Description

Image

Caption

Cellulose acetate used for a tool handle. © Thinkstock

The material

Cellulose is one of the main structural polymers in plants (specifically that of wood or cotton). These natural fibers are treated with acids to produce a resin, a process called 'esterification'. Cellulose acetate (CA), cellulose acetate butyrate (CAB) and cellulose acetate propionate (CAP) are three common cellulose materials. CA combines toughness, transparency and a natural surface texture. Some cellulose resins are biodegradable allowing their use for envelopes with transparent windows that can be disposed of as if they were paper alone.

General properties

Density		980	-	1.3e3	kg/m^3
Price	*	4.92	-	6.3	USD/kg
Date first used		1894			

Mechanical properties

Young's modulus	1.6	-	2	GPa
Shear modulus	0.146	-	1.47	GPa
Bulk modulus	3	-	3.2	GPa
Poisson's ratio	0.383	-	0.438	
Yield strength (elastic limit)	25	-	45	MPa
Tensile strength	25	-	50	MPa
Compressive strength	27.5	-	49.5	MPa
Elongation	5	-	50	% strain
Hardness - Vickers	10	-	15	HV
Fatigue strength at 10^7 cycles	10	-	20	MPa
Fracture toughness	1	-	2.5	MPa.m^0.5
Mechanical loss coefficient (tan delta)	0.00976	-	0.0966	

Thermal properties

Glass temperature	-9.15	-	107	℃
Maximum service temperature	52.9	-	89.9	℃
Minimum service temperature	-123	-	-73.2	℃
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.13	-	0.3	W/m.℃
Specific heat capacity	1.39e3	-	1.67e3	J/kg.℃
Thermal expansion coefficient	150	-	300	µstrain/℃

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	1e17	-	4.5e20	µohm.cm
Dielectric constant (relative permittivity)	3	-	5	
Dissipation factor (dielectric loss tangent)	0.005	-	0.01	
Dielectric strength (dielectric breakdown)	12	-	18	1000000 V/m

Optical properties

Transparency	Optical Quality			
Refractive index	1.46	-	1.5	

Critical Materials Risk

High critical material risk?	No

Processability

Castability	4	-	5	
Moldability	3	-	4	
Machinability	4	-	5	
Weldability	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%)	Excellent
Hydrochloric acid (10%)	Excellent

Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Unacceptable
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Unacceptable
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	Acceptable
Diesel oil	Excellent
Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
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)	Fair

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	* 85.4	-	94.4	MJ/kg
CO2 footprint, primary production	* 3.62	-	4	kg/kg
Water usage	* 228	-	252	l/kg

Material processing: energy

Polymer extrusion energy	* 5.77	-	6.37	MJ/kg
Polymer molding energy	* 17.1	-	18.9	MJ/kg
Coarse machining energy (per unit wt removed)	* 0.864	-	0.955	MJ/kg
Fine machining energy (per unit wt removed)	* 4.37	-	4.83	MJ/kg
Grinding energy (per unit wt removed)	* 8.26	-	9.13	MJ/kg

Material processing: CO2 footprint

Polymer extrusion CO2	* 0.432	-	0.478	kg/kg
Polymer molding CO2	* 1.28	-	1.42	kg/kg
Coarse machining CO2 (per unit wt removed)	* 0.0648	-	0.0716	kg/kg
Fine machining CO2 (per unit wt removed)	* 0.328	-	0.362	kg/kg
Grinding CO2 (per unit wt removed)	* 0.619	-	0.685	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 34.6	-	38.3	MJ/kg

CO2 footprint, recycling	* 2.72	-	3.01	kg/kg
Recycle fraction in current supply	* 0.5	-	1	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 18.4	-	19.4	MJ/kg
Combustion CO2	* 1.79	-	1.89	kg/kg
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✓			

Environmental notes

Cellulose - a natural, renewable material - forms one ingredient in cellulose-based polymers, which can therefore qualify as biopolymers. The processing, however, involves chemicals that create a problem of disposal. Most cellulose-based polymers burn easily, requiring protection from naked flame. Some are biodegradable.

Recycle mark

Supporting information

Design guidelines

Cellulose materials have good optical transparency (up to 90%) and mechanical properties; they are often used in products where surface finish is important. They can be translucent, transparent or opaque and come in a range of colors including pearlescent, opaque or metallic. Cellulose materials are anti-static and so dust does not stick to the surface. They have glossy surfaces and a self-polishing effect that allows surface scratches to disappear with use. They can be formulated for outdoor use. Cellulose acetates have a high vapor permeability and limited heat resistance; their electrical insulation and dimensional stability are poor; water absorption is high compared with PVC. Compared with CA, CAB and CAP are slightly softer, of lower densities and heat distortion temperatures and they flow more easily. CAB and CAP have a wider operating temperature range (0 to 60 C). In bulk, cellulose acetate often has a light yellow-brown color but it can also attain water, white transparency. Cellulose is easily made into fibers, fabrics and films, known under the trade name of Rayon. It has excellent flow properties and so is well-suited to injection molding but the resin must be kept dry. Stiffer flow grades are available for extrusion to produce film and sheet. These polymers are also some of the best for cutting, turning and milling. CAB is well-suited for thermoforming.

Technical notes

Grades of cellulose materials are varied by increasing the level of acid-treatment or by adding plasticizers. Increasing the plasticizer increases flow and toughness but reduces the creep resistance. But this lack of creep resistance can be used to an advantage in molding where parts can be shot in without problems because the stresses will relax quite quickly.

Typical uses

Tool handles, panels for illuminated signs, steering wheels, bathroom fittings, decorative trim for cars and consumer durables, drawing stencils, pens, pneumatic system traps, blister packaging, laminating with aluminum foil, spectacle frames, lenses, goggles, covers for television screens, cutlery handles.

Tradenames

Dexel, Rotuba, Tenite, Xylonite,

Links

Reference

ProcessUniverse

Producers