 10^7 cycles	*	3.22	-	4.02	ksi
Fracture toughness	*	2.73	-	4.55	ksi.in^0.5
Mechanical loss coefficient (tan delta)		0.06	-	0.09	

Thermal properties

Melting point		293	-	351	°F
Glass temperature		126	-	140	°F
Maximum service temperature	*	113	-	131	°F
Minimum service temperature		-4	-	14	°F
Thermal conductor or insulator?		Good insulator			
Thermal conductivity		0.0751	-	0.0924	BTU.ft/h.ft^2.F
Specific heat capacity		0.282	-	0.289	BTU/lb.°F
Thermal expansion coefficient	*	70	-	80.6	µstrain/°F

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Electrical properties

Electrical conductor or insulator?		Good insulator			
Electrical resistivity	*	3e17	-	6e17	µohm.cm
Dielectric constant (relative permittivity)	*	3	-	3.5	
Dissipation factor (dielectric loss tangent)	*	0.001	-	0.02	
Dielectric strength (dielectric breakdown)	*	381	-	432	V/mil

Optical properties

Transparency		Transparent			
Refractive index	*	1.4	-	1.48	

Processability

Moldability		4	-	5
Formability	*	4	-	5
Machinability	*	4	-	5
Weldability	*	3	-	4

Durability: water and aqueous solutions

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

Durability: acids

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

Durability: alkalis

Sodium hydroxide (10%)	Unacceptable
Sodium hydroxide (60%)	Unacceptable

Durability: fuels, oils and solvents

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

Vegetable oils (general)	Acceptable
White spirit	Limited use

Durability: alcohols, aldehydes, ketones

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

Durability: halogens and gases

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

Durability: built environments

Industrial atmosphere	Limited use
Rural atmosphere	Acceptable
Marine atmosphere	Acceptable
UV radiation (sunlight)	Good

Durability: flammability

Flammability	Highly flammable

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	* 5.31e3	-	5.87e3	kcal/lb
CO2 footprint, primary production	* 3.43	-	3.79	lb/lb
Water usage	* 7.86	-	8.69	gal(US)/lb
Eco-indicator 99	278			millipoints/kg

Material processing: energy

Polymer extrusion energy	* 618	-	683	kcal/lb
Polymer molding energy	* 1.67e3	-	1.84e3	kcal/lb
Coarse machining energy (per unit wt removed)	* 96.4	-	106	kcal/lb
Fine machining energy (per unit wt removed)	* 501	-	554	kcal/lb
Grinding energy (per unit wt removed)	* 950	-	1.05e3	kcal/lb

Material processing: CO2 footprint

Polymer extrusion CO2	* 0.428	-	0.473	lb/lb
Polymer molding CO2	* 1.15	-	1.27	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.0667	-	0.0737	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.347	-	0.383	lb/lb
Grinding CO2 (per unit wt removed)	* 0.657	-	0.727	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 3.77e3	-	4.17e3	kcal/lb
CO2 footprint, recycling	* 2.74	-	3.02	lb/lb
Recycle fraction in current supply	* 0.5	-	1	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 2.04e3	-	2.14e3	kcal/lb
Combustion CO2	* 1.79	-	1.88	lb/lb
Landfill	✓			
Biodegrade	✓			
Toxicity rating	Non-toxic			
A renewable resource?	✓			

Environmental notes

Biopolymers like PLA are made from renewable resources, although the processing involves non-renewable chemicals. PLA is biodegradable. If combusted, the CO2 footprint rises to 3.45 kg/kg.

Recycle mark

Supporting information

Design guidelines

PLA is a biopolymer that can be molded, thermoformed and extruded, much like any other thermoplastic. It is transparent and has FDA approval for food packaging. PLA film and sheet can be printed and laminated. Biopolymers are, however, expensive, costing 2 to 6 times as much as commodity plastics like polypropylene.

Technical notes

PLA is a thermoplastic derived primarily from annually renewable resources (maize, corn or milk). It is available in a number of grades, designed for ease of processing. In-line drying may be needed to reduce water content for extrusion and molding. The recommended molding temperature is 165 - 170 C.

Typical uses

Food packaging, plastic bags, plant pots, diapers, bottles, cold drink cups, sheet and film.

Tradenames

NatureWorks PLA, BOPLA

Further reading

See Reference link and Producer website.

Links

Reference

ProcessUniverse

Producers