Polytetrafluoroethylene (Teflon, PTFE)

Description

Image

Caption

PTFE is widely used for non-stick pans and spatulas. © Granta Design

The material

PTFE (Teflon) is a member of the fluoroplastic family, which includes chlorotrifluoroethylene, CTFE or CFE, polyvinyl fluoride, PVF, and polyvinylidene fluoride PVF2. PTFE has exceptionally low friction, is water repellant, and extremely stable. It was first commercialized in the late 1940's as Teflon. Non-stick cooking utensils (Tefal = Teflon coated aluminum) exploiting its chemical inertness, its thermal stability and its non-wettability - the reason nothing sticks to it. It is expensive as polymers go, but it is used in high-value applications (non-stick pans; Gore-Tex rain gear; artificial arteries).

Composition (summary)

$(CF_2-CF_2)_n$

General properties

Density		2.14e3	-	2.2e3	kg/m^3
Price	*	14.8	-	16.9	USD/kg
Date first used		1938			

Mechanical properties

Young's modulus		0.4	-	0.552	GPa
Shear modulus	*	0.138	-	0.19	GPa
Bulk modulus		1.5	-	1.6	GPa
Poisson's ratio		0.44	-	0.46	
Yield strength (elastic limit)		15	-	25	MPa
Tensile strength		20	-	30	MPa
Compressive strength		16.5	-	27.5	MPa
Elongation		200	-	400	% strain
Hardness - Vickers		5.9	-	6.5	HV
Fatigue strength at 10^7 cycles		5.75	-	7	MPa

Fracture toughness	* 1.32	-	1.8	MPa.m^0.5
Mechanical loss coefficient (tan delta)	* 0.0725	-	0.1	

Thermal properties

Melting point	315	-	339	°C
Glass temperature	107	-	123	°C
Maximum service temperature	250	-	271	°C
Minimum service temperature	* -263	-	-253	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.242	-	0.261	W/m.°C
Specific heat capacity	* 1.01e3	-	1.05e3	J/kg.°C
Thermal expansion coefficient	126	-	216	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	3.3e23	-	3e24	µohm.cm
Dielectric constant (relative permittivity)	2.1	-	2.24	
Dissipation factor (dielectric loss tangent)	* 1.5e-4	-	2.5e-4	
Dielectric strength (dielectric breakdown)	18.2	-	19.7	1000000 V/m

Optical properties

Transparency	Translucent			
Refractive index	1.31	-	1.35	

Critical Materials Risk

High critical material risk?	No

Processability

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

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%)	Excellent
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%)	Excellent

Durability: fuels, oils and solvents

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

Durability: alcohols, aldehydes, ketones

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

Durability: halogens and gases

Chlorine gas (dry)	Excellent
Fluorine (gas)	Excellent
O2 (oxygen gas)	Acceptable
Sulfur dioxide (gas)	Excellent

Durability: built environments

Industrial atmosphere	Excellent
Rural atmosphere	Excellent
Marine atmosphere	Excellent
UV radiation (sunlight)	Good

Durability: flammability

Flammability	Non-flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Excellent
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Excellent
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	*	108	-	120	MJ/kg
CO2 footprint, primary production	*	5.69	-	6.29	kg/kg
Water usage	*	434	-	480	l/kg
Eco-indicator 99		2.44e3			millipoints/kg

Material processing: energy

Polymer extrusion energy	*	8.03	-	8.85	MJ/kg
Polymer molding energy	*	20.7	-	22.8	MJ/kg
Coarse machining energy (per unit wt removed)	*	0.526	-	0.582	MJ/kg
Fine machining energy (per unit wt removed)	*	0.989	-	1.09	MJ/kg
Grinding energy (per unit wt removed)	*	1.5	-	1.66	MJ/kg

Material processing: CO2 footprint

Polymer extrusion CO2	*	0.642	-	0.708	kg/kg
Polymer molding CO2	*	1.66	-	1.83	kg/kg
Coarse machining CO2 (per unit wt removed)	*	0.0395	-	0.0436	kg/kg
Fine machining CO2 (per unit wt removed)	*	0.0742	-	0.082	kg/kg

Grinding CO_2 (per unit wt removed)	* 0.113	-	0.125	kg/kg

Material recycling: energy, CO_2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 27.9	-	30.9	MJ/kg
CO_2 footprint, recycling	* 2.2	-	2.43	kg/kg
Recycle fraction in current supply	* 0.5	-	1	%
Downcycle	✓			
Combust for energy recovery	✗			
Heat of combustion (net)	* 4.69	-	4.92	MJ/kg
Combustion CO_2	* 0.859	-	0.903	kg/kg
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

PTFE is non-flammable and FDA approved. Like all thermoplastics, simple PTFE can be recycled. But in making it into non-stick surfaces, or in transforming it into Gore-Tex, additives are made which prevent further recycling.

Recycle mark

Supporting information

Design guidelines

PTFE is 2.7 times denser than polyethylene and 12 times more expensive. But it is much more resistant to chemical attack; it can safely be used from -270 to + 250 C. It has remarkably low friction; and it has an exceptional ability to resist wetting. All fluoroplastics are white, and to some degree, translucent. They give long-term resistance to attacks of all sorts, including ultraviolet radiation. PTFE itself has a characteristically soft, waxy feel, partly because of the low coefficient of friction. It is an excellent electrical insulator, with low dielectric loss. It can be "foamed" to give a light, micro-porous film that rejects liquid water but allows water vapor to pass - the principle of Gore-Tex. The mechanical properties of PTFE are not remarkable, but it can be made more abrasive resistant by filling with inert ceramic and it can be reinforced with glass, nylon or Kevlar fibers to give a leather-like skin of exceptional toughness, strength and weather-resistance (exploited in tensile roofs). Bonding PTFE is difficult; thermal or ultrasonic methods are good; epoxy, nitrile-phenolic and silicone adhesives can be used. The use of Gore-Tex derivatives in fabrics is expanding, with new variants being developed. The pore size in these fabrics can be controlled to reject not merely water, but bacteria, with potential for protective clothing for surgeons, and possibly against certain kinds of biological weapons. PTFE itself has FDA approval. Its architectural use for dramatic, tent-like, roofing of large structures is increasing.

Technical notes

Fluorine is the most reactive of gasses, yet combined with carbon to form fluoropolymers and it becomes the most stable of molecules, resistant to practically everything except excessive heat. Polytetrafluoroethylene, PTFE, the simplest of these, is just polyethylene with all the hydrogens stripped off and replaced by fluorine: (-CF2)n. The others are variants on this.

Typical uses

Wire and cable covers, high-quality insulating tape, corrosion resistant lining for pipes and valves, protective coatings, seals and gaskets, low friction bearings and skis, transparent roofing and weather protection for other polymers (e.g. ABS), non-stick cooking products, water repellent fabrics.

Tradenames

Aflas, Algoflon, Duroid, Dyneon, Fluon, Fluorel, Hostaflon TF, Polyflon, Soreflon, THV, Teflon, Tetraflon, Tetrafluor

Links

Reference

ProcessUniverse

Producers