Catalog

UNIT - IV

NON-METALLIC MATERIALS

4.1 POLYMERS :

Polymers are large, high – molecular – weight molecules produced by joining smaller molecules called monomers.

E.g. Wood, Nylon, Resin.

Characteristics of Polymers :

Light weight
High corrosion resistance
Low density
Low thermal properties
Low electrical properties
Low mechanical properties
Low coefficient of friction
Good surface finish
Noise reduction
It can be produced in various colours
Easy to fabricate
Low cast

4.2 POLYMERIZATION :

It is the process of forming a polymer by linking together of monomers.

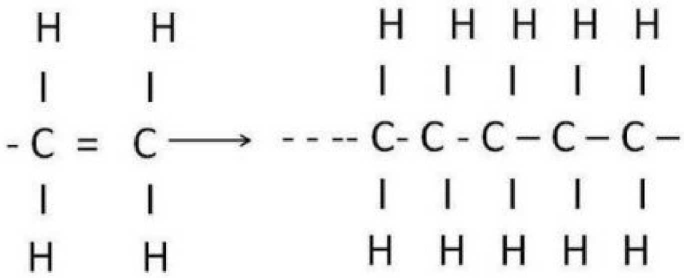
Two polymerization mechanisms used are :-

Addition Polymerisation

Condensation Polymerisation

1. Addititon Polymerisation :

It also known as chain reaction polymerization, is a process by which two or more chemically similar monomers are polymerised to form long chain molecules.



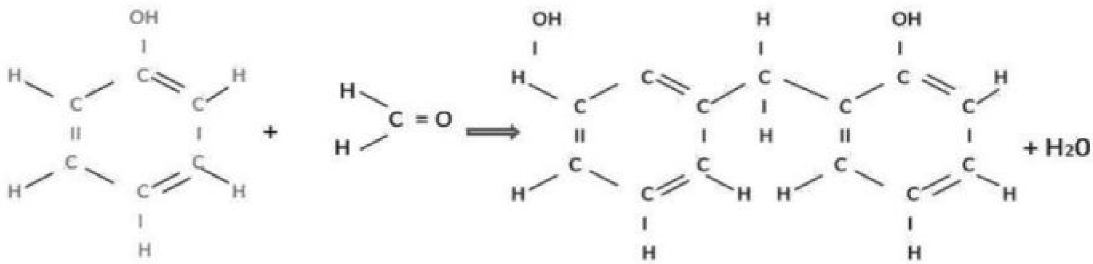
Ethylene Polyethyene

2. Condensation Polymerisation :

It is also known as steep-growth polymerisation, is the formation of polymers by steep wise inter molecular chemical reactions that normally involve at least two different monomers.

Phenol + Formal dehyde → Water + Phenol – Formal dehyde (Bakelite)

$C_6H_5OH + CH_2O \rightarrow H_2O + (C_{13}H_{10}(OH)_2)_n$



Bakelite Phenol Formaldehyde

Factor influencing characteristics of Polymers :

Molecular weight.

Molecular shape.

3. Molecular structure of molecular chains.

4.3 TYPES OF POLYMERS :

Thermo plastic

Thermo setting plastic

Elastomers

4.3.1 THERMO PLASTIC :

Thermo plastic polymers are formed by additional polymerization. Thermo plastic polymers soften upon heating and harden when cooled. Thermo plastic polymers are long – chain straight or branched molecules and the chains are held close to each other by secondary weak forces of the type vander wall forces. Thermo plastic polymers can be remolded or reshaped. Thermoplastic polymers have low melting temperatures and are not so strong as thermosetting plastics. Dielectric strength is low. Recycling is possible. Low cast fabrication.

E.g. PVC, PE, PP, PS, PMMA, PET, PC, PA, ABS, PI, PAI, PPO, PEEK, PTFE

4.3.2 THERMO SETTING PLASTICS :

Thermo setting polymers are formed by condensation polymerization. Thermosetting polymers become permanent hard when heat is applied and do not soften upon subsequent heating. Thermosetting polymers have a similar structure as the thermo plastics before heating, but cross linking occurs during heating. This result in a three dimensional giant molecule. Thermo setting polymers cannot be remolded or reshaped. Thermo setting polymers are very harder, stronger and more brittle than thermo plastics. Dielectric strength is high. Thermo sets possess lower ductility and poor impact properties. Recycling is not possible. Fabrication is expensive.

E.g. Phenol Formal dehyde , Urea formaldehyde epoxies, Phenolics and aminos.

4.3.3. ELASTROMERS :

The terms rubber and elastomer are often used interchangeably. They have large characteristic ability to undergo large elastic deformations without rupture. They are soft, and they have a low elastic modulus.

4.4 COMMODITY POLYMERS :

They are light weight polymers with low strength and stiffness and not suitable for high temperature uses. These polymers are inexpensive and can be reading formed into a variety of shapes ranging from plastic bags to bath tubes. They are mostly widely used polymers.

4.5 ENGINEERING POLYMERS :

The polymers with are designed to give improved strength, greater environmental resistance, better performance at elevated temperature are called engineering polymers. These materials are produced relatively in small quantities and are more expensive.

Polymers materials :

Plastics

Rubbers (Elastomers)

Fibers

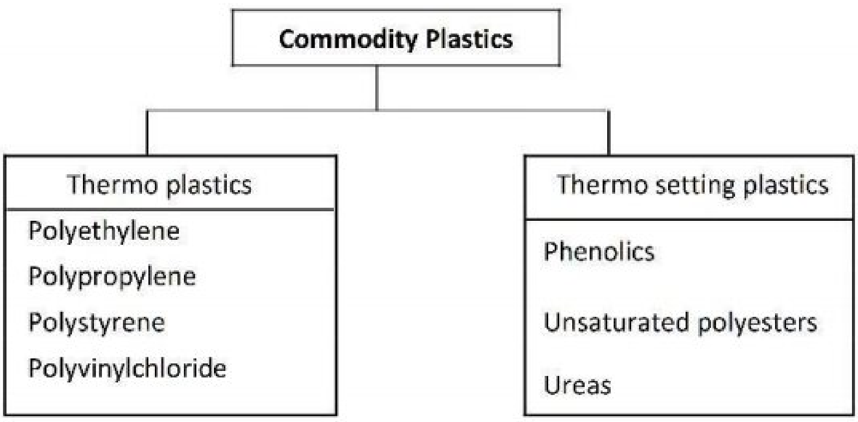
Coating

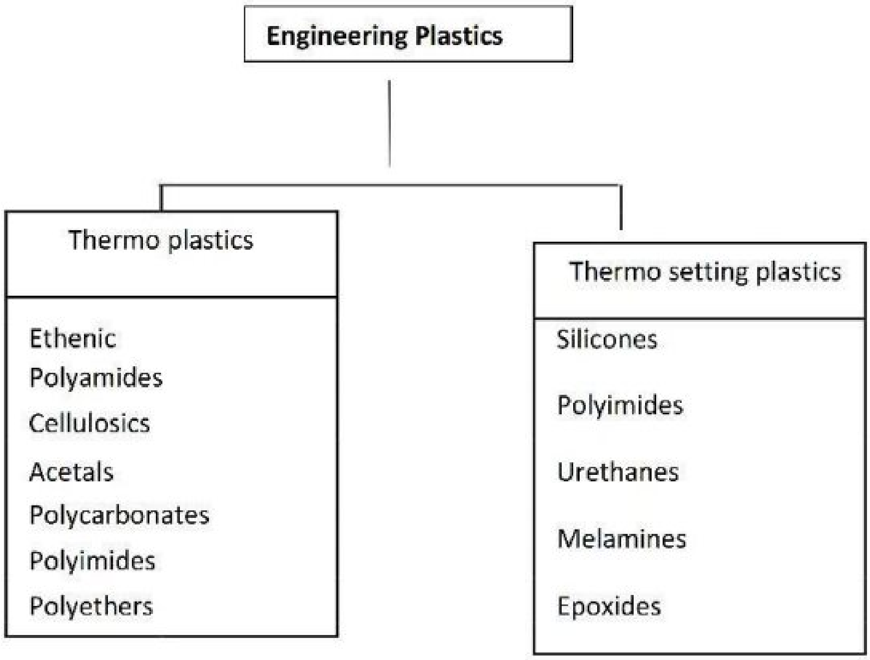
Adhesives

Foams

Films

A Plastic is defined as an organic polymer, which can be moulded into any desired shape and size with the help of heat, pressure (or) both.





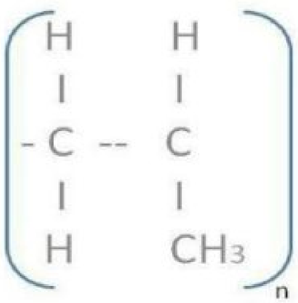
4.6 PROPERTIES AND APPLICATION OF POLYMERS :

Thermoplastics :

1. PP (Polypropylene) :

Trade names : Profax, Tenite, Moplen, Escon, Propylux.

Polypropylene (PP), also known as polypropene, is a thermoplastic polymer used in a wide variety of applications. It is produced via chain-growth polymerization from the monomer propylene.



PP Structure

Properties:

Higher strength and stiffness.

Low cost.

Excellent fatigue resistance.

Light weight.

Poor resistance to ultra violet sun lights.

Good chemical and thermal resistance.

Good surface hardness.

Brittle at low temperatures.

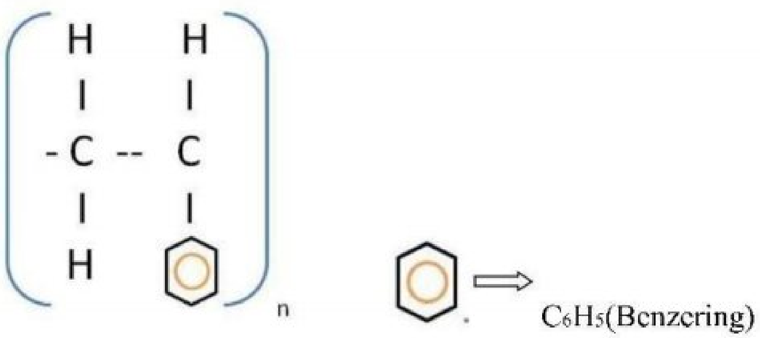
Applications :

Houses wares, car interior component, bottle caps, extruded pipes, carpet fibres, ropes, bags, battery cases, vacuum cleaner bodies etc.

2. PS (Poly styrene)

Trade name : Lustrex, Reyolite, Styron, Cerex, Loralin.

Polystyrene is a synthetic aromatic hydrocarbon polymer made from the monomer styrene. Polystyrene can be solid or foamed. General-purpose polystyrene is clear, hard, and rather brittle. It is an inexpensive resin per unit weight. It is a rather poor barrier to oxygen and water vapour and has a relatively low melting point.



Polyvinyl benzene structure

Properties :

Excellent Moldability.

Good electrical, heat and strain resistance.

Poor chemical resistance.

Poor corrosion resistance.

Good dimension stability.

Hard and brittle.

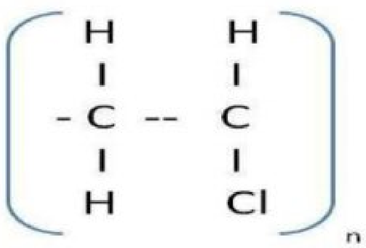
Applications:

Used for low-cost transparent mouldings such as CD cases, ball point pens, disposable food containers, lighting panels, toys, battery cases, rigid foams used for thermal insulation, automobile parts, radio/TV components.

PVC (Polyvinyl choride) :

Trade Names : Saron, Pliovic, Tygon, Vinylite, Elvanol, Resistoflex, Chemaco.

It is a tough chemically resistant synthetic resin made by polymerizing vinyl chloride and used for a wide variety of products including pipes, flooring, and sheeting.



Properties:

Strong and brittle.

Low cost.

Good flame, electrical, chemical, oil and weather resistance.

Good materials.

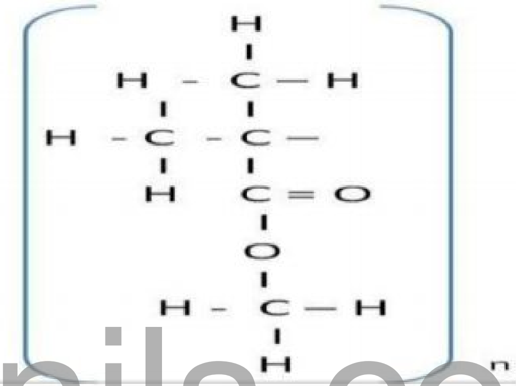
Applications:

- Pipes, valves, floor tiles, fittings, toys, wire insulations, safety glass etc.

PMMA (Polymethyl-methacrylate)

Trade Names : Perplex.

Polymethyl-methacrylate (PMMA),is a transparent thermoplastic often used in sheet form as a lightweight or shatter-resistant alternative to glass , Lucite, Flexi glass, Acrylite.



Properties :

Good strength and rigid.

High hardness.

Tend to absorb heat.

It can be readily coloured.

Used for decorative properties.

Good chemical resistance.

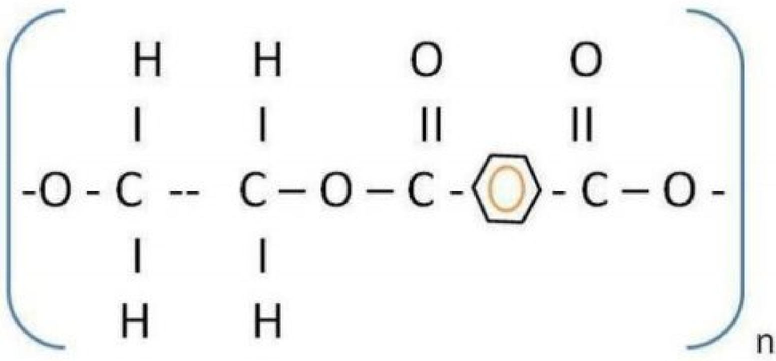
Applications:

Used as lenses in cameras, flash-lights, safe glasses, guards, pumps, pipes, covers, weather proof coatings.

PET (Polyethylene Terephthalate):

Trade name : Polyester, Mylar, Celanar Dacron.

Polyethylene terephthalate is the most common thermoplastic polymer resin of the polyester family and is used in fibres for clothing, containers for liquids and foods, thermoforming for manufacturing, and in combination with glass fibre for engineering resins.



Properties :

Good strength.

High stiffness thermoplastics.

Good fatigue strength .

Good mechanical and electrical properties.

Good resistance to humidity, acids, greases, oils and solvents.

They are produced as fibers, as transparent films and as moulding materials.

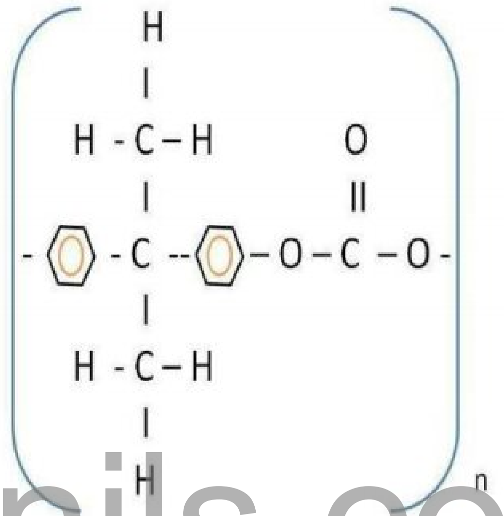
Applications:

Fibers for clothing, films for photography, recording tapes, containers, bottles,, autoparts, gears.

PC (Poly Carbonates) :

Trade names : Lexon, Merlon.

Polycarbonate is a dimensionally stable, transparent thermoplastic with a structure that allows for outstanding impact resistance. With high-performance properties, Polycarbonate is the leading plastic material for various applications that demand high functioning temperatures and safety features.



Properties:

High melting temperature.

Low flammability.

Good chemical resistance.

High tensile strength.

Good heat resistance.

Good mould ability.

High dimensional stability.

Low fatigue and wear resistance.

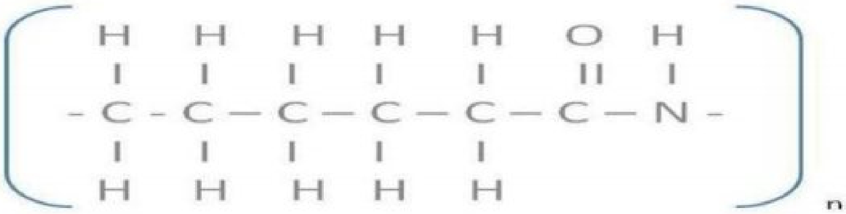
Applications:

Safety helmets, lenses, cams and gears, automotive parts like dash boards, casings, head lamp moldings, medical components and kitchen wares.

PA (Polyamides) :

Trade names : Nylon, Ultramid, Versalon, Zytel, Plaskon.

It is a synthetic polymer of a type made by the linkage of an amino group of one molecule and a carboxylic acid group of another, including many synthetic fibres such as nylon.



Properties:

Very strong and tough.

High impact strength.

Flexible.

High softening temperature.

Good mechanical properties .

Low surface friction.

Good abrasion resistance.

High lubricity.

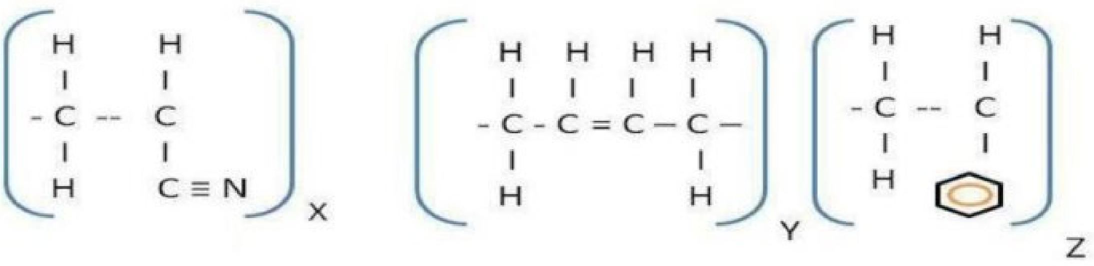
Applications:

Rope, soles for footwear, textiles for clothing and carpets, gears, cams, bearings, automobile speedometers, wiper gears, electrical applications.

ABS (Acrylonitrile butadiene styrene) :

Trade Names : Carbon cycolac, Lustron, Abson, Cadco, Seilon.

Acrylonitrile Butadiene Styrene is a terpolymer, or a polymer composed of three different monomers. This amorphous blend is made up of acrylonitrile, butadiene, and styrene in varying proportions. Each one of these monomers serve to impart an advantage to ABS: acrylonitrile provides chemical and thermal stability, butadiene increase toughness and impact strength, and styrene gives the plastic a nice and glossy finish.



Polyacrylonitrile Polybutadiene Polystyrene

Properties :

Good strength and toughness.

Good electric properties .

Heat Resistant.

Flammable and soluble in some organic solvents.

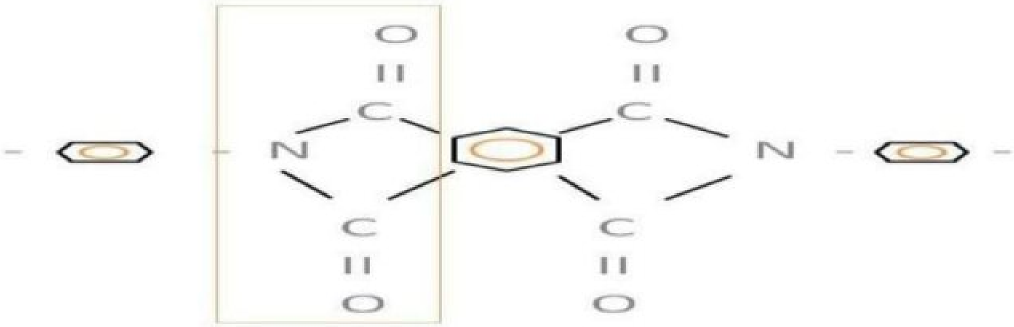
Applications :

Telephone receivers, helmets, computer housings, automobile parts, Domestic cleaners and mixers, bathroom fittings etc.

9. PI (Polyamides) :

Trade names : Vespel.

Polyamides is a synthetic polymer of a type made by the linkage of an amino group of one molecule and a carboxylic acid group of another, including many synthetic fibres such as nylon.



Properties :

Ring structure.

Reduce the process ability.

Good mechanical properties.

High resistance to organic solvents.

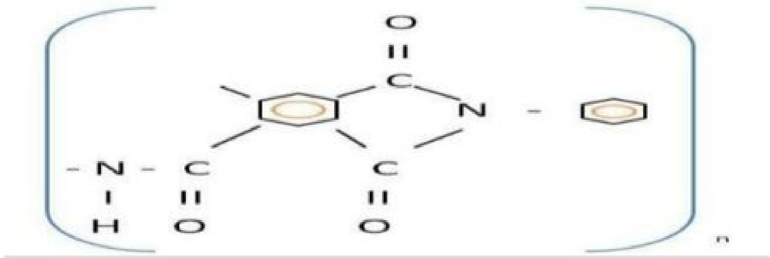
Applications :

- Circuit boards, electrical cable, space applications, composite matrix, resin form.

PAI (Polyamide Imide)

Trade Names : udel

Polyamide-imides are either thermosetting or thermoplastic, amorphous polymers that have exceptional mechanical, thermal and chemical resistant properties. Polyamide-imides are used extensively as wire coatings in making magnet wire.



Properties :

High strength polymers.

High temperature.

High expensive.

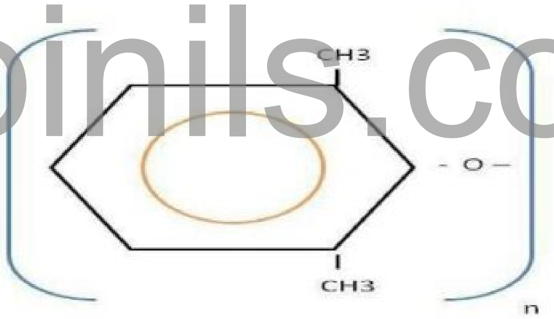
Applications :

Hot water system valves, electrical connectors, circuit boards, components for gas turbine and spark ignition engines.

PPO (Polyphenylene Oxide) :

Trades Names : Noryl.

Polyphenylene Oxide is a high-temperature thermoplastic. It is rarely used in its pure form due to difficulties in processing. It is mainly used as blend with polystyrene, high impact styrene-butadiene copolymer or polyamide.



Properties :

High rigidity.

Heat deflection temperatures.

Good strength.

High impact strength.

Low water absorption rate.

Have poor processing characteristics.

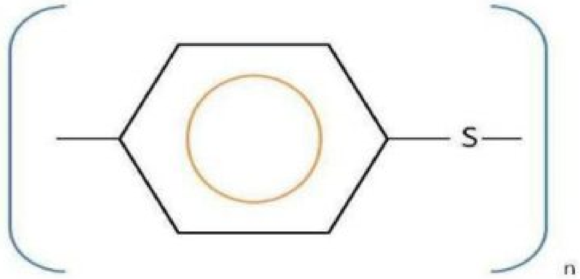
Good dimensional stability.

Applications :

Computer housings, TV tuners, electrical connectors, Automobile components.

12. PPS (Poly Phenylene Sulphide):

Polyphenylene sulfide (PPS) is an organic polymer consisting of aromatic rings linked by sulfides. Synthetic fiber and textiles derived from this polymer resist chemical and thermal attack. PPS is used in filter fabric for coal boilers, papermaking felts, electrical insulation, film capacitors, specialty membranes, gaskets, and packings.



Properties :

High rigid and strong.

Highly crystalline material.

Good chemical resistant material.

Used for electrical applications.

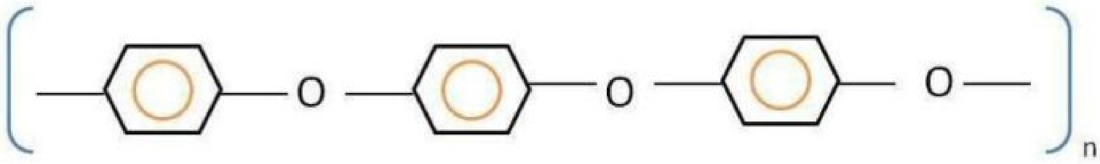
High strength.

Applications :

Chemical processing equipments, gear type pumps, pipes, valve fittings and coupling.

13. PEEK (Polyether ether ketone) :

PEEK is a semicrystalline thermoplastic with excellent mechanical and chemical resistance properties that are retained to high temperatures. The processing conditions used to mold PEEK can influence the crystallinity and hence the mechanical properties.



Properties :

High temperature plastics.

High mechanical properties.

Low flammibility.

Good fatigue and Chemical resistance.

Avoid too many chemicals, hot water and low pressure stream.

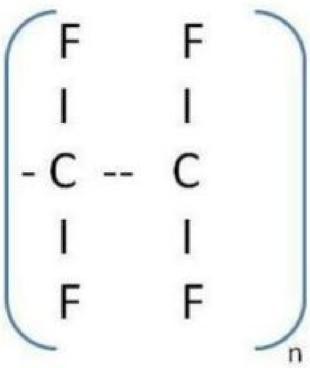
Applications :

- Electrical components, aircrafts and aerospace applications.

PTFE (Polytetra – Fluoro – ethylene):

Trade Names : Poly Fluroron, Teflon, Halon, Fluorothene.

Polytetrafluoroethylene (PTFE) is a synthetic fluoropolymer of tetrafluoroethylene that has numerous applications. PTFE is a fluorocarbon solid, as it is a high-weight compound consisting wholly of carbon and fluorine.



Properties :

Highly crystalline structure.

Good electrical properties.

Very low-coefficient of friction.

Low tensile strength.

Low creep resistance.

High melting viscosity.

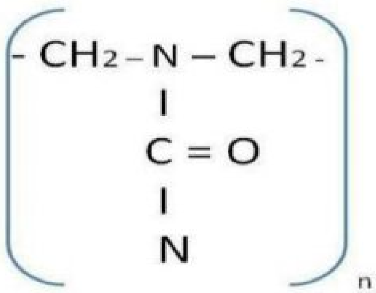
Applications:

Coatings, anticorrosive seats, pipes, valves, bearings bushes, electronic parts.

4.7 PROPERTIES AND APPLICATIONS OF THERMOSETTING PLASTICS:

1. UF (Urea Formaldehyde) :

Urea-formaldehyde, also known as urea-methanal, so named for its common synthesis pathway and overall structure,[1] is a non-transparent thermosetting resin or polymer. It is produced from urea and formaldehyde. These resins are used in adhesives, finishes, particle board, medium-density fibreboard (MDF), and molded objects. UF and related amino resins are a class of thermosetting resins of which urea-formaldehyde resins make up 80% produced globally. Examples of amino resins use include in automobile tires to improve the bonding of rubber to tire cord, in paper for improving tear strength, in molding electrical devices, Jar caps etc.



Properties :

Hard and rigid.

Good strength and impact resistance.

Good resistance to chemicals.

Good electrical insulators.

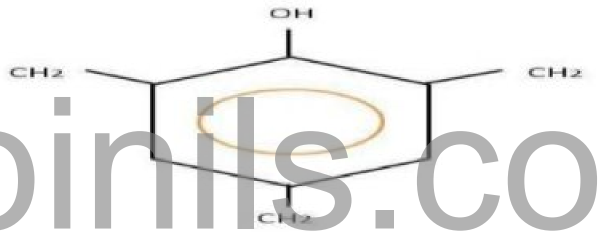
Variety of colours can be added.

Applications :

Electrical wall plates, switches, circuit, breakers, handles, furniture, bottle caps, cups, plates etc.

2. PF (Phenol Formaldehyde) or Bakelite:

Phenol formaldehyde resins (PF) or Phenolic resins are synthetic polymers obtained by the reaction of phenol or substituted phenol with formaldehyde. Used as the basis for Bakelite, PFs were the first commercial synthetic resins plastics. They have been widely used for the production of molded products including billiard balls, laboratory countertops, and as coatings and adhesives.



Properties:

High hardness.

Good strength.

Good heat and electrical properties.

Low thermal conductivity.

Good resistance to oils, grease etc.

High temperature.

Applications:

Electrical plugs, sockets, switches, handles, automobile components, moulding process, grinding wheels.

4.8 ENGINEERING CERAMICS :

Ceramics are non- metallic and inorganic solids that are processed and used at high temperature. Ceramics are electrical and thermal insulators with good chemical stability and good strength in compression. Engineering ceramics are mainly oxides, carbides, sulphides, and nitrides of metal.

Properties of Engineering Ceramics :

High strength.
High fracture toughness.
Fine grain size.
No porosity.
Poor machinability.
High stiffness.
High temperatures.
Good wear resistance.
Low thermal conductivity.
Good electrical stability.
High resistance to creep and fatigue.

4.8.1 PROPERTIES AND APPLICATIONS OF ENGINEERING CERAMICS:

1. Al_2O_3 (Alumina) :

Aluminium Oxide (Al_2O_3) is the oldest engineering ceramic and the most widely used engineering. It is obtained from the fusion of bauxite ore ($Al_2O_3.2H_2O$), iron fillings and coke in electric furnaces. The product obtained is cooled, crushed and then graded into various sizes.Al_2O_3 parts are manufactured from these powers by cold pressing and sintering. Alumina has a hexagonal structure with very strong ionic and covalent bonds.

Properties :

High hardness.
Moderate tensile strength.
Good wear resistance.

Good chemical properties.

Applications:

Grinding wheels, rocket nozzles, pump impellers, check valves, spark plugs, vacuum tubes, electronic micro circuits, metal cutting tool tips etc.

SiC (Silicon Carbide) :

It is an old ceramic material. It s made from silica sand, coke, small amount of Sodium Chloride and saw dust. Silicon Carbide is the hardest of the traditional abrasive materials. When the mixture is heated at high temperature in an electric type of furnace for a long time, then the carbon from coke diffuses into the sand and silicon carbide is formed. They are two types of silicon carbide is formed. They are two types of silicon carbide.

Hexagonal –alpha (α –sic)
Cubic – beta (β –sic)

α-sic is made by the reduction of silica sand with carbon in an electric furnace.

–sic is produced by a vapour phase reaction.

Properties :

High hardness.
High wear resistance.
High tensile strength.
Good stiffness.
Low density.
High temperatures.
Low coefficient of friction.
High thermal conductivity.
Good dimensional stability.
More expensive.

Applications:

Turbine blades, automobile engine, heat engine, tube, containers, griding wheels, heating elements.

3. Si_3N_4 (Silicon Nitrate) :

It is very useful type of engineering ceramics which is fully resistance to strong acids and other toe melting point metals. There are two types of silicon nitrate:

Reaction bonded silicon nitrate.

Hot pressed silicon nitrate.

Properties :

High thermal conductivity.

Low coefficient of thermal expansion.

Low density.

Low weight.

High resistance to thermal shocks.

High resistance to creep.

High temperatures.

Applications:

Cutting tool material, turbine blades, automobile engines, sand blast nozzles, spindle bearings, pump parts, components of paper industry.

4.PSZ (Partially stabilised Zirconia) :ZrO_2

PSZ is a zirconium oxide that is blended and sintered with other oxides such as those of Magnesium, Calcium to control the crystal structure transformations. The oxide of ZrO_2 exists in three different crystal line modifications :

1)It has a cubic structure at elevated temperatures.

2)During cooling, it tranforms first into a tetragonal structure.

3)At room temperature, it transforms into a monoclinic structure.

On cooling, transformation causes cracking due to 3% volume change, Hence, it is different to fabricate a pure ZrO_2 ceramic. In order to prevent this cracking, PSZ is stabilised by adding oxides such as Mgo,Cao. A fully stabilised PSZ contains only 18% of stabilizing oxide whereas a PSZ contains only 5% of stabilising oxide.

Properties :

Good tensile strength.

Good toughness.

High coefficient of thermal expansion.

Low thermal conductivity.

Low friction coefficient.

High modulus of elasticity.

Applications :

Rotor blades in Jet turbines, Die Material, Grinding applications, Cylinder liners, heat engine, aerospace coatings, automobile parts.

5.$Si_3Al_3O_3N_5$ (Sialons) :

It involved such as sililcon, aluminium, oxygen and nitrogen. It is formed by blending silicon nitride with different proportions of aluminium oxide, aluminium nitride. It is formed when aluminium and oxygen partially substitute for silicon and nitrogen in silicon nitrates.

Properties :

It is hard.

Light in weight.

High strength.

Good dimensional stability.

Low coefficient of thermal expansion.

High corrosion resistance.

High wear resistance.

High temperature.

Good mechanical properties.

Applications:

Cutting tool materials, dies, engine components, bearings, rock-coal cutting equipment.

4.9 TRADITIONAL CERAMICS :

- Clay products
- Refractories
- Abrasives
  - Emergy
  - Diamond
  - Quartz
  - Silicon Carbide
  - Aluminum oxide (Al_2O_3)
- Glasses
  - Silica glass
  - Non-Silicate glasses
  - Safety glass
  - Photosensitive glass
  - Cellular (or) Foam glass
  - Coated glass
- Cement
- Cermets
- Concrete

4.10 COMPOSITES :

Composites are produced when two or more materials are joined to give a combination of properties that cannot be attained in the original materials.

Classification of composites:

- Fiber –Rein Forced Composites.
- Particle – Rein Forced Composites.
- Structural Composites.

1.Fiber – Rein Forced Composites:

It consists of high strength fibers dispersed in soft and ductile matrix. The material has better stiffness, strength and toughness. It is to with stand the load, while matrix ensures uniform distribution of the applied load. The Matrix also acts as a protective covering to the Fibers against external environment, namely – corrosion, oxidation, electrical etc. They are (1) Continuous Fiber (2) Discontinuous Fiber.

2. Particle – Rein Forced Composites :

The strengthening is produced by particle of hard material. The matrix consists of soft phase. The function of particles is to impact strength and stiffness to the composite.Matrix ensures uniform distribution of applied load on the composite. Matrix also provides protective covering to the particles. They are (1) Large – particle composite (2) Dispersion strengthened particle reinforced composite.

3. Structural Composites:

They are made up of two or more homogeneous materials, The properties of these composites depends on the properties of constituent materials and their geometric design. They are,

Laminated composites.

Sandwhich panel composites.

Applications of Composites :

Air craft Industry.
Automobile Industry.
Constructive Industry.
Pressure Vessel.
Pipes and Fittings.
Marine Structure.
Power Plant Applications.

4.11 METAL MATRIX COMPOSITES :

These composites provide high temperature resistance. Non- Flammability and high resistance. It contains continuous fibers. Ductile metal matrix are present in it. Ductile metals are aluminium, magnesium, copper, titanium, nickel and super graphite, silicon carbide or boron, alumina.

Properties :

High strength and stiffness.
High coefficient of thermal expansion.
High wear resistance.

Application:

Aerospace, automobile, marine, construction field etc.

UNIT- 4: NON-METALLIC MATERIALS

PART: A

1. Define FRP

FIBER – reinforced plastic or fiber – reinforced polymer is a composite material made of a polymer matrix reinforced with fiber.

Generally, the fibers are fiber glasses, carbon or armed whereas the polymer is an epoxy vinylester or polyester thermosetting plastics.

FRP are widely used in aerospace, automotive, marriage and construction field.

Give few important characteristic of polymer.

Polymers are light in weight
They have high corrosion resistance
Low density
Low thermal and electrical properties.
Easy to fabricate
Low cost.

What is hybrid composite?

Hybrid composites are those composites which have a combination of two or more reinforced fiber.

The most common hybrid composites are carbon- armed reinforced epoxy (which combines strength and impact resistance) and glass- carbon reinforces epoxy (which gives a strong materials at responsible prices)

Hybrid composites are usually when a combination of properties of different types of fibre wants to be achieved, or when a longitudinal as well as lateral mechanical performance is required.

How are refractories classified?

Fire clay refractories
Silica refractories
Basic refractories
Special refractories

Define the term Degree of Polymerization? [N/D'16]

Degree of Polymerization is the number of repetitive units present in one molecule of a polymer.

What are PEEK and PMMA? [N/D'15]

PEEK is a Linear crystalline Hetero chain Polymer. It is a High temperature Plastics, Which is generally used for service of High temperatures.

PMMA also commonly known as Perspex is Produced by the addition Polymerization of Methyl Methacrylate.

6. Name any four Commodity plastics and Engineering plastics?

Commodity plastice	Engineering plastics
• Polyehtylene • Polypropylene • Polystyrene • Polyvinyl Chloride	• Ethenic • Polyamides • Cellulosics • Acetals

8. Distinguish between Thermo Plastics and Thermosetting Plastics? [A/M'15]

S.No	Thermo Plastics	Thermosetting Plastics
1	They are formed by addition Polymerization	They are formed by Condensation Polymerization
2	They can be Recycled again	They cannot be Recycled again

9. What are engineering ceramics? [M/J'16]

Engineering ceramics, are also known as technical/ industrial ceramics or advanced ceramics, are those ceramics that are specially used for engineering application or in industries. It is mainly oxides, carbides, sulphides, and nitrides of metals.

10. What are the three stages in addition polymerization?

The addition polymerization occurs in three stages:

Initiation,
Propagation, and
Termination

What is polymerisation? [M/J'16]

It is a process of forming a polymer by linking together of monomers.

State the advantages of fibre reinforced composites. [M/J'16]

Low relative density
Good resistance to corrosion
Good fatigue resistance
Low coefficient of thermal expansion.

PART: B

Describe the molecular structure, properties and application of the following polymers. [A/M'15]

(i) Polyvinyl chloride (PVC) (4)
(ii) Polystyrene (PS) (4)
Polyethylene terephthalate (PET) (4)
Poly carbonate (4)

Polyvinyl chloride:

Poly(vinyl chloride) (PVC) has a chemistry and a physical structure that makes it broadly unique in the polymer world. PVC (often referred to vinyls or vinyl resins) is made commercially at several molecular weights, depending on the intended applications: from Mw = 39000 g/mol, to Mw = 168000 g/mol. PVC chemistry follows:

vinyl chloride poly(vinyl chloride)

where n, i.e. degree of polymerization, ranges commercially from 625 to 2700. PVC has grown to be one of the major plastics of the world. It was the largest group of thermoplastic materials; however, the vinyl resins have been suppressed in volume by the olefin polymers. PVC is second in volume to polypropylene among plastic materials. The volume of each individual categories of polyethylene is smaller than PVC's.

Polystyrene:

Polystyrene (PS) is a synthetic aromatic polymer made from the monomer styrene. Polystyrene can be solid or foamed. General purpose polystyrene is clear, hard, and rather brittle. It is an inexpensive resin per unit weight. It is a rather poor barrier to oxygen and water vapor and has a relatively low melting point. Polystyrene is one of the most widely used plastics, the scale of its production being several billion kilograms per year. Polystyrene can be naturally transparent, but can be colored with colorants. Uses include protective packaging, containers (such as "clamshells"), lids, bottles, trays, tumblers, and disposable cutlery.

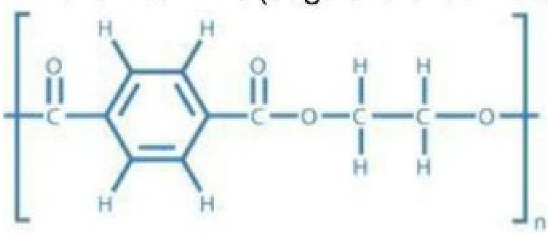
Properties:

- Flow properties may be the most important properties of polystyrene processes. There are two widely accepted industry methods for the measurement of processing properties.
- These include the melt flow index and the solution viscosity. The melt flow index is measured by ASTM method as a measure of the melt viscosity at 2000 C and a 5kg load.
- Polystyrenes are commercially produced with melt flow ranges of less than 1 to greater than 50, although the most widely available grades generally have melt flows between 2.0 and 20g per 10min.
- Solution viscosity is another method for measuring the molecular structure of the polystyrene. Solution viscosity can be measured as an 8% solution in toluene and increases with increasing molecular weight.
- Crystal polystyrenes have very low impact strengths of less than 0.5ft-lb. Commercially available impact polystyrene grades can be obtained with values of 1.0 - 4.0 ft-lb. Generally, polystyrenes are not produced with greater than 15% total rubber because of polymerization processing constraints
- The glass transition temperature for unmodified polystyrene is 373 K, and the glass transition temperatures for polybutadienes are 161-205 K, subject to the cis, trans, and vinyl content.

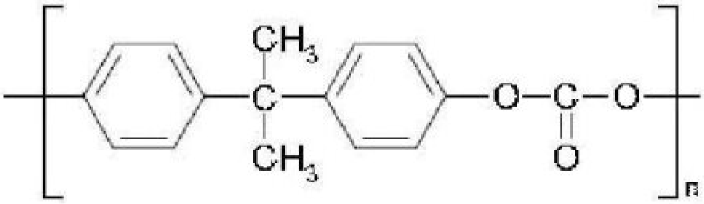
Polyethylene terephthalate:

PET is an acronym for polyethylene terephthalate, which is a long-chain polymer belonging to the generic family of polyesters. PET is formed from the intermediates, terephthalic acid (TPA) and ethylene glycol (EG), which are both derived from oil feedstock. There are other polyesters based on different intermediates but all are formed by a polymerisation reaction between an acid and an alcohol. PET, in its purest form, is an amorphous glass-like material. Under the influence of direct modifying additives it develops crystallinity. Also, crystallinity can be developed by heat treatment of the polymer melt.

The three major packaging applications of PET are as containers (bottles, jars and tubs), semi-rigid sheet for thermoforming (trays and blisters) and thin oriented films (bags and snack food wrappers).



Poly carbonate:



Polycarbonate is a durable material. Although it has high impact-resistance, it has low scratch-resistance. Therefore, a hard coating is applied to polycarbonate eyewear lenses and polycarbonate exterior automotive components. The characteristics of polycarbonate compare to those of polymethyl methacrylate (PMMA, acrylic), but polycarbonate is stronger and will hold up longer to extreme temperature. Polycarbonate is highly transparent to visible light, with better light transmission than many kinds of glass.

Polycarbonate has a glass transition temperature of about 147 °C (297 °F), so it softens gradually above this point and flows above about 155 °C (311 °F). Tools must be held at high temperatures, generally above 80 °C (176 °F) to make strain-free and stress-free products. Low molecular mass grades are easier to mold than higher grades, but their strength is lower as a result. The toughest grades have the highest molecular mass, but are much more difficult to process.

2. Describe the molecular structure, properties and application of the following polymeric materials. [N/D'15] (i)Poly methyl methacrylate (PMMA) (4) (ii)Poly tetra f1uoro ethylene (PTFE) (4)
(iii)Polyethylene terephthalate (PET) (4)
(iv)Acryl nitride butadiene styrene. (4)

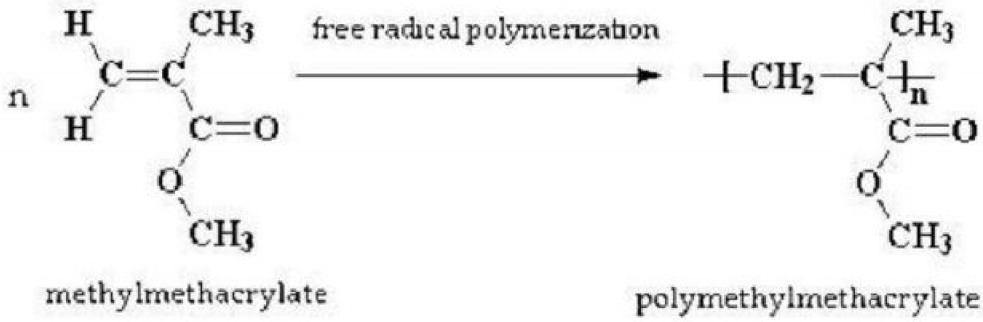
Poly methyl methacrylate:

General Poly(methacrylates) are polymers of the esters of methacrylic acids. The most commonly used among them is poly(methyl methacrylate) (PMMA).

Poly(methyl methacrylate) or poly (methyl 2-methylpropenoate) is the polymer of methyl methacrylate, with chemical formula C5H8O2)n. It is a clear, colourless poly- mer available on the market in both pellet and sheet form under the names Plexiglas, Acrylite, Perspex, Plazcryl, Acrylplast, Altuglas, Lucite etc. It is commonly called acrylic glass or simply acrylic.

Another polymer, poly(methyl acrylate) (PMA) is a rubbery material, similar to poly(methyl methacrylate), but softer than it, because its long polymer chains are thinner and smoother and can more easily slide past each other.

Poly(methyl methacrylate) is produced by free-radical polymerization of methyl- methacrylate in mass (when it is in sheet form) or suspension polymerization according to the following chart:



PMMA is a linear thermoplastic polymer. PMA has a lack of methyl groups on the backbone carbon chain - its long polymer chains are thinner and smoother and can slide past each other more easily, so the material becomes softer.

PMMA has high mechanical strength, high Young's modulus and low elongation at break. It does not shatter on rupture. It is one of the hardest thermoplastics and is also highly scratch resistant. It exhibits low moisture and water absorbing capacity, due to which products made have good dimensional stability. Both of these charac-teristics increase as the temperature rises.

Application:

Optics: Dust covers for hi-fi equipment, sunglasses, watch glasses, lenses, magnifying glasses;

Vehicles: Rear lights, indicators, tachometer covers, warning triangles;

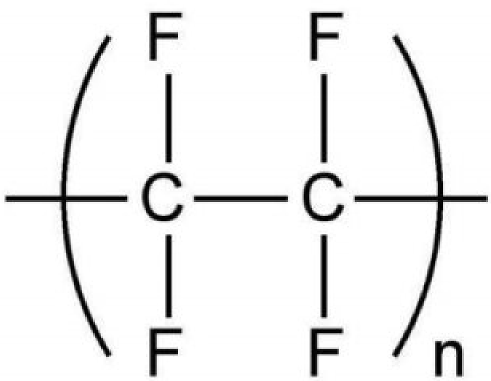
Electrical engineering: Lamp covers, switch parts, dials, control buttons;

Office equipment: Writing and drawing instruments, pens;

Medicine: Packaging for tablets, pills, capsules, suppositories, urine containers, sterilisable equipment;

Others: Leaflet dispensers, shatter-resistant glazing, shower cubicles, transparent pipelines, illuminated signs, toys.

Poly tetra f1uoro ethylene:



Polytetrafluoroethylene (PTFE) is a synthetic fluoropolymer of tetrafluoroethylene that has numerous applications. The best known brand name of PTFE-based formulas is Teflon by DuPont Co., which discovered the compound.

PTFE is a fluorocarbon solid, as it is a high-molecular-weight compound consisting wholly of carbon and fluorine. PTFE ishydrophobic: neither water nor water-containing substances wet PTFE, as fluorocarbons demonstrate mitigated London dispersion forces due to the high electronegativity of fluorine. PTFE has one of the lowest coefficients of friction against any solid.

PTFE is used as a non-stick coating for pans and other cookware. It is very non-reactive, partly because of the strength of carbon–fluorine bonds and so it is often used in containers and pipework for reactive and corrosive chemicals. Where used as a lubricant, PTFE reduces friction, wear and energy consumption of machinery. It is also commonly used as a graft material in surgical interventions. Properties:

PTFE is a thermoplastic polymer, which is a white solid at room temperature, with a density of about 2200 kg/m^3.

According to DuPont, its melting point is 600 K (327 °C; 620 °F). It maintains high strength, toughness and self-lubrication at low temperatures down to 5 K (−268.15 °C; −450.67 °F), and good flexibility at temperatures above 194 K (−79 °C; −110 °F).

PTFE gains its properties from the aggregate effect of carbon-fluorine bonds, as do all fluorocarbons. The only chemicals known to affect these carbon-fluorine bonds are reactive metals like alkali metals and at higher temperature also e.g. aluminium and magnesium and fluorinating agents such as xenon difluoride and cobalt(III) fluoride.

The major application of PTFE, consuming about 50% of production, is for wiring in aerospace and computer applications (e.g. hookup wire, coaxial cables). This application exploits the fact that PTFE has excellent dielectric properties.

This is especially true at high radio frequencies, making it suitable for use as an insulator in cables and connectorassemblies and as a material for printed circuit boards used at microwave frequencies.
Combined with its high melting temperature, this makes it the material of choice

as a high-performance substitute for the weaker and lower-melting-point polyethylene commonly used in low-cost applications.

In industrial applications, owing to its low friction, PTFE is used for applications where sliding action of parts is needed: plain bearings, gears, slide plates, etc. In these applications, it performs significantly better than nylon and acetal; it is comparable to ultra-high-molecular-weight polyethylene (UHMWPE).

Although UHMWPE is more resistant to wear than PTFE, for these applications, versions of PTFE with mineral oil or molybdenum disulfide embedded as additional lubricants in its matrix are being manufactured. Its extremely high bulk resistivity makes it an ideal material for fabricating long-life electrets, useful devices that are the electrostatic analogues of magnets.

Polyethylene terephthalate:

PET is an acronym for polyethylene terephthalate, which is a long-chain polymer belonging to the generic family of polyesters. PET is formed from the intermediates, terephthalic acid (TPA) and ethylene glycol (EG), which are both derived from oil feedstock. There are other polyesters based on different intermediates but all are formed by a polymerisation reaction between an acid and an alcohol. PET, in its purest form, is an amorphous glass-like material. Under the influence of direct modifying additives it develops crystallinity. Also, crystallinity can be developed by heat treatment of the polymer melt.

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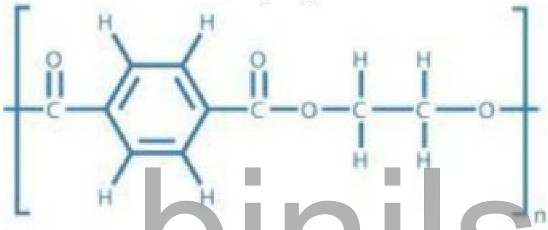

Properties:

PET in its natural state is a colorless, semi-crystalline resin. Based on how it is processed, PET can be semi-rigid to rigid, and it is very lightweight. It makes a good gas and fair moisture barrier, as well as a good barrier to alcohol (requires additional "barrier" treatment) and solvents. It is strong and impact-resistant. PET becomes white when exposed to chloroform and also certain other chemicals such as toluene.

About 60% crystallization is the upper limit for commercial products, with the exception of polyester fibers. Clear products can be produced by rapidly cooling molten polymer below Tg glass transition temperature to form an amorphous solid. Like glass, amorphous PET forms when its molecules are not given enough time to arrange themselves in an orderly, crystalline fashion as the melt is cooled. At room temperature the molecules are frozen in place, but, if enough heat energy is put back into them by heating above Tg, they begin to move again, allowing crystals to nucleate and grow. This procedure is known as solid-state crystallization.

When allowed to cool slowly, the molten polymer forms a more crystalline material. This material has spherulites containing many small crystallites when crystallized from an amorphous solid, rather than forming one large single crystal. Light tends to scatter as it crosses the boundaries between crystallites and the amorphous regions between them. This scattering means that crystalline PET is opaque and white in most cases. .

PET Product	Applications
Bottles	Beverages, soft drinks, fruit juices, and mineral waters. Especially suitable for carbonated drinks. Cooking and salad oils, sauces and dressings.
Wide mouth jars and tubs	Jams, preserves, fruits and dried foods
Trays	Pre-cooked meals for re-heating in either microwave or conventional ovens, pasta dishes, meats and vegetables
Films and metallised foils	'Boil in bag' pre-cooked meals, snack foods, nuts, sweets, long life confectionery, ice creams, and spreads
Coatings	Microwave susceptors
PET products with added oxygen barrier	Beer, vacuum packed dairy products e.g. cheese, processed meats, 'Bag in Box' wines, condiments, coffee, cakes, syrups,

Acryl nitride butadiene styrene:

- Acrylonitrile butadiene styrene (ABS) (chemical formula $(C_8H_8)_x\cdot(C_4H_6)_y\cdot(C_3H_3N)_z$) is a common thermoplastic polymer. Its glass transition temperature is approximately 105 °C (221 °F). ABS is amorphous and therefore has no true melting point.
- ABS is a terpolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions can vary from 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene.

The result is a long chain of polybutadiene criss-crossed with shorter chains of poly(styrene-co-acrylonitrile).

The nitrile groups from neighboring chains, being polar, attract each other and bind the chains together, making ABS stronger than pure polystyrene. The styrene gives the plastic a shiny, impervious surface.

- The polybutadiene, a rubbery substance, provides toughness even at low temperatures. For the majority of applications, ABS can be used between −20 and 80 °C (−4 and 176 °F) as its mechanical properties vary with temperature.

The properties are created by rubber toughening, where fine particles of elastomer are distributed throughout the rigid matrix.

Properties:

The most important mechanical properties of ABS are impact resistance and toughness. A variety of modifications can be made to improve impact resistance, toughness, and heat resistance.

The impact resistance can be amplified by increasing the proportions of polybutadiene in relation to styrene and also acrylonitrile, although this causes changes in other properties.

Impact resistance does not fall off rapidly at lower temperatures. Stability under load is excellent with limited loads.

Thus, by changing the proportions of its components, ABS can be prepared in different grades. Two major categories could be ABS for extrusion and ABS for injection moulding, then high and medium impact resistance. Generally ABS would have useful characteristics within a temperature range from −20 to 80 °C (−4 to 176 °F).

Applications:

ABS's light weight and ability to be injection moulded and extruded make it useful in manufacturing products such as drain-waste-vent (DWV) pipe systems, musical instruments (recorders, plastic clarinets, and piano movements), golf club heads (because of its good shock absorbance), automotive trim components, automotive bumper bars, medical devices for blood access, enclosures for electrical and electronic assemblies, protective headgear, whitewater canoes, buffer edging for furniture and joinery panels, luggage and protective carrying cases, small kitchen appliances, and toys, including Lego and Kre-O bricks. Household and consumer goods are the major applications of ABS. Keyboard keycaps are commonly made out of ABS.

Explainthe following Engineering Ceramics:[A/M'15]

a) AL_2O_3 b) SiC c) Si_3N_4

AL_2O_3

Aluminium oxide Alumina:

Otherwise known as emery.

Made from minera bauxite.

Properties:

Increase hardness and moderate strength.

Withstand high voltage as well as temperature.

Inexpensive and increase resistance to abrasion.

Decrease density and increase electrical resisting

Strong in compression

Used in high temperature furnaces, because increase melting point.

Used in grinding wheels because it has increase compressive strength and wear resistance.

Used in rocket nozzles, pump impellers, check valves and nozzles subjected to erosion.

Spark plugs, vacuum tubes and electronics micro circuits.

Silicon Carbide:

Oldest ceramic material

Used for abrasives for grinding wheels and emery papers.

Silicon are made from any one of the following four processes

a)Pressureless sintering

b)reaction bonding

c)hot pressing

d)chemical vapour deposition

Pressure less sintering - powder form heated with inert gas at 2050 ^{o}c

Reaction bonding – silicon powder react with carbonaceous gases at high temperature.

Hot pressuing – powder by uniaxial pressure at 2150 ^{o} c.(pressure 30 MPa)

properties :

increase strength , stiffness and hardness

increase thermal conductivity

increase dimensional stability and polishability

resistant to abrasion and wear

increase chemical resistant.

Optical mirrors because of dimensional stability and polishabiling

Used in nuclear reactor fuel elements.

Used for mech seals, bearings and engine components.

Silicon Nitride:

Two main types of reaction bonding.

Silicon nitride and Pressure sintered silicon nitride it has 20% Porosity

Advantage is low size charge during firing.

Disadvantage is decrease strength and mechanical properties.

Pressure sintered silicon nitride has 00% theoretical density. Properties :

Brittle and react with atmosphere.

No loss of strength at temp 1000oC.

Increase thermal shock resistance.

Decrease thermal expansion

Better toughness than Sic and Al2O3.

Stiffer than steel.

Cutting tool materials

Used in heat exchangers, furnace components and crucibles.

Used in automobile industry.
Used for gas turbine parts, resist thermal cycling.

i) Describe the difference between thermoplastics and thermosetting plastics. (8)

Property	Thermoplastics	Thermosetting plastics
Action of heat Type of bonding	They soften on heating and set on cooling every time	They set on heating and cannot be resoftened.
between adjacent polymer chains	The polymer chains are held together by weak force called Van der Waal's force of attraction.	The polymers chains are linked by strong chemical bonds. (covalent bonds)
Solubility Expansion due to	They are soluble in organic solvents.	They are insoluble in organic solvents.
Heating	They expand very much on heating.	Their expansion is only marginal due to heat.
Type of polymerisation	They are formed by addition polymerization	They are formed by condensation polymerization
Type of moulding Scrap recovery	They are processed by injection moulding.	They are processed by compression moulding.
Example	Scarp can be reused. Polythene, PVC, Nylon	Scarp cannot be reused. Bakelite, Plaskon

What do you understand by polymerization? With the help of suitable examples, compare and contrast the process of addition polymerization and condensation polymerization. [M/J'16]

Polymer means many monomers. Sometimes polymers are also known as macromolecules or large-sized molecules. Usually, polymers are organic (but not necessarily).
A monomer is a molecule that is able to bond in long chains.
A polymer can be made up of thousands of monomer. This linking up of monomers is called polymerization.
Polymerization is a process of reacting monomer molecules together in a chemical reaction to form polymer chains or three-dimensional networks.

Name(s)	Formula	Monomer	Properties	Uses
Polyethylene low density (LDPE)	$-(CH_2-CH_2)_n-$	ethylene $CH_2=CH_2$	soft, waxy solid	film wrap, plastic bags

b

Polyethylene high density (HDPE)	–(CH_2-CH_2)n–	ethylene CH_2=CH_2	rigid, translucent solid	electrical insulation bottles, toys
Polypropylene (PP) different grades	–[CH_2-CH(CH_3)]n–	propylene CH_2=$CHCH_3$	atactic: soft, elastic solid isotactic: hard, strong solid	similar to LDPE carpet, upholstery
Poly(vinyl chloride) (PVC)	–(CH_2-CHCl)n–	vinyl chloride CH_2=CHCl	strong rigid solid	pipes, siding, flooring

Difference between addition polymerization and condensation polymerization

Addition polymerization	**Condensation polymerization**
The addition polymerization means that two monomers react with each other and no other small molecules are generated. The best example is polymerization of ethylene.	The condensation polymerization, as a contrast, normally involves the generation of small molecule products.
It requires two like molecules.	It requires two unlike molecules.
Kinetic long linear chain reaction.	Intermolecular reaction.
Very fast reaction $10^{-2} – 10^{-6}$sec	Slow reaction takes hours and days to complete.
No by total.	By product it produced.
Polymer produced thermoplastic.	Chemo setting plastic produced.
Example: PVC, Teflon, Poly ethylene.	Example: Bakelite, Silicon, GRP, Polystyrene.

PART-C

Write properties and applications for a) ZrO2 (b) SIALON

Zirconium oxide:

Otherwise known as partially stabilized Zirconia.

It is blended and sintered with other oxide such of magnesium oxide or Calcium oxide to control crystal structure transformation.

It has monoclinic crystal structure at room temperature.

Tetra gonal structure at low temperature.

Cubic structure at high temperature.

Cooling curves cracking and it is difficult to fabricate pure Zirconia ceramic. Properties :

Better fracture toughness than ceramics

b

Soften than ceramics.
Increase tensile strength.
Increase thermal insulators.
Increase resistance to thermal shock , wear and corrosion.

Applications:

Used in IC engines.
Hot extrusion of metal , aerospace , coating etc.

Sialon: $Si_3 Al_3 O_3 N_5$

It is formed by blending and sintering silicon nitride, alumina, silica and aluminium nitride.

Presence of Aluminium oxide in sialon increase hardness because of presence in silicon nitride increase toughness.

Two commercial varieties of sialon.
a)low substitutional sialon b) high substitution sialon

properties :

- Increase strength and hardness.
- Increase resistance to corrosion , wear and thermal shocks.
- Used electrical insulator.
- Good tensile and compressive strength upto 1400Oc.
- Increase stability dimensional and increase coefficient of thermal expansion.

Application :

Used in cutting tool materials.
Used for engine components and bearings.

Name the suitable alloys, polymers and ceramics for manufacturing the following items.

(i) Bush (ii) Furnace heating element (iii) Lathe bed
(iv) Coins (v) Girders for airship (vi) Big end bearing
(vii)Knobs (viii) Windshields (ix)Conduit pipes
(xi)Touch screen (xi) Turbine blade
(xii)Furnace linings (xiii) Grinding(abrasive) wheels
(xiv)Coating on cutting inserts (xv) Cutting inserts for ferrous alloys

Bush - Polyamides
Furnaces heating element - Ferritic stainless steel
Lathe bed - Cast iron
Coins - Gliding metal or bronze
Girders for Airship - Aluminium/ austenitic stainless steel
Big end Bearing -Aluminium base bearing
Turbine Blade - Yalloy/ monel metal

Conduit Pipes -PVC
Knobs -Styrene acrylo-nitrile copolymer SAN
Windshields - Acrylic plastic
Touch Screens - Indium tin oxide ITO
Furnace lining -Refractories/ceramics
Grinding (abrasive) wheels - Abrasives/ceramics
Coating on cutting inserts - Diamond
cutting inserts for ferrous alloy - cemented carbides