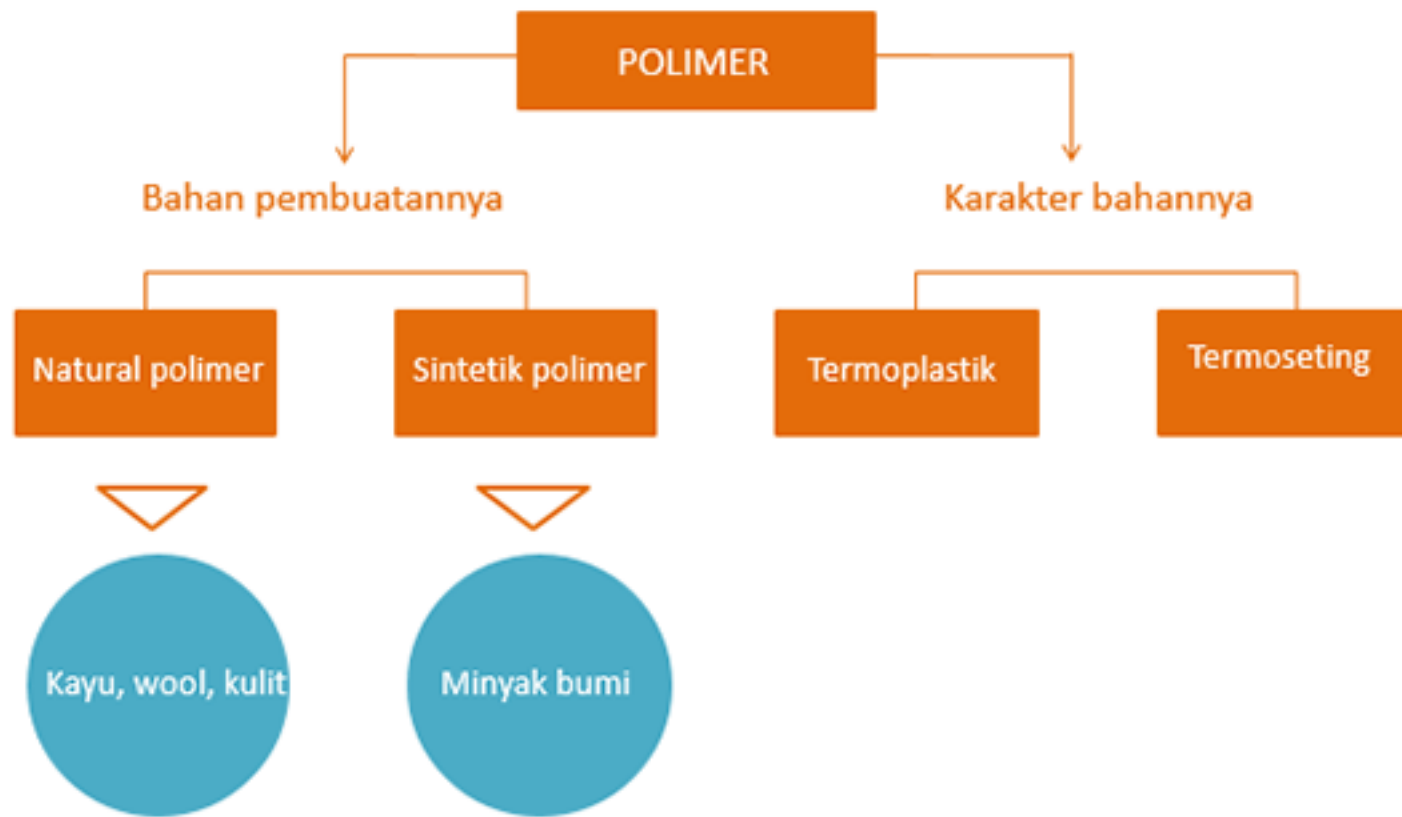


PRD 508 – Pengetahuan Material
CMF– Colour Material Finish

Polimer

Polimer didefinisikan sebagai substansi yang terdiri dari molekul-molekul yang menyertakan rangkaian satu atau lebih dari satu unit monomer. Manusia sudah berabad-abad menggunakan polimer dalam bentuk minyak, aspal, dan permen karet.



Termoplastik polimer

Acrylonitrile-butadiene-styrene (abs)

Cellulose

Ionomers

Polyamide (Nylon, pa)

Polycarbonate (pc)

Polvetheretherkeytone (peek)

Polyethylene (pe)

Polymethylmethacrylate (pmma)

Polvoxymethylene (pom)

Polypropylene (pp)

Polystyrene (ps)

Polytetrafluoroethylene (ptfe)

Polyvinylchloride (tppvc)

Polyurethanes (tppu)

Polyesters (pet, pete, pbt)

Termoseting polimer

Epoxy

Phenolic

Polyester

Polyurethane (tspu)

Polyvinylchloride (tspvc)

Elastomer (polimer kenyal)

Acrylic elastomers
Butyl rubbers (nr)
Chlorinated elastomers (Neoprene)
Ethylene-propylene (epdm)
Ethylene-vinyl-acetate (eva)
Fluorocarbon elastomers (Viton)
Isoprene
Natural rubber
Nitrile (nbr, buna-n)
Polybutadiene elastomers
Polysulphide elastomers
Silicone
Styrene-butadiene (sbs)
Thermoplastic elastomers (tpe, tpo)

Polimer that are foamed

Phenolic
Polyethylene
Polypropylene
Polystyrene
Polyurethane

Attributes of Polyethylene

Price, \$/kg	1.10-4.00
Density, Mg/m ³	0.92-1.4

Technical Attributes

El. modulus, GPa	0.03-1.4
Elongation, %	10-1400
Fr. toughness, MPa·m ^{1/2}	0.40-5.16
Vickers hardness, H _v	5-8
Yld. strength, MPa	8-31
Service temp., °C	-40-100
Specific heat, J/kg·K	1559-1916
Th. conduct., W/m·K	0.12-0.50
Th. expansion, 10 ⁻⁴ /K	106-450

Eco-Attributes

Energy content, MJ/kg	104-114
Recycle potential	High

Aesthetic Attributes

Low (o), High Pitch (10)	3-7
Muffled (o), Ringing (10)	1-3
Soft (o), Hard (10)	5-7
Warm (o), Cool (10)	4-5
Gloss, %	5-136

Features (Relative to Other Polymers)

Easily molded
Durable
Low cost

Polyethylene (PE)

Termoplastik

Function : Oil containers, street bollards, milk bottles, toys, beer crates, food packaging, shrink wrap, squeeze tubes, disposable clothing, plastic bags, Tupperware, chopping boards, paper coatings, cable insulation, artificial joints, and as fibers low cost ropes and packing tape reinforcement.

Environmental aspect : 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.



Attributes of Polypropylene

Price, \$/kg	0.90-1.00
Density, Mg/m ³	0.89-0.92

Technical Attributes

El. modulus, GPa	0.90-1.55
Elongation, %	100-600
Fr. toughness, MPa·m ^{1/2}	3-4-5
Vickers hardness, H _v	6-11
Yld. strength, MPa	20.7-37.2
Service temp., °C	-40-120
Specific heat, J/kg·K	1870-1956
Th. conduct., W/m·K	0.11-0.17
Th. expansion, 10 ⁻⁶ /K	122-180

Eco-Attributes

Energy content, MJ/kg	76-84
Recycle potential	Medium

Aesthetic Attributes

Low (o), High pitch (10)	6-7
Muffled (o), Ringing (10)	3-4
Soft (o), Hard (10)	6-7
Warm (o), Cool (10)	4
Gloss, %	20-94

Features (Relative to Other Polymers)

Easily molded
Durable and tough
Low cost

Polypropylene (PP)

Termoplastik

Application : Uses Ropes, general polymer engineering, automobile air ducting, parcel shelving and air-cleaners, garden furniture, washing machine tanks, 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.

Environment : 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.



Polystyrene (PS)

Termoplastik

Application : Disposable cups; light fittings; toys; pens; models; in expanded form packaging, thermal insulation and ceiling tiles; tv cabinets; wall tiles; disposable dishes; furniture; molded parts and containers; cd covers, disposable glass, razors, hot drink cups.

Environment : ps can be recycled. The monomer, styrene, is irritating to the eyes and throat, but none survives in the polymer. flammability of ps foam, and the use of cfc as blowing agents in the foaming process was, at one time, a cause for concern. New flame retardants allow ps foams to meet current fire safety standards, and cfc blowing agents have been replaced by pentane, CO2 or hfc's which do not have a damaging effect on the ozone layer



Attributes of Polystyrene

Price, \$/kg	1.30-1.60
Density, Mg/m ³	1.04-1.05

Technical Attributes

El. modulus, GPa	2.28-3.34
Elongation, %	1.2-3.6
Fr. toughness, MPa·m ^{1/2}	0.7-1.1
Vickers hardness, Hv	9-16
Yld. strength, MPa	28.72-56.2
Service temp., C	-18-100
Specific heat, J/kg·K	1691-1758
Th. conduct., W/m·K	0.12-0.13
Th. expansion, 10 ⁻⁶ /K	90-153

Eco-Attributes

Energy content, MJ/kg	101-110
Recycle potential	Low

Aesthetic Attributes

Low (o), High Pitch (10)	7
Muffled (o), Ringing (10)	4
Soft (o), Hard (10)	7
Warm (o), Cool (10)	4
Gloss, %	9-96

Features (Relative to Other Polymers)

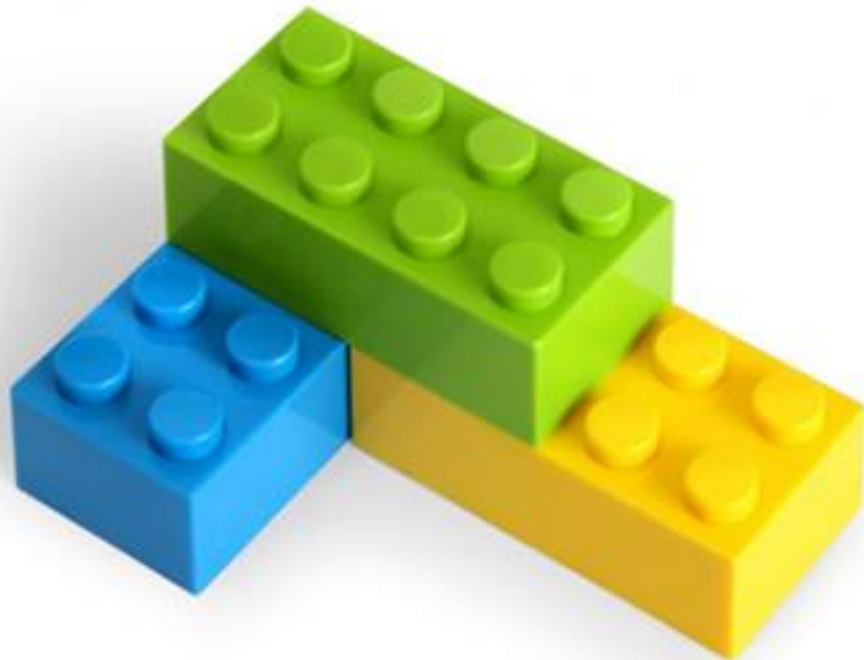
Optically clear
Easily foamed
Low cost

Acrylonitrile-butadiene-styrene (ABS)

Termoplastik

Application : cases for computers and TVs, telephones, food mixers, vacuum cleaners, baths, shower trays, pipes, luggage shells, RV parts, shower stalls, cassette holders, automotive parts, safety hard hats, Legos, computer mice, razors, handles, shavers, chairs. **san:** telephone cases, food processing bowls, medical syringes, mixing bowls, beakers, coffee filters, cassettes, industrial battery cases, toothbrushes, cosmetic packs, dinnerware, food containers. **asa:** appliance panels and knobs, toys, medical instruments, rear view mirrors, garden tables and chairs, hose fittings, garden tools, letter boxes, boat shells, windsurfing boards.

Environment : The acrylonitrile monomer is nasty stuff, almost as poisonous as cyanide. Once polymerized with styrene it becomes harmless. Some grades of abs are FDA compliant and can be recycled.



Attributes of ABS

Price, \$/kg	1.50-2.80
Density, mg/m ³	1.01-1.21

Technical Attributes

El. modulus, GPa	1.1-2.9
Elongation, %	1.5-100
Fr. toughness, MPa·m ^{1/2}	1.2-4.2
Vickers hardness, H _v	6-15
Yld. strength, MPa	18.5-51
Service temp., °C	-18-90
Specific heat, J/kg·K	1386-1919
Th. conduct., W/m·K	0.18-0.33
Th. expansion, 10 ⁻⁶ /K	84.6-234

Eco-Attributes

Energy content, MJ/kg	95-104
Recycle potential	Medium

Aesthetic Attributes

Low (o), High Pitch (10)	6-7
Muffled (o), Ringing (10)	3-4
Soft (o), Hard (10)	6-7
Warm (o), Cool (10)	4-5
Gloss, %	10-96

Features (Relative to Other Polymers)

Durable and tough
Readily colored
Easily molded

Attributes of Nylon

Price, \$/kg	2.90-11.50
Density, mg/m ³	1-1.42

Technical Attributes

El. modulus, GPa	0.67-4.51
Elongation, %	4-1210
Fr. toughness, mPa·m ^{1/2}	0.58-8.03
Vickers hardness, Hv	6-28
Yld. strength, mPa	20.7-101.6
Service temp., °C	-80-120
Specific heat, J/kg·K	1421-2323
Th. conduct., W/m·K	0.18-0.35
Th. expansion, 10 ⁻⁶ /K	50.4-216

Eco-Attributes

Energy content, MJ/kg	110-120
Recycle potential	Medium

Aesthetic Attributes

Low (o), High Pitch (10)	6-7
Muffled (o), Ringing (10)	3-4
Soft (o), Hard (10)	6-7
Warm (o), Cool (10)	4-5
Gloss, %	65-150

Features (Relative to Other Polymers)

Strong
Tough
Durable

Polyamide (PA), Nylon

Termoplastik

Application : Light duty gears, bushings, sprockets and bearings; electrical equipment housings, lenses, containers, tanks, tubing, furniture casters, plumbing connections, bicycle wheel covers, ketchup bottles, chairs, toothbrush bristles, handles, bearings, food packaging. Nylons are used as hot-melt adhesives for book bindings; as fibers ropes, fishing line, carpeting, car upholstery and stockings; as aramid fibers cables, ropes, protective clothing, air filtration bags and electrical insulation.

Environment : Nylons have no known toxic effects, although they are not entirely inert biologically. Nylons are oil-derivatives, but this will not disadvantage them in the near future. With refinements in polyolefin catalysis, nylons face stiff competition from less expensive polymers.



Attributes of Acrylic

Price, \$/kg	1.70-2.40
Density, mg/m ³	1.16-1.22

Technical Attributes

El. modulus, GPa	2.24-3.8
Elongation, %	2-10
Fr. toughness, MPa·m ^{1/2}	0.7-1.6
Vickers hardness, H _v	16-21
Yld. strength, MPa	53.8-72.4
Service temp., °C	-50-100
Specific heat, J/kg·K	1485-1606
Th. conduct., W/m·K	0.08-0.25
Th. expansion, 10 ⁻⁶ /K	72-162

Eco-Attributes

Energy content, MJ/kg	97-105
Recycle potential	Low

Aesthetic Attributes

Low (o), High Pitch (10)	7
Muffled (o), Ringing (10)	4
Soft (o), Hard (10)	7
Warm (o), Cool (10)	4-5

Features (Relative to Other Polymers)

Optically clear
Easily colored
UV resistant

Polymethylmethacrylate (PMMA), Acrylic

Termoplastik

Application : Uses Lenses of all types; cockpit canopies and aircraft windows; signs; domesticbaths; packaging; containers; electrical components; drafting equipment; tool handles; safety spectacles; lighting, automotive tail lights, chairs, contact lenses, windows, advertising signs, static dissipation products; compact disks.

Environment : Acrylics are non-toxic and recyclable.

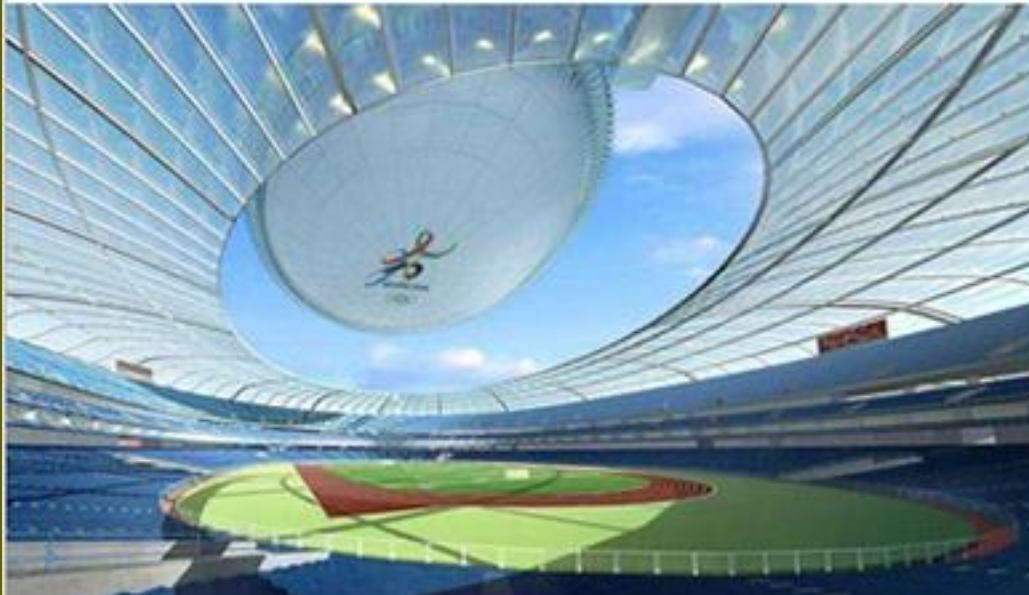


Polycarbonate (PC)

Termoplastik

Application : Compact disks, housings for hair dryers, toasters, printers and power tool housings, refrigerator linings, mechanical gears, instrument panels, motorcycle helmets, automotive bumpers and body parts, riot shields.

Environment : The processing of engineering thermoplastics requires a higher energy input than that of commodity plastics, but otherwise there are no particular environmental penalties. pc can be recycled if unreinforced.



Attributes of Polycarbonate

Price, \$/kg	3.80-4.30
Density, mg/m ³	1.14-1.21

Technical Attributes

El. modulus, GPa	2.21-2.44
Elongation, %	70-150
Fr. toughness, MPa·m ^{1/2}	2.1-4.602
Vickers hardness, H _v	17-22
Yld. strength, MPa	59.1-69
Service temp., °C	-40-120
Specific heat, J/kg·K	1535-1634
Th. conduct., W/m·K	0.19-0.22
Th. expansion, 10 ⁻⁶ /K	120.1-136.8

Eco-Attributes

Energy content, MJ/kg	120-130
Recycle potential	High

Aesthetic Attributes

Low (o), High Pitch (10)	7
Muffled (o), Ringing (10)	4
Soft (o), Hard (10)	7
Warm (o), Cool (10)	4-5

Features (Relative to Other Polymers)

Optically clear
Strong
Tough

Polyoxymethylene (POM), Acetal

Termoplastik

Application : Automobile carburetors and door handles, videocassette parts, gears and bearings, tool handles, plumbing parts, clothing zips.

Environment : Acetal, like most thermoplastics, is an oil derivative, but this poses no immediate threat to its use.



Attributes of Acotal

Price, \$/kg	2.70-4.00
Density, mg/m ³	1.39-1.43

Technical Attributes

El. modulus, GPa	2.35-6.27
Elongation, %	10-75
Fr. toughness, MPa·m ^{1/2}	1.71-4.2
Vickers hardness, H _v	14-24
Yld. strength, MPa	48.6-72.4
Service temp., °C	-30-110
Specific heat, J/kg·K	1364-1433
Th. conduct., W/m·K	0.22-0.35
Th. expansion, 10 ⁻⁶ /K	75-200

Eco-Attributes

Energy content, MJ/kg	115-121
Recycle potential	High

Aesthetic Attributes

Low (o), High Pitch (10)	7
Muffled (o), Ringing (10)	4-5
Soft (o), Hard (10)	7
Warm (o), Cool (10)	4-5

Features (Relative to Other Polymers)

Low friction
Wear resistant
Water resistant

Polytetrafluoroethylene (PTFE)

Termoplastik

Attributes of PTFE

Price, \$/kg

13.90-15.90

Density, mg/m³

2.14-2.2

Technical Attributes

El. modulus, GPa

0.4-0.55

Elongation, %

200-400

Fr. toughness, MPa·m^{1/2}

5-7

Vickers hardness, H_v

59-65

Yld. strength, MPa

19.7-21.7

Service temp., °C

-270-250

Specific heat, J/kg·K

1014-1054

Th. conduct., W/m·K

0.24-0.26

Th. expansion, 10⁻⁶/K

126-216

Eco-Attributes

Energy content, MJ/kg

180-195

Recycle potential

High

Aesthetic Attributes

Low (0), High Pitch (10)

5

Muffled (0), Ringing (10)

2-3

Soft (0), Hard (10)

6

Warm (0), Cool (10)

5

Gloss, %

85-95

Features (Relative to Other Polymers)

Extremely durable

High temperatures

Low friction

Application : 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; translucent roofing and weather protection for other polymers (e.g. abs); non-stick cooking products; water repellent fabrics.

Environment : 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 GoreTex, additives are made which prevent further recycling.



Attributes of Ionomers

Price, \$/kg	1.40-1.60
Density, mg/m ³	0.93-0.96

Technical Attributes

El. modulus, GPa	0.2-0.42
Elongation, %	300-700
Fr. toughness, MPa·m ^{1/2}	1.14-3.43
Vickers hardness, H _v	2-5
Yld. strength, MPa	8.27-15.9
Service temp., °C	-30-70
Specific heat, J/kg·K	1814-1887
Th. conduct., W/m·K	0.24-0.28
Th. expansion, 10 ⁻⁴ /K	180-306

Eco-Attributes

Energy content, MJ/kg	115-120
Recycle potential	High

Aesthetic Attributes

Low (o), High Pitch (10)	5-6
Muffled (o), Ringing (10)	2-3
Soft (o), Hard (10)	6
Warm (o), Cool (10)	4-5
Gloss, %	20-143

Features (Relative to Other Polymers)

Strong
Tough
Low permeability

Ionomers

Termoplastik

Application : 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, bottles.

Environment : Ionomers have properties that resemble thermosets yet they can be recycled – an attractive combination.



Celluloses (CA)

Termoplastik

Application : Film packaging, sunglasses, safety glasses, eye glass frames, laminated brochures, tool handles, hammer heads, electric screwdrivers, photographic film, typewriter keys, blister packaging, combs, hair decoration.

Environment : renewable material – forms one ingredient in cellulose-based polymers. The processing, however, involves chemicals that create a problem of disposal. Most cellulose-based polymers burn easily, requiring protection from naked flame. Some are bio-degradable.



Attributes of Celluloses

Price, \$/kg	3.40-3.90
Density, mg/m ³	0.98-1.4

Technical Attributes

El. modulus, GPa	0.75-4.1
Elongation, %	5-100
Fr. toughness, MPa·m ^{1/2}	0.85-3.20
Vickers hardness, H _v	18-15
Yld. strength, MPa	24.8-52.4
Service temp., °C	-10-60
Specific heat, J/kg·K	1386-1665
Th. conduct., W/m·K	0.13-0.34
Th. expansion, 10 ⁻⁶ /K	118.8-360

Eco-Attributes

Energy content, MJ/kg	120-126
Recycle potential	High

Aesthetic Attributes

Low (o), High Pitch (10)	6-7
Muffled (o), Ringing (10)	3-4
Soft (o), Hard (10)	6-7
Warm (o), Cool (10)	4-5

Features (Relative to Other Polymers)

A bio-polymer
Transparent
Tough

Polyvinylchloride (PVC)

thermoplastic, elastomeric and thermosetting

Application : pipes, fittings, profiles, road signs, cosmetic packaging, canoes, garden hoses, vinyl flooring, windows and cladding, vinyl records, dolls, medical tubes. elovc:artificial leather, wire insulation, film, sheet, fabric, car upholstery.

Environment : The polymer pvc has no known harmful effects. Disposal, however, can be a problem: thermal degradation releases chlorine, HCl and other toxic compounds, requiring special high temperature incineration for safety.



Attributes of PVC

Price, \$/kg	1.00-1.20
Density, mg/m ³	1.3-1.58

Technical Attributes

El. modulus, GPa	2.14-4.14
Elongation, %	11.93-80
Fr. toughness, MPam ^{1/2}	1.46-5.12
Vickers hardness, H _v	10-15
Yld. strength, MPa	35.4-52.1
Service temp., °C	-20-70
Specific heat, J/kg·K	1355-1445
Th. conduct., W/m·K	0.15-0.29
Th. expansion, 10 ⁻⁶ /K	1.8-180

Eco-Attributes

Energy content, MJ/kg	77-83
Recycle potential	High

Aesthetic Attributes

Low (o), High Pitch (10)	6-7
Muffled (o), Ringing (10)	4
Soft (o), Hard (10)	7
Warm (o), Cool (10)	4-5

Features (Relative to Other Polymers)

Corrosion resistant
Low cost
Resilient

Polyurethane (PU)

Polimer that are foamed

Attributes of tpPU

Price, \$/kg	5.44-6.01
Density, mg/m ³	1.12-1.24

Technical Attributes

El. modulus, GPa	1.31-2.07
Elongation, %	60-550
Fr. toughness, MPa ^m ^{1/2}	1.84-4.97
Vickers hardness, H _v	16-22
Yld. strength, MPa	40-53.8
Service temp., °C	-30-80
Specific heat, J/kg·K	1554-1616
Th. conduct., W/m·K	0.24-0.24
Th. expansion, 10 ⁻⁶ /K	90-144

Eco-Attributes

Energy content, MJ/kg	110-118
Recycle potential	High

Aesthetic Attributes

Low (o), High Pitch (10)	6-7
Muffled (o), Ringing (10)	3-4
Soft (o), Hard (10)	7
Warm (o), Cool (10)	4-5
Gloss, %	100

Features (Relative to Other Polymers)

Flexible
Tough
Durable

Application : Cushioning and seating, packaging, running shoe soles, tires, wheels, fuel hoses, gears, bearings, wheels, car bumpers, adhesives, fabric-coatings for inflatables, transmission belts, diaphragms, coatings that are resistant to dry-cleaning, furniture, thermal insulation in refrigerators and freezers; as elastomers: truck wheels, shoe heels, bumpers, conveyor belts and metal forming dies.

Environment : synthesized from diisocyanate and a polyester or polyether. The

diisocyanate is toxic, requiring precautions during production, pu itself is inert and nontoxic. The flammability of pu foam, and the use of cfcs as blowing agents in the foaming process were, at one time, a cause for concern. Thermoplastic pus can be recycled (thermosetting pus cannot), and when all useful life is over, incinerated to recover heat. Legislation for return of packaging and disposal problems may disadvantage pu.



Polyesters (PET, PBT, PETg)

thermoplastic

Application : Decorative film, metallized balloons, photography tape, videotape, carbonated drink containers, oven-proof cookware, windsurfing sails, credit cards, carpets, clothing brushes, boats, fishing rods, automobile body panels.

Environment : bottles take less energy to make than glass bottles of the same volume, and they are much lighter – saving fuel in delivery. Thick-walled bottles can be reused; thin-walled bottles can be recycled – and are, particularly in the us.



Attributes of tpPolyester

Price, \$/kg	1.25-2.5
Density, Mg/m ³	1.19-1.81

Technical Attributes

El. modulus, GPa	1.6-4.4
Elongation, %	1.3-5
Fr. toughness, MPam ^{1/2}	1.05-9.16
Vickers hardness, H _v	11-40
Yld. strength, MPa	30-40
Service temp., C	-20-160
Specific heat, J/kg·K	1160-1587
Th. conduct., W/m·K	0.28-0.58
Th. expansion, 10 ⁻⁴ /K	115-170

Eco-Attributes

Energy content, MJ/kg	89-95
Recycle potential	High

Aesthetic Attributes

Low (o), High Pitch (10)	6-8
Muffled (o), Ringing (10)	4-6
Soft (o), Hard (10)	7-8
Warm (o), Cool (10)	4-5

Features (Relative to Other Polymers)

Versatility
Cheap
Strong and tough

Phenolic

Polimer that are foamed (thermosetting)

Application : Switchboards, insulating washers, intricate punched parts (phenolic with paper laminate), gears, pinions, bearings, bushings (phenolic with cotton laminate), gaskets and seals (phenolic with glass), used to bond friction materials for automotive brake linings, beads, knife handles, paperweights, billiard balls, domestic plugs and switches, telephones, fuse box covers, distributor heads, saucepan handles and knobs, golf ball heads for typewriters, toilet seats. As a foam, phenolic resin is used in paneling for building work; its fine resistance is a particular attraction.

Environment : Phenolics, like all thermosets, cannot be recycled.



Attributes of Phenolic

Price, \$/kg	0.90-1.20
Density, Mg/m ³	1.24-1.32

Technical Attributes

El. modulus, GPa	2.76-4.83
Elongation, %	1.5-2
Fr. toughness, MPa·m ^{1/2}	0.79-1.21
Vickers hardness, H _v	8-15
Yld. strength, MPa	27.6-49.68
Service temp., °C	-20-160
Specific heat, J/kg·K	1467-1526
Th. conduct., W/m·K	0.141-0.152
Th. expansion, 10 ⁻⁶ /K	120.1-124.9

Eco-Attributes

Energy content, MJ/kg	94-100
Recycle potential	Low

Aesthetic Attributes

Low (o), High Pitch (10)	7
Muffled (o), Ringing (10)	4
Soft (o), Hard (10)	7
Warm (o), Cool (10)	4

Features (Relative to Other Polymers)

Flame retardant
Durable
Strong and tough

Urea-formaldehyde

Thermosetting

Application : decorative laminates, textiles, paper, foundry sand molds, wrinkle resistant fabrics, cotton blends, etc. It is also used to glue wood together. Urea formaldehyde was commonly used when producing electrical appliances casing (e.g. desk lamps)

Environment : Generally there are no observable health effects from formaldehyde when air concentrations are below 1.0 ppm. The onset of respiratory irritation and other health effects, and even increased cancer risk begins when air concentrations exceed 3.0-5.0 ppm. This triggers watery eyes, nose irritations, wheezing and coughing, fatigue, skin rash, severe allergic reactions, burning sensations in the eyes and throat, nausea, and difficulty in breathing in some humans (usually > 1.0 ppm).



They (thermoplastic) are
all recycable



Sekian
td 01-2021