

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	1.24e3	kg/m ³
Price	* 2.8 - 3.42	USD/kg
Date first used	1993	

Mechanical properties

Young's modulus	3.3 - 3.6	GPa
Shear modulus	* 1.2 - 1.29	GPa
Bulk modulus	* 5.7 - 6.3	GPa
Poisson's ratio	* 0.38 - 0.4	
Yield strength (elastic limit)	55 - 72	MPa
Tensile strength	47 - 70	MPa
Compressive strength	66 - 86	MPa
Elongation	3 - 6	% strain
Hardness - Vickers	* 17 - 22	HV
Fatigue strength at 10 ⁷ cycles	* 22.2 - 27.7	MPa
Fracture toughness	* 3 - 5	MPa.m ^{0.5}
Mechanical loss coefficient (tan delta)	0.06 - 0.09	

Thermal properties

Melting point	145	-	177	°C
Glass temperature	52	-	60	°C
Maximum service temperature	* 45	-	55	°C
Minimum service temperature	-20	-	-10	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.13	-	0.16	W/m.°C
Specific heat capacity	1.18e3	-	1.21e3	J/kg.°C
Thermal expansion coefficient	* 126	-	145	µstrain/°C

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)	* 15	-	17	1000000 V/m

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
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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	* 49	-	54.2	MJ/kg
CO2 footprint, primary production	* 3.43	-	3.79	kg/kg
Water usage	* 65.6	-	72.5	l/kg
Eco-indicator 99	278			millipoints/kg


Material processing: energy

Polymer extrusion energy	* 5.7	-	6.3	MJ/kg
Polymer molding energy	* 15.4	-	17	MJ/kg
Coarse machining energy (per unit wt removed)	* 0.89	-	0.983	MJ/kg
Fine machining energy (per unit wt removed)	* 4.62	-	5.11	MJ/kg
Grinding energy (per unit wt removed)	* 8.77	-	9.69	MJ/kg

Material processing: CO2 footprint

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

Material recycling: energy, CO2 and recycle fraction

Recycle				
Embodied energy, recycling	* 34.8	-	38.5	MJ/kg
CO2 footprint, recycling	* 2.74	-	3.02	kg/kg

Recycle fraction in current supply	* 0.5	-	1	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 18.8	-	19.8	MJ/kg
Combustion CO2	* 1.79	-	1.88	kg/kg
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

Tradenames

NatureWorks PLA, BOPLA

Further reading

See Reference link and Producer

Links

Reference

ProcessUniverse

Producers

