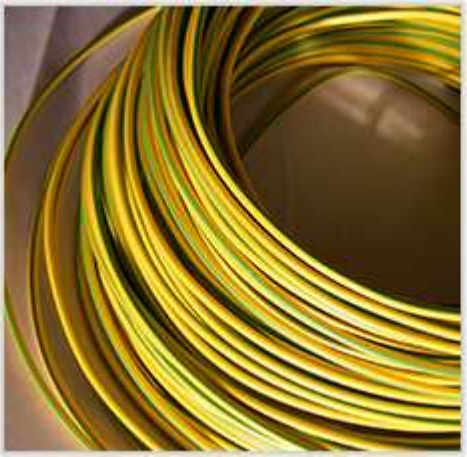
Description

Image


Caption

1. Bubble wrap © PublicDomainPictures at Pixabay [Public domain] 2. Cable insulation © Byrev at Pixabay [Public domain] 3. PE bottles © HebiFot at Pixabay [Public domain]

The material

POLYETHYLENE, (-CH2-)n, first synthesized in 1933, looks like the simplest of molecules, but the number of ways in which the - CH2 - units can be linked is large. It is the first of the polyolefins, the bulk thermoplastic polymers that account for a dominant fraction of all polymer consumption. Polyethylene is inert, and extremely resistant to fresh and salt water, food, and most water-based solutions. Because of this it is widely used in household products, food containers like Tupperware and chopping boards. Polyethylene is cheap, and particularly easy to mold and fabricate. It accepts a wide range of colors, can be transparent, translucent or opaque, has a pleasant, slightly waxy feel, can be textured or metal coated, but is difficult to print on.

Composition (summary)

(-CH2-CH2-)n

General properties

Density		939	-	960	kg/m^3
Price	*	1.61	-	1.65	USD/kg
Date first used		1936			

Mechanical properties

Young's modulus		0.621	-	0.896	GPa
Shear modulus	*	0.218	-	0.314	GPa
Bulk modulus		2.15	-	2.25	GPa
Poisson's ratio	*	0.418	-	0.434	
Yield strength (elastic limit)		17.9	-	29	MPa
Tensile strength		20.7	-	44.8	MPa
Compressive strength		19.7	-	31.9	MPa
Elongation		200	-	800	% strain

Hardness - Vickers		5.4	-	8.7	HV
Fatigue strength at 10^7 cycles		21	-	23	MPa
Fracture toughness	*	1.44	-	1.72	MPa.m^0.5
Mechanical loss coefficient (tan delta)	*	0.0446	-	0.0644	

Thermal properties

Melting point		125	-	132	°C
Glass temperature		-25.2	-	-15.2	°C
Maximum service temperature	*	90	-	110	°C
Minimum service temperature	*	-123	-	-73.2	°C
Thermal conductor or insulator?		Good insulator			
Thermal conductivity		0.403	-	0.435	W/m.°C
Specific heat capacity	*	1.81e3	-	1.88e3	J/kg.°C
Thermal expansion coefficient		126	-	198	µstrain/°C

Electrical properties

Electrical conductor or insulator?		Good insulator			
Electrical resistivity		3.3e22	-	3e24	µohm.cm
Dielectric constant (relative permittivity)		2.2	-	2.4	
Dissipation factor (dielectric loss tangent)	*	3e-4	-	6e-4	
Dielectric strength (dielectric breakdown)		17.7	-	19.7	1000000 V/m

Optical properties

Transparency		Translucent			
Refractive index		1.5	-	1.52	

Critical Materials Risk

High critical material risk?		No			

Processability

Castability		1	-	2	
Moldability		4	-	5	
Machinability		3	-	4	
Weldability		5			

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%)	Acceptable
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	Acceptable
Carbon tetrachloride	Acceptable
Chloroform	Limited use
Crude oil	Acceptable
Diesel oil	Excellent
Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
Silicone fluids	Acceptable
Toluene	Acceptable
Turpentine	Excellent
Vegetable oils (general)	Excellent
White spirit	Excellent

Durability: alcohols, aldehydes, ketones

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

	Excellent
Methyl alcohol (methanol)	Excellent

Durability: halogens and gases

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

Durability: built environments

Industrial atmosphere	Excellent
Rural atmosphere	Excellent
Marine atmosphere	Excellent
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

Geo-economic data for principal component

Annual world production, principal component	6.8e7	-	6.9e7	tonne/yr
Reserves, principal component	* 1.66e9	-	1.88e9	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 77	-	85.1	MJ/kg
CO2 footprint, primary production	* 2.64	-	2.92	kg/kg
Water usage	* 55.3	-	61.1	l/kg
Eco-indicator 95	330			millipoints/kg
Eco-indicator 99	287			millipoints/kg

Material processing: energy

Polymer extrusion energy	* 5.9	-	6.52	MJ/kg
Polymer molding energy	* 20.8	-	23	MJ/kg
Coarse machining energy (per unit wt removed)	* 0.688	-	0.76	MJ/kg
Fine machining energy (per unit wt removed)	* 2.6	-	2.88	MJ/kg

Grinding energy (per unit wt removed)	* 4.73	-	5.23	MJ/kg

Material processing: CO2 footprint

Polymer extrusion CO2	* 0.442	-	0.489	kg/kg
Polymer molding CO2	* 1.56	-	1.73	kg/kg
Coarse machining CO2 (per unit wt removed)	* 0.0516	-	0.057	kg/kg
Fine machining CO2 (per unit wt removed)	* 0.195	-	0.216	kg/kg
Grinding CO2 (per unit wt removed)	* 0.355	-	0.392	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 47.1	-	52	MJ/kg
CO2 footprint, recycling	* 3.7	-	4.09	kg/kg
Recycle fraction in current supply	7.5	-	9.5	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 44	-	46.2	MJ/kg
Combustion CO2	* 3.06	-	3.22	kg/kg
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

PE is FDA compliant - indeed it is so non-toxic that it can be embedded in the human body (heart valves, hip-joint cups, artificial artery). PE, PP and PVC are made by processes that are relatively energy-efficient, making them the least energy-intensive of commodity polymers. The ethylene from which it is made at present is an oil derivative, but PE can be produced from renewable resources - from alcohol derived from the fermentation of sugar or starch, for instance. Its utility per kilogram far exceeds that of gasoline or fuel-oil (and its energy is stored and still accessible), so that production from oil will not disadvantage it in the near future. Polyethylene is readily recyclable if it has not been coated with other materials, and - if contaminated - it can be incinerated to recover the energy it contains.

Recycle mark

Supporting information

Design guidelines

PE is commercially produced as film, sheet, rod, foam and fiber. Drawn PE fiber has exceptional mechanical stiffness and strength, exploited in geo-textile and structural uses. PE is a good electrical insulator with low dielectric loss, so suitable for containers for microwave cooking. It has poor resistance to aromatics and chlorine; it is slow burning in fire. PE is cheap, easy to form, biologically inert and recyclable; it is one of the materials of the next 20 years.

Technical notes

Low density polyethylene (LDPE), used for film and packaging, has branched chains which do not pack well, making it less dense than water. Medium (MDPE) and High (HDPE) density polyethylenes have longer, less branched chains, making them stiffer and stronger; they are used for containers and pipes. Modern catalysis allows side-branching to be suppressed and molecular length to be controlled precisely, permitting precise tailoring both of the processing properties critical for drawing, blow molding, injection molding or extrusion and the use-properties of softening temperature, flexibility and toughness. Linear low-density polyethylene (LLPDE) is an example. In its pure form it is less resistant to organic solvents, but even this can be overcome by converting its surface to a fluoro-polymer by exposing it to fluorine gas. Treated in this way (when it known is known as 'Super PE') it can be used for petrol tanks in cars and copes with oil, cleaning fluid, cosmetics and that most corrosive of substances: cola concentrate. Very low density polyethylene (VDLPE) is similar to EVA and plasticized PVC.

Typical uses

Oil container, street bollards, milk bottles, toys, beer crate, food packaging, shrink wrap, squeeze tubes, disposable clothing, plastic bags, paper coatings, cable insulation, artificial joints, and as fibers - low cost ropes and packing tape reinforcement.

Tradenames

Alathon, Aquathene, Bapolene, Dowlex, Eltex, Empee, Eraclene, Ferrene, Fortiflex, HiVal, Hid, Kemcor, Lacqtene, Lupolen, Marlex, Nortuff, Novapol, Paxon, Petrothene, Polyfort, Rigidex, Sclair, Stamylyn, Statoil, Unival, Zemid

Links

Reference

ProcessUniverse

Producers