

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)

$(CH_2-CH(CH_3))_n$

General properties

| | | | | |
|-----------------|---------|---|------|--------------------|
| Density | 55.6 | - | 56.8 | lb/ft ³ |
| Price | * 0.957 | - | 1.09 | 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 | |

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 | 4.23e7 | - | 4.33e7 | ton/yr |
| Reserves | * 1.18e9 | - | 1.2e9 | l. 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, general polymer engineering, 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, Astryl, 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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