ME3392

ENGINEERING MATERIALS AND METALLURGY

NON METALLIC MATERIALS -

UNIT IV

POLYMERS (Plastics, Rubbers and Adhesives)

CERAMICS AND COMPOSITES

VEERAPANDIAN.K

AP/MECH

INTRODUCTION - polymers

- Polymers are used in number of applications ----
- **toys,**
- **home appliances,**
- **structural and decorative items,**
- **coatings, paints, adhesives,**
- **automobile tyres**
- **Foams and packing**

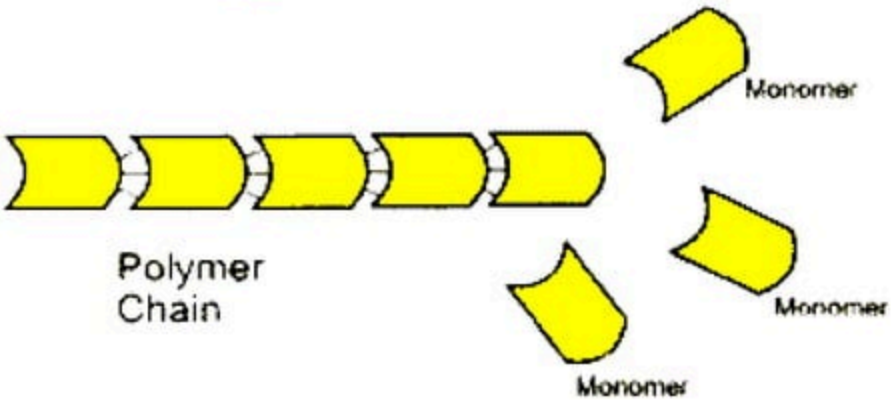
Large size molecule

Key

monomer 1

chemical bond

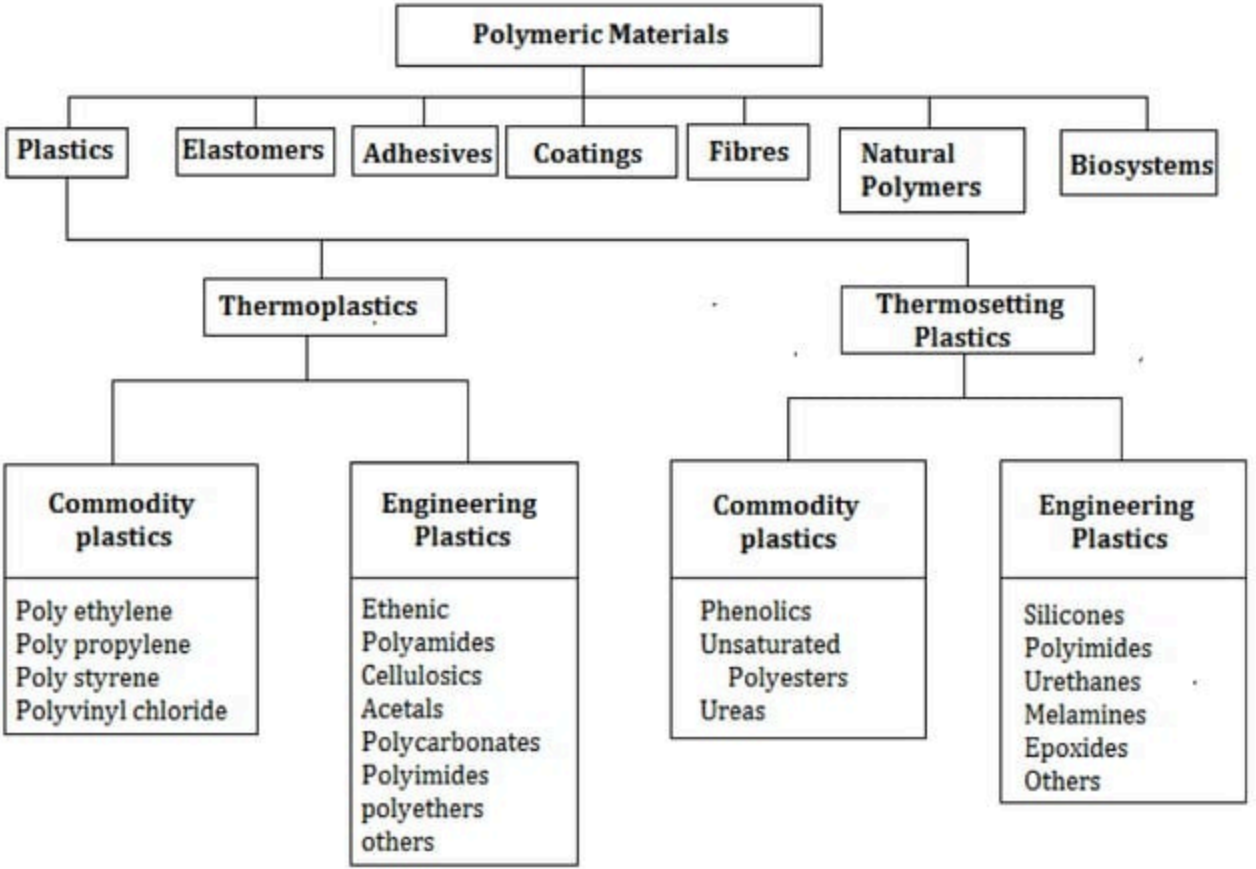
monomer 2



Polymers

Are made up of many small, repeating molecular units known as

Monomers


Polymeric Materials
Plastics
Elastomers
Adhesives
Coatings
Fibres
Natural Polymers
Biosystems
Thermoplastics
Thermosetting Plastics
Commodity plastics
Poly ethylene
Poly propylene
Poly styrene
Polyvinyl chloride
Engineering Plastics
Ethenic
Polyamides
Cellulosics
Acetals
Polycarbonates
Polyimides
polyethers
others
Commodity plastics
Phenolics
Unsaturated Polyesters
Ureas
Engineering Plastics
Silicones
Polyimides
Urethanes
Melamines
Epoxides
Others

properties of Polymers

- Excellent mechanical properties over temperatures from below -40°C (-40°F) to above 148°C (300°F),
- Self-extinguishing, non-dripping characteristics,
- Excellent durability, dimensional stability and low water absorption,
- Resistance to aqueous chemical environments.
- Excellent impact strength.

POLYMERISATION

- Its reaction of **joining of small molecules** to form molecule having higher weight called polymer.

Classification of Polymers:

- **Homopolymers** - consist of chains with identical bonding linkages to each monomer unit. This usually implies that the polymer is made from all identical monomer molecules.
  These may be represented as : -[A-A-A-A-A-A]-

- **Copolymers** - consist of chains with two or more linkages usually implying two or more different types of monomer units.
  These may be represented as : -[A-B-A-B-A-B]-

- **Addition Polymers** - the monomer molecules bond to each other without the loss of any other atoms. Alkene monomers are the biggest groups of polymers in this class.

- **Condensation Polymers** - usually two different monomer combine with the loss of a small molecule, usually water. Polyesters and polyamides (nylon) are in this class of polymers. Polyurethane Foam in graphic.

- **Thermoplastics** - plastics that soften when heated and become firm again when cooled.

- **Thermosets** - plastics that soften when heated and can be molded, but harden permanently. They will decompose when reheated. An example is Bakelite, which is used in toasters, handles for pots and pans, dishes, electrical outlets and billiard balls.

Terminology used in polymers

1.Monomer

They are made up of small and repeating molecular units known as Monomers

2. Polymer

it's a macro molecule formed by repeated linking of many monomers

3. polymerization

it's a process of forming a polymer

Terminology used in polymers

4. homopolymer

It consist of chains with identical bonding linkages to each monomer unit. This usually implies that the polymer is made from all identical monomer molecules.
These may be represented as : -[A-A-A-A-A-A]-

5. Copolymers

It consist of chains with two or more linkages usually implying two or more different types of monomer units.
These may be represented as : -[A-B-A-B-A-B]-

Terminology used in polymers

6. Degree of polymerization

$$= \frac{\text{molecular weight of a polymer}}{\text{molecular weight of a single monomer}}$$

7. High polymer

Solid polymer which have very high molecular weights (10000 to 1000000 g/mol)

8. Oligo polymer

They are liquid / gas polymers with very short chains (having the molecular weight on the order of 100 g/mol)

Types of homo polymers

- **Linear polymer**

  Here the mer units are joined to end to end in single chain.

- **Branched polymer**

  Here the side branch chains are connected to the main chain

Types of homo polymers

- **Cross linked polymer**

  Here the adjacent linear chains are joined one to another at various positions by covalant bond

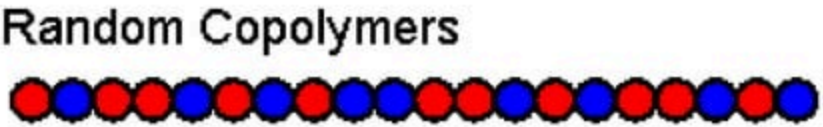
- **Network polymers**

  It has three active covalent bonds (trifunctional mer units) which form these dimensional networks instead of the linear chain frame work

Types of copolymers

1. Random copolymers

Here 2 different units are randomly dispersed along a chain



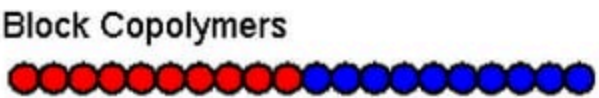
2. Alternating copolymer

The 2 mer units placed alternatively

Types of copolymers

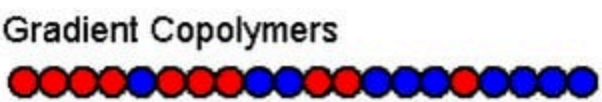
3.Block copolymer

Identical mers are clustered in blocks along the chain.



4.Graft copolymer

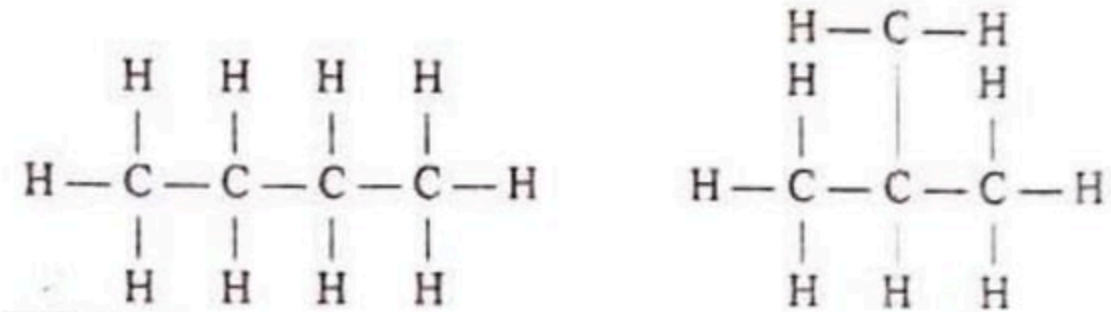
In this , homopolymer side branches of one type may be grafted to homopolymer main chains that are composed of a different mer.



Types of copolymers

5. Isomerism:

It is a phenomenon wherein different atomic configurations are possible for the same configuration. For example, there are two isomers for butane (C_4H_{10}) as shown in Fig.

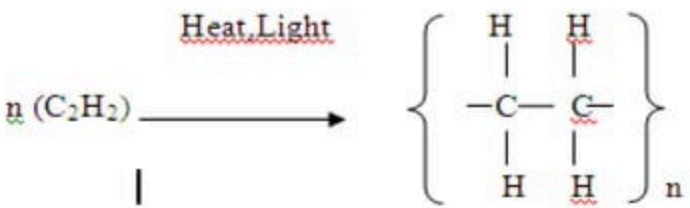


Polymerization

- Polymerization may be defined as the process of growing large molecules from small ones. Polymerization links together monomers.
- Monomers are molecules which combined end to end to form large molecules known as polymer. They are three general methods (or) mechanism of polymerization.
- **Addition of polymerization**
- **Condensation of polymerization**
- **Copolymerization**

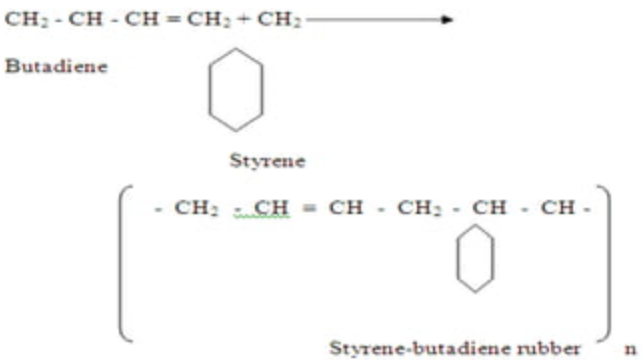
Addition polymerisation

- **Definition:** A chemical reaction in which simple molecules (monomers) are added to each other to form long-chain molecules (polymers) without by-products. The molecules of the monomer join together to form a polymeric product in which the molecular formula of the repeating unit is identical with that of the monomer. The molecular weight of the polymer so formed is thus the total of the molecular weights of all of the combined monomer units.



Copolymerization:

- Copolymerization is another kind of addition polymerization. Many monomers will not polymerize with themselves, but will copolymerize with other compounds. Copolymerization is the addition polymerization of two or more different monomers. Examples of butadiene-styrene, a rubber used in tires.



Condensation polymerization:

- Bakelite, the first commercial plastics, owes its origin to the process called condensation polymerization.
- Condensation polymerization occurs in the combination of a compound with itself or other compounds, accompanied by the elimination of some simple compound as H_2O, HCl ,etc .,as a result of polymerization.
- Phenol + Formaldehyde → Water + Phenol-formaldehyde
- $C_6H_5OH + CH_2O \rightarrow H_2O + C_{13}H_{10}(OH)_2$ n

Properties and applications of thermoplastics

PLASTICS

Polyethylene (PE)

- Polyethylene is made from petroleum or natural gas Raw products.
- The early processes for production involved extremely high pressure and temperature as high as 400 low density Polyethylene.
- It's produced two process. High density and low density Polyethylene.
- High density Polyethylene is made by low pressure and low temperature. The current trend is to use these latter processes because of their lower energy requirements.
- The most recent processes produces' Polyethylene grade called linear low-density Polyethylene (LLDPE).

Properties of PE

- They have excellent resistance to most solvent and chemicals.
- It has a good flexibility property.
- They are non-toxic.
- They possess good electrical insulation properties.

Application of PE

- Polyethylene used in packaging film, coating and laminations.
- It used to produced gaskets and seals.
- Wrapping for textile products.
- It is used for Cable coating and insulation tapes.
- They are used for transporting water and various other chemicals.
- Polyethylene containers are used as packaging material for pharmaceuticals, corrosive chemicals, and cosmetics.

Polypropylene (PP)

- Polypropylene is formed the manomer propane
- i.e., Propylene.
- Polypropylene has becomes a major plastics, especially for injection molding.
- It is similar to high density polyethylene (HDPE). It is lightest of the plastics and strength to weight ratio is high.

Properties of PP

- They are high melting point.
- They are lighter weight.
- It has excellent fatigue resistance.
- They are stiffer, hardener and stronger.
- It has good chemical and thermal resistance.
- Low density.
- Good surface hardness and good dimensional stability.
- Good resistance against moisture and chemicals.

Application of PP

- Automotive and house ware.
- Fiber products for carpeting.
- It is also used for hinges components.
- Laboratory ware and bottles of various types.
- Shoes, textile cones and bobbins, toys.

Polystyrene (PS)

- This plastics account for about 20% of all the thermoplastics in commercials use.
- Polystyrene is made from ethyl benzene.
- A large benzene ring replaces a hydrogen atom on an ethylene molecule.
- Polystyrenes are predominantly amorphous and a tactic.

Properties of PS

- PS possesses good dimensional stability
- Low mould shrinkage and can be processed at a low cost.
- Dielectric resistance is satisfactory.
- Surface hardness of PS is better than PP.
- Mechanical properties within the operating temperature limit.
- It is soluble in many hydrocarbons.
- It is easy thermoform ability.

Application of PS

- It is used for household items such as imitation glass and cut glass varieties.
- The copolymerized PS can be used for injection molded industrial components.
- PS is also used in refrigeration components and many applications.
- PS are used in the insulation of cold storage warehouse, building foundations.
- Packaging items for delicate instruments such as cameras, calculators.
- Other application includes automobile interior parts dials and knobs.

Polyvinyl Chloride (PVC)

- The widely used acronym for polyvinyl chloride is PVC.
- It is one of the most widely used plastics in terms of volume produced.
- PVC is made by reacting acetylene gas (C_2H_2) with hydrochloride acid in the presence of a suitable catalyst.

- The manomer has one chlorine atom substituted for a hydrogen atom.

Properties of PVC

- PVC has a relative high density (52.5 – 63)
- Medium heat deflection temperature (52 -82)
- Good electrical properties
- High solvent resistance, flame and chemical resistance.
- PVC is a high rigid and brittle material.

Application of PVC

- Non plasticized PVC grade are widely used for manufacturing of pipes and conduits.
- PVC finds use in furniture and automobile upholstery, shaped cushion, interior wall coverings, rainwear, shoes, luggage and shower curtains.
- PVC is used for auto top covering, electric wires insulation, floor mats and interior and exterior trim.
- Other applications include garden hoses, refrigerator gaskets, appliance components and house ware.
- PVC organ sol, which is a solution of the resin in solvent is used for impregnating fabrics, paper coatings, lamp shade etc.,

Polymethyl methacrylate (PMMA)

- This complicated name applies to a polymer that everyone is familiar with. Polymethyl methacrylate is the polymer used to make the clear, sheet material in unbreakable windows.

- It may be more readily recognized by the trade name Plexiglas.

- Another name commonly used for polymers based on polymethyl methacrylate is acrylics.

Properties of PTFE

- Acrylics are noted for excellent optical properties.
- Its have good mechanical properties.
- Good thermal resistance and very good dimensional stability.
- It also has an excellent weather resistance.
- Acrylic moldings have deep luster and high surface gloss.

Application of PTFE

- One of the most popular applications of acrylics is in making thermoformed sheets.
- It is used in wind shield for automobile, boats, and snow mobiles, aircraft and instruments dials.
- Due to glossiness and transparency acrylics find uses as decorative and novelty items.

Polypthylene Terephthalate (PET)

- Thermoplastics polyesters have been used for about 35 years, predominantly in films for packaging and in fibers.
- Everyone is familiar with polyester clothing and polyester auto tire reinforcement.
- These are thermoplastics polyester, usually polyethylene terephthalate.

Properties (PET)

- PBT has good injection characteristics and mechanical properties similar to nylon.
- It has a use temperature above that of most nylons, and it does not have the moisture absorption problems of nylon.
- PET and PBT are closely related polymers in use properties with only subtle difference.
- PET is slightly stronger and lower in cost.

Application of (PET)

- Structural application in appliances, automobiles, and consumer products.
- About 45% of the production of PET goes into films for photography and packaging.
- PET has been used for plastics liter-size beverage bottles and for engineering plastics application such as auto parts, gear, and cams.
- PBT is widely used in blends.
- It is also used in electrical application.

Polycarbonates (PC)

- Polycarbonates are really polyester, since both are ester of carbonic acid and an aromatic biphenol.
- The polycarbonate is amorphous linear polyesters with excellent mold ability and impact strength.
- Which is made from the condensation of biphenol A and carbonic acid.

Properties of (PC)

- PCs possess excellent dimensional stability over a wide range of temperature.
- Good ductility properties they can be nailed sawed, punched, drilled, cold drawn.
- It has electrical and chemical resistance properties.
- They have a good strength and rigidity and because of high modulus of elasticity, possess good creep resistance.
- PC parts have good stability and accurate molded parts.

Application of (PC)

- PCs are used in the manufacture of helmets, safety shields, street lamp cover, factories and school windows, machine guard, gears and cams.
- PCs find uses as housing for high voltage lamps, aircraft parts, instruments panel.
- Other applications include electronic equipment, equipment for cars, electrical relay covers, business machine, gauges, refrigerator parts, food vending machine.
- It is used in structural application. Principle application for automotive trim, lenses and like, and for all sorts of application parts.

Polyamides (PA)

- An important polymer family that forms characteristics amid linkage (CO-NH) during polymerization is called the polyamides (PA).
- The most important members of the PA family are nylons, of which the two principle grade are nylon – 6 and nylon 6, 6 (the number are codes that indicate the number of carbon atoms in the monomer) . Nylon – 6, which were developed at Du point in the 1930s.Properties of nylon – 6, developed in Germany are similar.

Properties of (PA)

- Nylon is strong, highly elastics, tough abrasion resistant, and self – lubricating.
- It retain good mechanical properties at temperature up to about 125 (250)
- One shortcoming is that it absorbs water with an accompanying degradation in properties.

Application of (PA)

- Nylon is commonly a good substitute for metals in bearings, gear, and similar parts.
- The majority of applications of nylon (about) are in fiber for carpets, apparel, and tire cord.

Acrylonitrile Butadiene Styrene (ABS)

- It's a type of polystyrene (PS)

- - This material is a terpolymer of acrylonitrile, butadiene and styrene.
- Usual compositions are about half styrene with the balance divided between butadiene and acrylonitrile.
- Acrylonitrile Butadiene Styrene (ABS) polymer was first discovered during World War II

FEATURES

- Flame Retardant ,
- High Heat Resistance ,
- Good Impact Resistance ,
- High Impact Resistance ,
- High Flow ,
- General Purpose ,
- Good Flow ,
- Good Process ability,
- High Gloss ,
- Good Dimensional Stability

USES

- Automotive Applications ,
- Electrical/Electronic Applications ,
- General Purpose ,
- Housings ,
- Appliances ,
- Business Equipment ,
- Automotive Interior Parts ,
- Thin-walled Parts ,
- Appliance Components ,
- Computer Components ..

Application of ABS

- helmets,
- refrigerator doors,
- computer housings,
- suitcases,
- steering wheels,
- grills for hot air systems,
- pump impellers,
- telephone housings,
- electrical conduct, tubes and pipes.
- In view of its low temperature resistance, ABS is used for fishing tackle boxes, fishing reels, etc.
- Various thermoformed components are used in boats and trailer components.

Disadvantages

- Limited weathering resistance
- Moderate heat, moisture and chemical resistance
- Relatively high cost
- Flammable with high smoke generation

Polyimides (PI)

- Polyimides are a group of linear aromatic polymers
- They are produced in condensation reaction

Characteristics of PIs:

- Good mechanical properties
- Excellent thermal resistance up to 250ºC
- Good resistance to organic solvents expect, alikies and concentrated acids

Applications of PIs:

- High temperature electrical cables.
- Printed circuit boards,
- Turbine blades and other components requiring fire resistance, strength at high temperatures and good electrical properties.

Polyamide-imides (PAI)

- Polyamide-imides are amorphous thermoplastic materials with excellent mechanical properties, especially at elevated temperatures.
- Its similar to PI .
- Its also a aromatic polymer for use at high temp.

Properties of polyamide imide

- The distinguishing characteristic of this family of polymers is high strength and a high maximum operating temperature.
- Polyamide imides have a high modulus of elasticity.
- They are transparent to microwave and are not affected by radiations.
- They have excellent thermal resistant upto 250 ˚. Celcius.
- Used in spark ignition engines.

Applications of polyamide imide

- Most involve carrying loads at elevated temperatures or some elevated temperature electrical application.
- Users capitalize on this PAT's elevated temperature strength.
- Valves made from PAI replace bronze castings in hot water plumbing systems.
- Polyamide imides are premium engineering plastics.
- They should be used where elevated temperature strength and injection moldability are important selection factors.

Polyphenylene oxide (PPO)

- Its 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 of PPOs

- PPE is an amorphous high-performance plastic. The glass transition temperature is 215 °C, but it can be varied by mixing with polystyrene. Through modification and the incorporation of fillers such as glass fibers, the properties can be extensively modified.

Applications of PPOs:

- structural parts, electronics, household and automotive items that depend on high heat resistance, dimensional stability and accuracy.

Polyphenylene sulphide (PPS)

- It is an organic polymer consisting of aromatic rings linked by sulfides. Synthetic fiber and textiles derived from this polymer resist chemical and thermal attack.

Characteristics of PPSs

- It's a high temperature thermoplastic polymers
- resistance to heat, acids, alkalies, mildew, bleaches, aging, sunlight, and abrasion.
- It absorbs only small amounts of solvents and resists dyeing.

Applications of PPSs

- filter fabric for coal boilers,
- papermaking felts,
- electrical insulation,
- film capacitors, specialty membranes, gaskets, and packings.

Polyether ether ketone (PEEK)

- It is a linear crystalline hetro chain polymer for High temperature plastics

Characteristics of PEEKs:

- Melting temperature is high.
- Low flammability and low smoke emission.
- Good fatigue and chemical resistance.

Applications of PEEKs:

- High temperature engineering components, high temperature electrical coatings and aerospace applications.

Engineering CERAMICS

Classifications of engineering ceramics

- Alumina (Al_2O_3)
- Silicon Carbide (SiC)
- Silicon Nitride (Si_3N_4)
- Partially stabilized Zirconia
- Sialons

Alumina (aluminium oxide) Al_2O_3

- Its produced from **bauxite**
- It is **the most widely used oxide ceramic material**. As a raw material, Al_2O_3 powder is produced in large quantities from the mineral **bauxite**
- It is most cost effective & widely used material.

Properties of Alumina

- Excellent hardness, wear resistance
- They are more stiffer than steel
- More stronger in compression than hardened steel
- Very good environmental resistance
- high tensile and toughness properties.
- Excellent dielectric properties
- Resist strong acid and alkali attack at high temperatures.
- Good thermal conductivity.
- Excellent size and shape capability.

Applications of alumina

- Spark plug insulators
- Electronic circuits
- Rocket nozzles
- Electrical and electronics devices
- Bearings and seal rings
- Gas laser tubes
- Wear pads
- High temperature electrical insulators
- High voltage insulators
- Furnace liner tubes

Silicon carbide (sic)

- **Silicon carbide (SiC) is an important ceramic material that is made by allowing sand to react with powdered carbon at high temperature round 2000°C . Carbon monoxide is also formed.**
- The powdered material is formed or compacted by using most of the conventional ceramic forming processes such as die pressing, isostatic pressing and injection moulding. Then sintered silicon carbide can then be machined to precise tolerances using a range of precision diamond grinding or lapping techniques.

Properties of Sic

- High tensile strength
- High stiffness , hardness
- Better dimensional stability
- Good wear resistant, Low porosity
- Good corrosion resistant.

Applications of Sic

As a abrasives for grinding wheel
As a coating material
As a refractory tubes
In nuclear reactor
In bearings
And in very high temperature places

Silicon nitrate (Si_3n_4)

The silicon nitride ceramics involves **powder preparation, mixing, shaping and sintering or hot-pressing at temperatures typically above 1700°C.**

The material is dark gray to black in color and can be polished to a very smooth reflective surface, giving parts with a striking appearance.

Properties of silicon nitrides

- Resistant to strong acids
- Resistance to thermal shock
- Low density and low weight
- Low thermal expansion
- More stiffer

Applications of silicon nitrides

Used in

- Cutting tool materials
- Turbine parts
- Pump parts
- High temperature engineering components

Partially stabilized zirconia (PSZ)

- It's a zirconium oxide
- Blended and sintered with others like magnesium oxide, calcium oxide
- Zirconia is an extremely refractory material.

Properties of PSZ

- High tensile strength
- Low thermal conductivity

Applications of PSZ

- As a blade in jet engine
- As a joint in furnace portions
- Internal combustion engine parts

Sialons

- They are Si – Al – O – N
- They are formed when Aluminium and oxygen partially substitute for **silicon** and **nitrogen** in **silicon nitride**
- Sialon, is a silicon nitride ceramic with a small percentage of aluminum oxide added.

They are formed when silicon nitride (Si_3N_4), aluminium oxide (Al_2O_3) and aluminium nitride (AlN) are reacted together

Properties of sialons

- High tough and strength
- Good mechanical properties
- Light weight
- Low co-efficient of thermal expansion

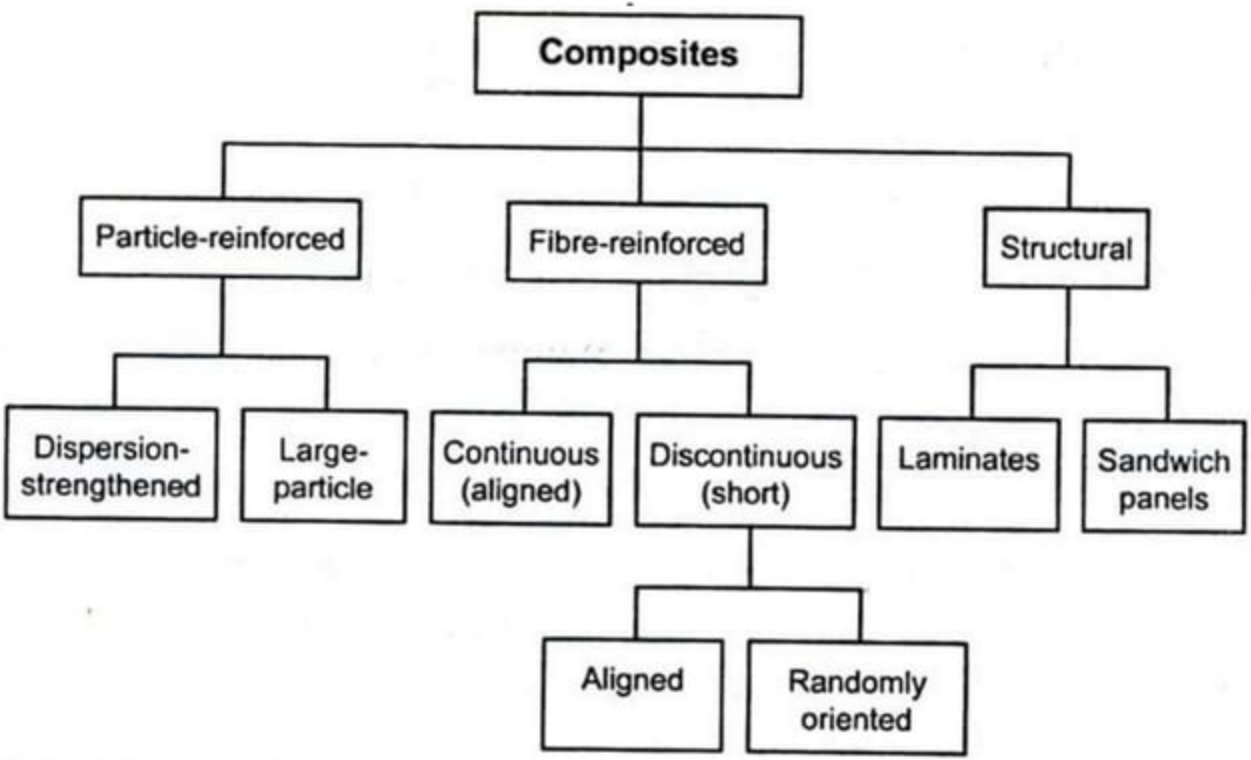
Applications of sialons

Used in

- Cutting material
- Nozzles , Welding shields
- Radiant heater tubes
- impellers

composites

To get a require properties in metals

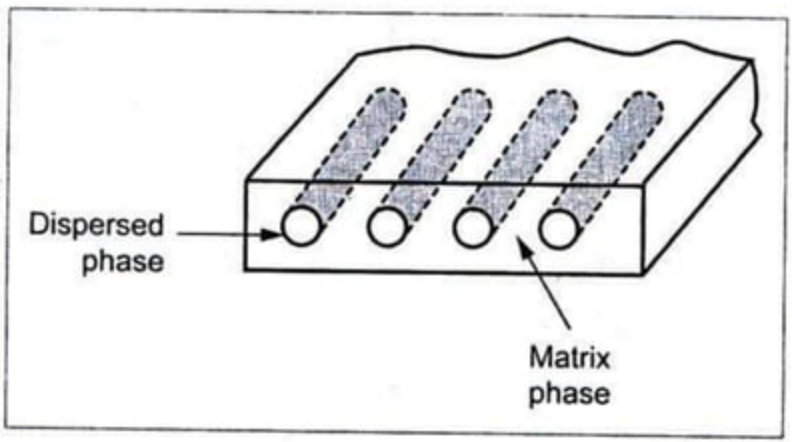

Composites
Particle-reinforced
Fibre-reinforced
Structural
Dispersion-strengthened
Large-particle
Continuous (aligned)
Discontinuous (short)
Laminates
Sandwich panels
Aligned
Randomly oriented

why

- Two or more metals added to get require qualities in metal.
- The weakness of one metal rectified by the strength of second metal
- Example

  Aerospace components

  That should have low weight , stiffness, impact and corrosion resistance, good abrasive properties.



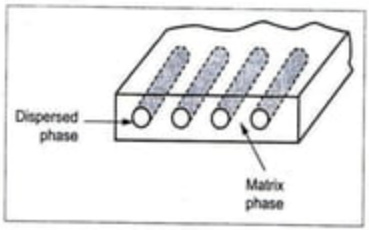
Constituents of composites

most common man-made composites

- **Polymer Matrix Composites (PMC's)** –as FRP - Fibre Reinforced Polymers (or Plastics) – these materials use a polymer-based resin as the matrix, and a variety of fibres such as glass, carbon and aramid as the reinforcement.
- **Metal Matrix Composites (MMC's)** - Increasingly found in the automotive industry, these materials use a metal such as aluminium as the matrix, and reinforce it with fibres such as silicon carbide.
- **Ceramic Matrix Composites (CMC's)** - Used in very high temperature environments, these materials use a ceramic as the matrix and reinforce it with short fibres, or whiskers such as those made from silicon carbide and boron nitride.

Particle re-inforced composites

- Its consist of particles of one material dispersed in a matrix of a second material



Constituents of composites

- The fine dispersion particle posses good strength in composites.
- The size, distribution and orientation of particles defines the strength of the composite.
- **Types**

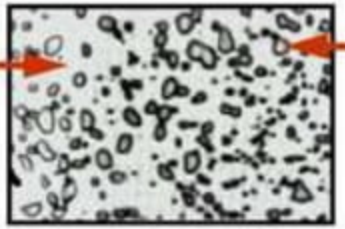
1. dispersion strengthened composites

2. Large particle composites

Particle Reinforced Composites

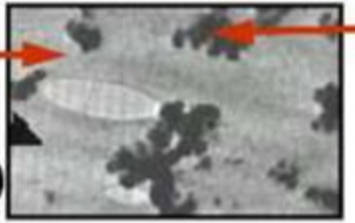
Spheroidized Steel

Matrix:
Ferrite
(α - iron)
Ductile



Particle:
Fe_3C
(cementite)
Brittle

Matrix:
Rubber
(Compliant)



Particle:
Carbon
(Stiffer)

Automobile Tire

1.Dispersion strengthened composites

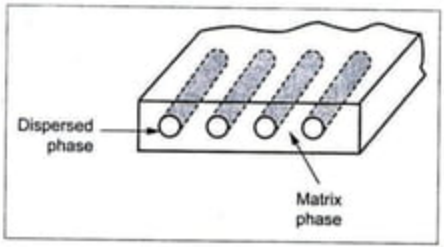
- The particles are smaller and having diameter 0.01 – 0.1 microns and volume concentration 1 – 15 %
- This method is similar to that for precipitation hardening.
- Due to this , the composites have good yield and tensile strength. And the plastic deformation is restricted.

Examples and applications of some dispersion-strengthened composites

S.No.	Composite system	Applications
1.	Ag–CdO	Electrical contact materials
2.	Al–Al_2O_3	Possible use in nuclear reactors.
3.	Be–BeO	Aerospace and nuclear reactors.
4.	Co–ThO_2, Y_2O_3	Possible creep-resistant magnetic materials
5.	Ni, Cr–ThO_2	Turbine engine components
6.	Pb–PbO	Battery grids
7.	Pt-ThO_2	Filaments, electrical components
8.	W–ThO_2, ZrO_2	Filaments, heaters

2. Large particle composites

- The particles diameter greater than 1 micrometer and volume concentration are greater than 25 %
- Here the load on this composite is shared by both matrix and particles.
- It posses good strength



Constituents of composites

- Tungsten carbide or Titanium carbide embedded in a metal matrix of cobalt or nickel.
- These composites used as a cutting tool

Other particle re-inforced composite

- Bricks
- Concrete
- Grinding and cutting wheel
- Electrical contacts (Tungsten re – inforced silver)
- Polymer & Elastomers (such as vulcanised rubber)

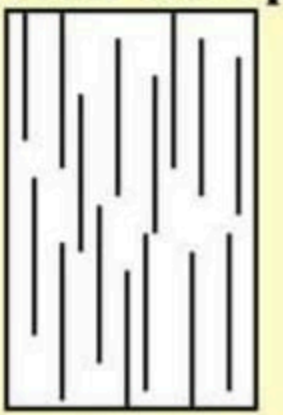
FIBRE REINFORCED COMPOSITES

- Here the dispersed phase is in the form of fibres.

- These fibre reinforced composites having improved strength, fatigue resistant, stiffness and strength-to-weight ratio

Fiber Orientations in Fiber Reinforced Composites

Continuous and aligned fibers



Discontinuous and aligned fibers

Discontinuous and randomly oriented fibers

Some fibre and matrix materials used in the fibre-reinforced composites

Fibre materials	Matrix materials
1. Polymers Kevlar, nylon, polyethylene 2. Metals Be, Boron, W 3. Glass E-glass, S-glass 4. Carbon HS (high strength) HM (high modulus) 5. Ceramics Al_2O_3, B_4C, SiC, ZrO_2 6. Whiskers† Al_2O_3, Cr, graphite, SiC, Si_3N_4	1. Thermosetting resins Polyester resins, epoxide resins 2. Thermoplastics PA, PAI, PBT, PET, PES, PPS, PEEK 3. Metal matrices Al, Ti, Mg, Cr and Ni, together with their alloys. 4. Composite matrices

Some fibre-reinforced composites and their applications

S.No.	Fibre-reinforced composite system	Typical applications
1.	Borsic aluminium	Fan blades in engines, other aircraft and aerospace applications.
3.	Kevlar-epoxy and Kevlar-polyester	Aircraft, aerospace applications (including space shuttle), boat hulls, sporting goods (including tennis rackets, golf club shafts, fishing rods), flak jackets.
3.	Graphite-polymer	Aerospace and automotive applications, sporting goods.
4.	Glass-polymer	Light weight automotive applications, wear and marine applications, corrosion-resistant applications, sporting goods equipment, aircraft and aerospace components.

Applications of composites

1.	***Commercial aircraft*** Used for air conditioning duct, radar dome, landing gear door, seats, floorings, window reveals, ceiling panels, propeller blades, nose, wing body, elevators, ailerons, air brake, *etc.*
2.	***Military aircraft*** Used for speed brake, rubber trunnion, forward fuselag, elevators, ailerons, landing gear doors, horizontal stabilizers, *etc.*
3.	***Missiles*** Used for remote piloted vehicles, filament wound rocket motors, wings, rotor cases, *etc.*
4.	***Space hardwares*** Used for antennas, struts, support trusses, trusses for telescopes, storage tanks for gases and fluids at cryogenic temperatures, *etc.*

5.	***Automobile and trucks*** Used for drive shafts, bumpers, door and window frames, starter motor commutators, body panels, radiator and other hoses, timing and V belts, drive chains, *etc.*
6.	***Electrical and electronics*** Used for microphone housing, miniature-electronic card holder, ribs to protect printed circuit boards, parabolic antenna, *etc* ; electrical equipments—switch casings, cable and distribution cabinets, junction boxes, *etc.*
7.	***Marine applications*** Used for small boat hulls, sonar domes, masts, tanks, decks, submarine masts, spinnakar pole on the racing yatch, plates in nuclear submarine lead acid batteries, *etc.*

8.	***Sporting equipments*** Used for tennis rackets, golf club shafts; bicycle components such as wheel, frame, forks, handlebars, pedal crank arms, package carriers, fenders, *etc.*; gliders; boats; sail boards.
9.	***Other applications*** Other applications include bridge building; joint implants, heart valves; leaf springs; chemical industries application—for storing aggressive chemicals; wine vats and pipelines for water and sewage; in reinforced wood products, *etc.*