Starch-based thermoplastics (TPS)

Description

Image

Caption

1. Corn maize starch © PDPics at Pixabay [Public domain] 2. Knives, forks, and spoons made from a biodegradable starch-polyester material © at Wikimedia Commons [Public domain]

The material

Starch is a naturally occurring polysaccharide made up of glucose molecules. Its molecular chains are shorter than those of cellulose and the bonds between the sugar molecule building blocks are different. Starch is therefore a polymer, but the problem with using it for making structural products is that it is softened by and dissolves in water. Mater-Bi is a family of biodegradable thermoplastics materials made from maize starch. They are water resistant and resembles polymers made from petro-chemicals. They retain their properties while in use, but when composted in an environment containing bacteria, they biodegrade to carbon dioxide, water and fibrous residue.

Composition (summary)

Complex hydrocarbons.

General properties

Density	78.7	-	79.9	lb/ft^3
Price	* 0.925	-	2.78	USD/lb
Date first used	1990			

Mechanical properties

Young's modulus	0.0348	-	0.218	10^6 psi
Shear modulus	* 0.0218	-	0.131	10^6 psi
Bulk modulus	* 0.29	-	0.363	10^6 psi
Poisson's ratio	* 0.4	-	0.44	
Yield strength (elastic limit)	2.32	-	3.19	ksi
Tensile strength	2.32	-	3.19	ksi
Compressive strength	* 2.9	-	4.06	ksi
Elongation	10	-	80	% strain
Hardness - Vickers	* 4.8	-	6.6	HV

Fatigue strength at 10^7 cycles	* 0.812	-	1.12	ksi
Fracture toughness	* 0.728	-	1.18	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 0.05	-	0.2	

Thermal properties

Melting point	277	-	356	°F
Glass temperature	* 50	-	68	°F
Maximum service temperature	* 140	-	176	°F
Minimum service temperature	* -76	-	-58	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	* 0.0751	-	0.133	BTU.ft/h.ft^2.F
Specific heat capacity	* 0.358	-	0.406	BTU/lb.°F
Thermal expansion coefficient	* 100	-	133	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	* 1e16	-	1e18	µohm.cm
Dielectric constant (relative permittivity)	* 4	-	5	
Dissipation factor (dielectric loss tangent)	* 0.05	-	0.15	
Dielectric strength (dielectric breakdown)	* 305	-	406	V/mil

Optical properties

Transparency	Transparent

Critical Materials Risk

High critical material risk?	No

Processability

Moldability	4	-	5
Machinability	4	-	5
Weldability	3	-	4

Durability: water and aqueous solutions

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

Durability: acids

Acetic acid (10%)	Unacceptable
Acetic acid (glacial)	Unacceptable

Citric acid (10%)	Limited use
Hydrochloric acid (10%)	Limited use
Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Unacceptable
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Limited use
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	Excellent
Carbon tetrachloride	Excellent
Chloroform	Unacceptable
Crude oil	Unacceptable
Diesel oil	Limited use
Lubricating oil	Limited use
Paraffin oil (kerosene)	Limited use
Petrol (gasoline)	Limited use
Silicone fluids	Excellent
Toluene	Unacceptable
Turpentine	Excellent
Vegetable oils (general)	Acceptable
White spirit	Excellent

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	Acceptable
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	* 2.59e3	-	2.87e3	kcal/lb
CO2 footprint, primary production	* 1.05	-	1.16	lb/lb
Water usage	* 12	-	35.9	gal(US)/lb
Eco-indicator 99	253			millipoints/kg

Material processing: energy

Polymer extrusion energy	* 625	-	691	kcal/lb
Polymer molding energy	* 1.87e3	-	2.07e3	kcal/lb
Coarse machining energy (per unit wt removed)	* 70.6	-	78.1	kcal/lb
Fine machining energy (per unit wt removed)	* 244	-	269	kcal/lb
Grinding energy (per unit wt removed)	* 436	-	481	kcal/lb

Material processing: CO2 footprint

Polymer extrusion CO2	* 0.433	-	0.479	lb/lb
Polymer molding CO2	* 1.3	-	1.43	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.0489	-	0.054	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.168	-	0.186	lb/lb
Grinding CO2 (per unit wt removed)	* 0.301	-	0.333	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 3.65e3	-	4.04e3	kcal/lb
CO2 footprint, recycling	* 2.65	-	2.93	lb/lb
Recycle fraction in current supply	* 0.5	-	1	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 1.79e3	-	1.88e3	kcal/lb
Combustion CO2	* 1.59	-	1.67	lb/lb
Landfill	✓			
Biodegrade	✓			
Toxicity rating	Non-toxic			
A renewable resource?	✓			

Environmental notes

Polysaccharides (starches) are made from renewable resources and are biodegradable -- both excellent eco-qualifications. If combusted, the CO2 footprint rises to 3 kg/kg.

Recycle mark

Supporting information

Design guidelines

Mater-Bi can be used in most established plastics processing operations including the manufacture of films and foam, injection molding and thermoforming. Bottles and containers made from Mater-Bi are safe for many food applications, including oils or oily food, but over a long period of time the material is slightly permeable to water. It has been developed to have properties comparable to plastics such as polystyrene, polyethylene and polyurethane. The Mater-Bi range of polysaccharides can be extruded, injection molded, thermo-formed and foamed.
The materials achieve 90 per cent degradation in 50 - 120 days under normal aerobic composting conditions, decomposing to compost that is used for soil improvement for farming and growing. They have been accepted for certification as biodegraded compost under European Standard EN13432.

Technical notes

Mater-Bi is a biopolymer made from maize starch using additives to create macromolecules. The process uses the amylose component of the starch that is converted chemically to a less granular or crystalline form. This is then reacted chemically by a process called complexing with natural or synthetic complexing agents that promote bond formation between the starch molecule chains.

Typical uses

Injection molded: pencil sharpeners, rulers, cartridges, toys, plant pots, plastic bones and other toys for pets, plastic cutlery, hair combs.
Thermo-formed: trays for fresh food packaging, especially fruit and vegetables.
Film extrusion: shopping bags, bubble film for wrapping, plastic laminates for paper cups and plates, bags for rubbish disposal, lining for baby nappies, mulching films for horticulture, wrapping for fruit, vegetables and sanitary products

Tradenames

TPS, Mater-Bi

Links

Reference

ProcessUniverse

Producers