Description

Image

Caption

1. Polypropylene samples showing texture and transparency. © Chris Lefteri 2. Polypropylene glasses. © Thinkstock

The material

Polypropylene, PP, first produced commercially in 1958, is the younger brother of polyethylene - a very similar molecule with similar price, processing methods and application. Like PE it is produced in very large quantities (more than 30 million tons per year in 2000), growing at nearly 10% per year, and like PE its molecule-lengths and side-branches can be tailored by clever catalysis, giving precise control of impact strength, and of the properties that influence molding and drawing. In its pure form polypropylene is flammable and degrades in sunlight. Fire retardants make it slow to burn and stabilizers give it extreme stability, both to UV radiation and to fresh and salt water and most aqueous solutions.

Composition (summary)

(CH2-CH(CH3))n

General properties

Density	55.6	-	56.8	lb/ft^3
Price	* 0.771	-	0.803	USD/lb
Date first used	1957			

Mechanical properties

Young's modulus	0.13	-	0.225	10^6 psi
Shear modulus	0.0458	-	0.0795	10^6 psi
Bulk modulus	0.363	-	0.377	10^6 psi
Poisson's ratio	0.405	-	0.427	
Yield strength (elastic limit)	3	-	5.4	ksi
Tensile strength	4	-	6	ksi
Compressive strength	3.64	-	8.01	ksi
Elongation	100	-	600	% strain

Hardness - Vickers	6.2	-	11.2	HV
Fatigue strength at 10^7 cycles	1.6	-	2.4	ksi
Fracture toughness	2.73	-	4.1	ksi.in^0.5
Mechanical loss coefficient (tan delta)	0.0258	-	0.0446	

Thermal properties

Melting point	302	-	347	°F
Glass temperature	-13.3	-	4.73	°F
Maximum service temperature	212	-	239	°F
Minimum service temperature	-190	-	-99.7	°F
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.0653	-	0.0965	BTU.ft/h.ft^2.F
Specific heat capacity	0.447	-	0.467	BTU/lb.°F
Thermal expansion coefficient	68	-	100	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	3.3e22	-	3e23	µohm.cm
Dielectric constant (relative permittivity)	2.1	-	2.3	
Dissipation factor (dielectric loss tangent)	3e-4	-	7e-4	
Dielectric strength (dielectric breakdown)	577	-	625	V/mil

Optical properties

Transparency	Translucent		
Refractive index	1.48	-	1.5

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%)	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	Limited use
Carbon tetrachloride	Limited use
Chloroform	Limited use
Crude oil	Acceptable
Diesel oil	Excellent
Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
Silicone fluids	Excellent
Toluene	Excellent
Turpentine	Unacceptable
Vegetable oils (general)	Acceptable
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)	Unacceptable
Fluorine (gas)	Unacceptable
O2 (oxygen gas)	Unacceptable
Sulfur dioxide (gas)	Excellent

Durability: built environments

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

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		4.23e7	-	4.33e7	ton/yr
Reserves, principal component	*	1.18e9	-	1.2e9	I. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	*	8.2e3	-	9.07e3	kcal/lb
CO2 footprint, primary production	*	2.96	-	3.27	lb/lb
Water usage	*	4.46	-	4.94	gal(US)/lb
Eco-indicator 95		331			millipoints/kg
Eco-indicator 99		254			millipoints/kg

Material processing: energy

Polymer extrusion energy	*	637	-	704	kcal/lb
Polymer molding energy	*	2.21e3	-	2.44e3	kcal/lb
Coarse machining energy (per unit wt removed)	*	87.8	-	97	kcal/lb
Fine machining energy (per unit wt removed)	*	415	-	458	kcal/lb

Grinding energy (per unit wt removed)	* 778	-	859	kcal/lb

Material processing: CO2 footprint

Polymer extrusion CO2	* 0.441	-	0.488	lb/lb
Polymer molding CO2	* 1.53	-	1.69	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.0608	-	0.0671	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.287	-	0.317	lb/lb
Grinding CO2 (per unit wt removed)	* 0.538	-	0.595	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 5.1e3	-	5.63e3	kcal/lb
CO2 footprint, recycling	* 3.7	-	4.09	lb/lb
Recycle fraction in current supply	5.1	-	6	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 4.76e3	-	5.01e3	kcal/lb
Combustion CO2	* 3.06	-	3.22	lb/lb
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

PP is exceptionally inert and easy to recycle, and can be incinerated to recover the energy it contains. PP, like PE and PVC, is made by processes that are relatively energy-efficient, making them the least energy-intensive of commodity polymers. 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

Recycle mark

Supporting information

Design guidelines

Standard grade PP is inexpensive, light and ductile but it has low strength. It is more rigid than PE and can be used at higher temperatures. The properties of PP are similar to those of HDPE but it is stiffer and melts at a higher temperature (165 - 170 C). Stiffness and strength can be improved further by reinforcing with glass, chalk or talc. When drawn to fiber PP has exceptional strength and resilience; this, together with its resistance to water, makes it attractive for ropes and fabric. It is more easily molded than PE, has good transparency and can accept a wider, more vivid range of colors. PP is commonly produced as sheet, moldings fibers or it can be foamed. Advances in catalysis promise new co-polymers of PP with more attractive combinations of toughness, stability and ease of processing. Mono-filaments fibers have high abrasion resistance and are almost twice as strong as PE fibers. Multi-filament yarn or rope does not absorb water, will float on water and dyes easily.

Technical notes

The many different grades of polypropylene fall into three basic groups: homopolymers (polypropylene, with a range of molecular weights and thus properties), co-polymers (made by co-Polymerization of propylene with other olefines such as ethylene, butylene or styrene) and composites (polypropylene reinforced with mica, talc, glass powder or fibers) that are stiffer and better able to resist heat than simple polypropylenes.

Typical uses

Ropes, automobile air ducting, parcel shelving and air-cleaners, garden furniture, washing machine tank, wet-cell battery cases, pipes and pipe fittings, beer bottle crates, chair shells, capacitor dielectrics, cable insulation, kitchen kettles, car bumpers, shatter proof glasses, crates, suitcases, artificial turf, thermal underwear.

Tradenames

Adpro, Amoco, Appryl, Aqualoy, Astryn, Cefor, Comalloy, Comshield, Dypro, EA36NA, Eltex P, Empee, Escorene, Ferrex, Ferrolene, Fortilene, Fotilene, Hifax, Hostalen PP, Latene, Marlex, Moplen, Multi-Flam, Multi-Pro, Nortuff, Novalen, Novolen, Nyloy, Petrothene, Polyfort, Polypro, Precolor, Pro Fax, Propak, Rexflex, Stamylyn, Starlylen, Statoil, Technoprene, Thermocomp, Vestolen, WPP, Washpen

Links

Reference

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Producers