Description

Image

Caption

1. Golf ball casings are made of ionomer. © Emi Yañez at Flickr - (CC BY 2.0) 2. Golf ball at a golf course © Felix7634 at en.wikipedia - (CC BY-SA 3.0)

The material

Ionomers, introduced by DuPont in 1964, are flexible thermoplastics but they have ionic cross-links, from which they derive their name. Their thermoplastic character allows them to be processed by blow molding, injection molding and thermoforming, and to be applied as coatings. But cooled below 40C they acquire the characteristic of thermosets: high strength, good adhesion and chemical stability.

Compositional summary

Ethylene copolymer containing carboxylic acid groups

General properties

Density		930	-	960	kg/m^3
Price	*	3.22	-	4.21	USD/kg
Date first used		1965			

Mechanical properties

Young's modulus		0.2	-	0.424	GPa
Shear modulus	*	0.0485	-	0.147	GPa
Bulk modulus		1	-	1.3	GPa
Poisson's ratio	*	0.436	-	0.453	
Yield strength (elastic limit)		8.27	-	15.9	MPa
Tensile strength		17.2	-	37.2	MPa
Compressive strength		9.1	-	17.5	MPa
Elongation		300	-	700	% strain
Hardness - Vickers		2.5	-	4.8	HV
Fatigue strength at 10^7 cycles	*	6.88	-	14.9	MPa
Fracture toughness	*	1.14	-	3.43	MPa.m^0.5

Mechanical loss coefficient (tan delta)	* 0.0943	-	0.286	

Thermal properties

Melting point	80.9	-	95.9	°C
Glass temperature	* 30	-	64	°C
Maximum service temperature	48.9	-	61.9	°C
Minimum service temperature	* -123	-	-73.2	°C
Thermal conductor or insulator?	Good insulator			
Thermal conductivity	0.239	-	0.276	W/m.°C
Specific heat capacity	* 1.81e3	-	1.89e3	J/kg.°C
Thermal expansion coefficient	180	-	306	µstrain/°C

Electrical properties

Electrical conductor or insulator?	Good insulator			
Electrical resistivity	3.3e21	-	3e22	µohm.cm
Dielectric constant (relative permittivity)	2.2	-	2.4	
Dissipation factor (dielectric loss tangent)	* 0.00295	-	0.00305	
Dielectric strength (dielectric breakdown)	15.7	-	17.7	1000000 V/m

Optical properties

Transparency	Transparent		
Refractive index	1.5	-	1.52

Processability

Castability	4	-	5
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	Limited use

Durability: acids

Acetic acid (10%)	Excellent
Acetic acid (glacial)	Unacceptable
Citric acid (10%)	Excellent
Hydrochloric acid (10%)	Excellent

Hydrochloric acid (36%)	Excellent
Hydrofluoric acid (40%)	Excellent
Nitric acid (10%)	Excellent
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Excellent
Phosphoric acid (85%)	Excellent
Sulfuric acid (10%)	Excellent
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

Sodium hydroxide (10%)	Excellent
Sodium hydroxide (60%)	Excellent

Durability: fuels, oils and solvents

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

Durability: alcohols, aldehydes, ketones

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

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)	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		102	-	112	MJ/kg
CO2 footprint, primary production		3.96	-	4.37	kg/kg
Water usage	*	267	-	295	l/kg

Material processing: energy

Polymer extrusion energy	*	5.94	-	6.56	MJ/kg
Polymer molding energy	*	22	-	24.3	MJ/kg
Coarse machining energy (per unit wt removed)	*	0.63	-	0.697	MJ/kg
Fine machining energy (per unit wt removed)	*	2.03	-	2.24	MJ/kg
Grinding energy (per unit wt removed)	*	3.58	-	3.96	MJ/kg

Material processing: CO2 footprint

Polymer extrusion CO2	*	0.445	-	0.492	kg/kg
Polymer molding CO2	*	1.65	-	1.82	kg/kg
Coarse machining CO2 (per unit wt removed)	*	0.0473	-	0.0523	kg/kg
Fine machining CO2 (per unit wt removed)	*	0.152	-	0.168	kg/kg
Grinding CO2 (per unit wt removed)	*	0.269	-	0.297	kg/kg

Material recycling: energy, CO2 and recycle fraction

Recycle		✓			
Embodied energy, recycling	*	41	-	50	MJ/kg

CO_2 footprint, recycling	* 2.5	-	3	kg/kg
Recycle fraction in current supply	0.5	-	1	%
Downcycle	✓			
Combust for energy recovery	✓			
Heat of combustion (net)	* 36.4	-	38.3	MJ/kg
Combustion CO_2	* 2.68	-	2.82	kg/kg
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			
A renewable resource?	✗			

Environmental notes

Ionomers have properties that resemble thermosets, yet they can be recycled like thermoplastics -- an attractive combination.

Recycle mark

Supporting information

Design guidelines

Ionomers are very tough, they have high tensile strength and excellent impact, tear, grease and abrasion resistance. Optical clarity is also quite high. They are most often produced as film. Ionomers have outstanding hot tack (10 times that of LDPE). Their resistance to weather is similar to that of PE, and like PE, they can be stabilized with the addition of carbon black. Permeability is also similar to that of PE, except for carbon dioxide where the permeability is lower. Low temperature flexibility is excellent but they should not be used at temperatures above 71 C. Because of the ionic nature of the molecules, ionomers have good adhesion to metal foil, nylon and other packaging films. Foil and extrusion coating are common. Ionomers have higher moisture vapor permeability (due to the low crystallinity) than polyethylene, are easily sealed by heat and retain their resilience over a wide temperature range.

Technical notes

Ionomers are co-polymers of ethylene and methacrylic acid. Some grades contain sodium and those have better optical properties and grease resistance; some contain zinc and have better adhesion. The ionic crosslinks are stable at room temperature, but break down upon heating above about 40 C. The advantages of crosslinking are seen in the room temperature toughness and stiffness. At high temperatures the advantages of linear thermoplastics appear - ease of processing and recyclability.

Typical uses

Food packaging, athletic soles with metal inserts, ski boots, ice skate shells, wrestling mats, thermal pipe insulation, license plate holders, golf ball covers, automotive bumpers, snack food packaging, blister packs,

Tradenames

Bexloy, Formion, Iotek, Lucalen, Surlyn

Links

Reference	
ProcessUniverse	
Producers	