Dhanalakshmi College of Engineering.

Department of Mechanical Engineering.

ME 6403. Engineering Materials and Metallurgy.

UNIT - IV. Non-Metallic Materials.

Polymers:

The term polymer is derived from two Greek words 'poly' and 'mers'. The term 'poly' means 'many', and the term 'mer' means 'parts or units'. Thus polymers are composed of a large number of repeating units of small molecules called monomers.

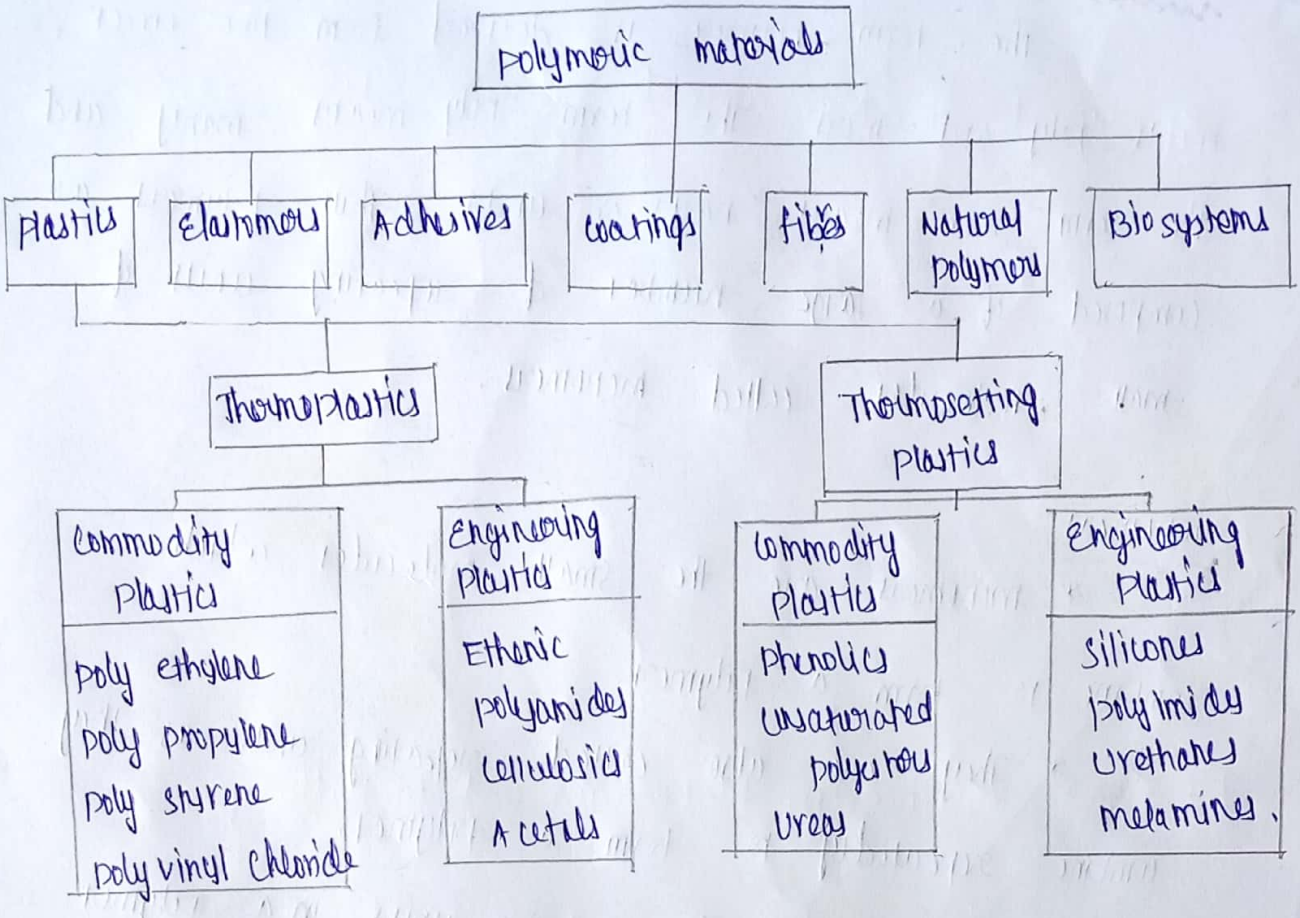
monomers:

* monomers are the small molecules which combine to form a polymer.
* They are also called repeating units as they combine repeatedly to form a polymer.
* The number of repeating units in a polymer is known as degree of polymerisation.

polymerisation:

* polymerisation is a reaction which involves the union of small molecules to form molecules having higher molecular weight called polymer.
* Therefore, a polymer is made up of thousands of monomers joined together to form a large molecules.

classification of polymers:



Terminology used in polymers:

* **monomer:**
It is a small molecules consisting of a single mer, i.e., a single unit / blocking block.

* **polymer:**
It is a macromolecule formed by the repeated linking of many monomers.

* **polymerisation:**
It is the process of forming a polymer.

Types of copolymers:

* Random copolymer:

In this, the two different units are randomly dispersed along the chain. as shown in fig (a)

* Alternating copolymers:

In this, the two mer units alternate chain positions. as shown in fig (b)

* Block copolymer:

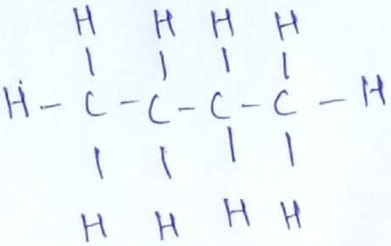
In this, the identical mers are clustered in blocks along the chains as shown in figure (c)

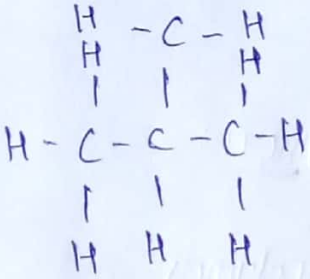
* Graft copolymer:

In this, homopolymer side branches of one type may be grafted to homopolymer main chains that are composed of a different mer. as shown in figure (d).

* Isomerism:

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



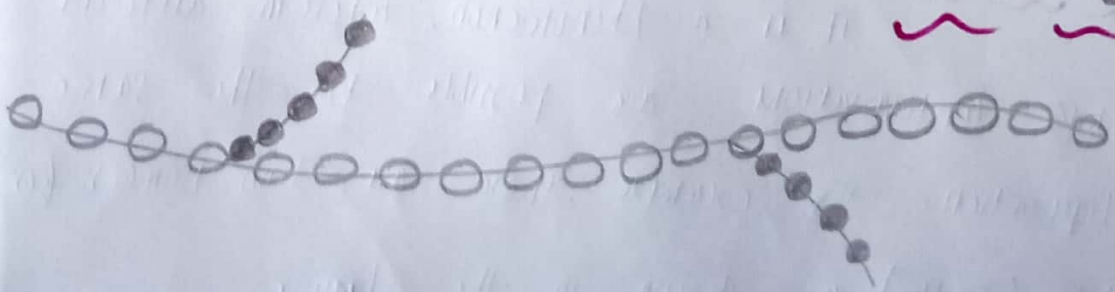


(a) RANDOM

(b) ALTERNATING

(c) BLOCK

(d) GRAFT COPOLYMERS



Types of Homopolymers:

* Linear polymers:

Linear polymers are those in which the mer units are joined together end to end in single chains.

* Branched polymers:

Branched polymers are those in which side-branch chains are connected to the main ones,

* Cross-linked polymers:

In cross-linked polymers, adjacent linear chains are joined one to another at various positions by covalent bond.

* Network polymers:

Network polymers have three active covalent bonds (known as trifunctional mer units), which form three-dimensionals networks instead of the linear chain framework.

* Homopolymer:

It is a polymer made out of identical monomer. In other words, when all the repeating units along a chain are of the same type, the resulting polymer is called a homopolymer.

* Copolymer:

It is a polymer which is obtained by adding different types of monomers.

* Degree of polymerisation:

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

* High-polymers:

Solid polymers which have very high molecular weights are called high-polymers.

* Oligo-polymers:

Oligo-polymers are liquid/gas polymers with very short chains.

PLASTICS:

A Plastic may be defined as an organic polymer, which can be moulded into any desired shape and size with the help of heat, Pressure, or both. Standard forms in which plastics are available include powders, sheets, films, rod, tube and liquids.

★ NATURAL VS SYNTHETIC PLASTIC:

The Natural plastics are available as such in the Nature are called Natural plastics.

The synthetic plastics which are Prepared artificially are called synthetics.

★ SOURCES OF RAW MATERIALS FOR PLASTICS:

The Three Main sources of raw Materials are

(i) Animal and vegetable By-Products.
(ii) Coal By Products.
(iii) Petroleum by-Products.

★ Classification of Plastics:

There are two types of Plastics. They are

(i) ThermoPlastics.
(ii) Thermo setting plastics.

(i) Thermo Plastics:

Thermo Plastics are known as Thermoplasts whose plasticity Increases with the increase in Temperature.

Thermo Plaste are solidified and reheated, as many time as desired.

Some of the Important Thermo-plastics are

a) Polythenes.
b) Polystyrenes.
c) Polyvinyls.
d) acrylics.

(ii) Thermosetting Plastics:

Thermosetting plastics, are known as Thermosets, are plastics which become permanently hard when heat is applied and do not soften upon subsequent heating.

Example for thermosetting plastics are

a) Polyesters.
b) Phenolic.
c) Epoxides.

Thermo plastics.

* They are formed by addition polymerisation.
* They are composed of chain molecules.
* Softening is possible on reheating.
* They can be easily moulded and remoulded into any shape.
* They can be recycled again.
* They are soft, weak, and less brittle.
* Soluble in organic solvents.
* Not suitable for high temperature services.
* Exapus: polythenes.
  polystyrenes.
  pvc.

Thermo Setting Plastics:

They are formed by condensation polymerisation.

They are composed of three dimensional network of cross linked molecules.

Softening is not possible.

They cannot be remoulded into any new shape.

They cannot be recycled again.

They are hard, strong and more brittle.

Not soluble in organic solvents.

They are usable in Hige Temperature processes.

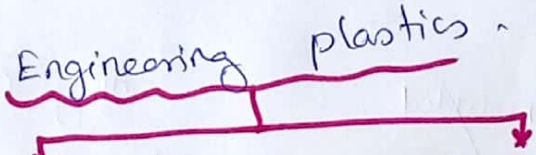
polyesters.
phenolics.
epoxides.

Engineering Plastics:-

The plastics which are used in engineering applications are known as Engineering plastics.

They Have Higher strength, greater environmental resistance, and better physical properties.

They are more costlier than commodity plastics.



Thermo plastics.

- Ethenic.
- polyamides.
- Cellulosics.
- Acetals.
- polycarbonates.
- polymides.
- polyethers.

Thermo setting plastics.

- Silicones.
- polyimides.
- Urethanes.
- melamines.
- Epoxides.

Applications of Thermoplastics:-

Hydrocarbon plastics:

- polyethylene.
- polypropylene.
- polystyrene.
- polyvinyle chloride.
- poly tetra fluoro ethylene.

Acrylic materials.

- PMMA - polymethyl methacrylate.
- PAN - polyacrylonitrile.

Polyvinyl chloride (PVC)

Poly (vinyle chloride) PVC has a chemistry and a physical structure that makes it broadly unique in the polymer world. It is made commercially at several molecular weights, depending on the intended application. from Mw = 39000 g/mol, to Mw = 168000 g/mol

n = degree of polymerization

PVC has grown to be one of the major plastics of the world. The vinyl resins have been suppressed in volume by the olefin polymers. PVC in second in volume to polypropylene among plastic materials.

Polystyrene:

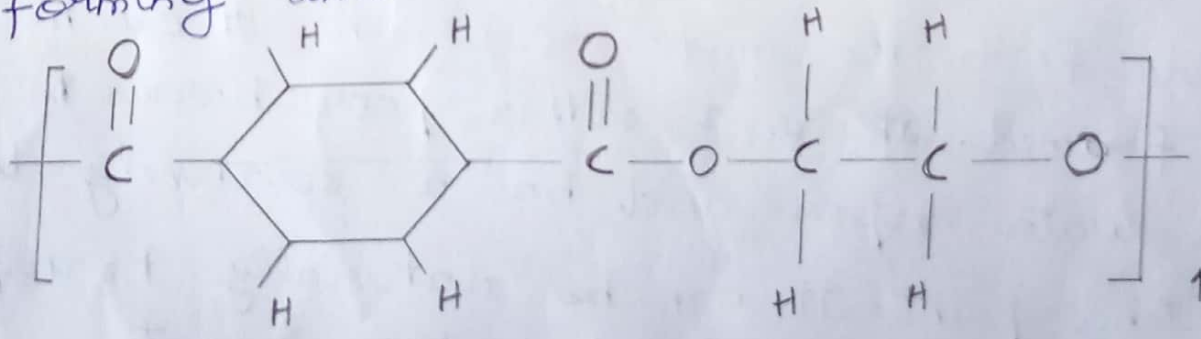
It is a synthetic aromatic polymer made from the monomer styrene. It can be solid or foamed. It is a rather poor barrier to oxygen and water vapor and has a relatively low melting point. It can be naturally transparent, but can be colored with colorants.

* Flow properties are the most important properties of polystyrene process.
* 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 mol weight.
* Crystal polystyrenes have very low impact strengths of less than 0.5 ft-lb.

Polyethylene terephthalate:

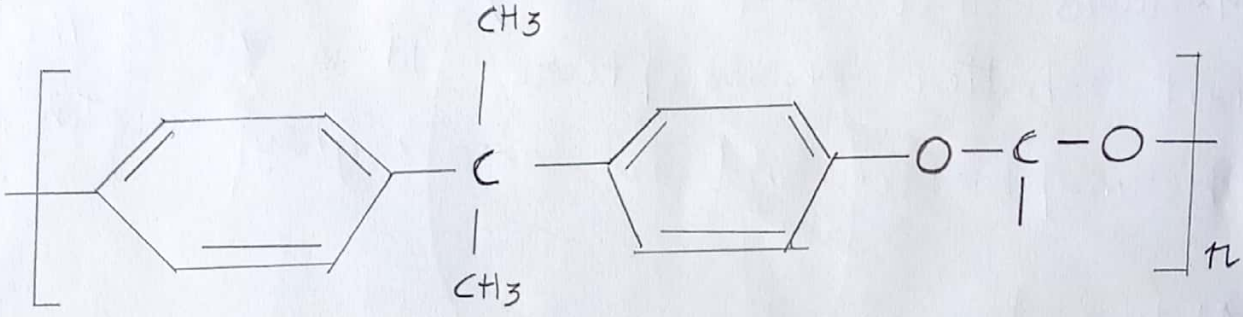
PET is an acronym for polyethyle terephthalate, which is a long-chain polymer belonging to the generic family of polyesters. PET is formed from the intermediates, terephthalic acid (TPA) and EG, which are both derived from oil feedstock. PET in its purest form, is an amorphous glass-like material under the influence of direct modifying additives it develops crystallinity.

The three major packaging applications of PET are as containers, semi-rigid sheet for thermoforming and thin oriented films.



Polycarbonate:

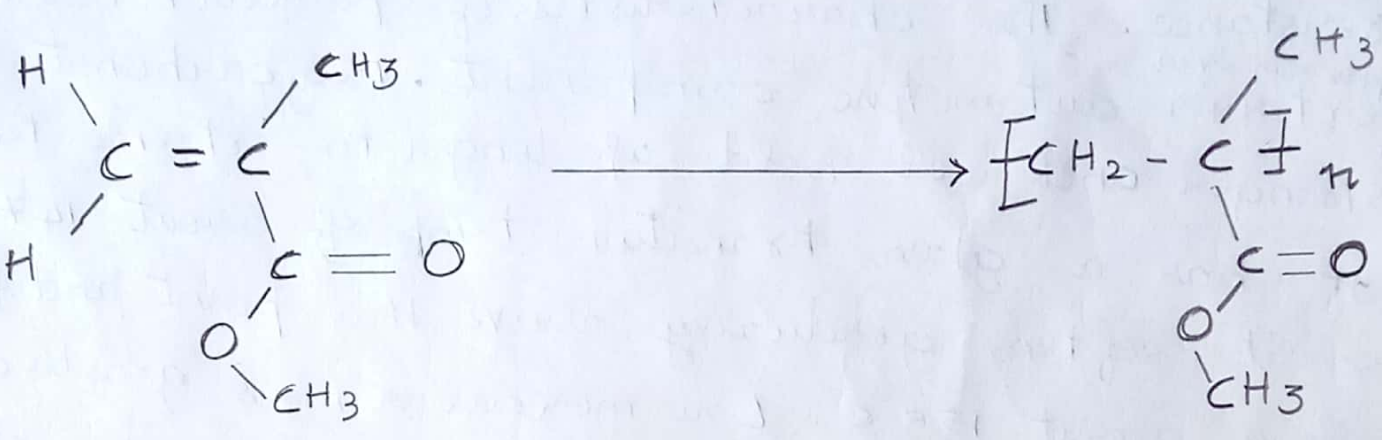
It is a durable material. Although it has high impact-resistance, it has low scratch-resistance. The characteristics of polycarbonate include application over exterior automotive components. Polycarbonate is stronger and will hold up longer to extreme temp. It has a glass transition temp of about 147°C so it softens gradually above this point and flows above about 155°C. Low molecular mass grades are easier to mold than higher grades, but their strength is lower as a result.



2. Poly methyl methacrylate:

These are polymers of the esters of methacrylic acids. The most commonly used among them is polymethyl methacrylate. It is the polymer of methyl methacrylate, with chemical formula $(C_5H_8O_2)_n$. Another polymer poly (methyl acrylate) is a rubbery material similar to that of poly methyl acrylate.

Poly (methyl methacrylate) is produced by free radical polymerization of methyl- methacrylate in mass or suspension polymerization.



It 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

Application:

* Optics
* Vehicles
* Electrical Engineering.

Poly tetra fluro ethylene:

It is a synthetic fluoropolymer of tetra fluro ethylene that has numerous applications. It is a flurocarbon solid, as it is a high-molecular weight

Acryl nitride butadiene styrene:

Its chemical formula is $(C_4H_6)_y \cdot (C_3H_3N)_z$ is a common thermoplastic polymer. Its glass transistion temp is 105°C. It is amorphous and therefore has no true melting point.

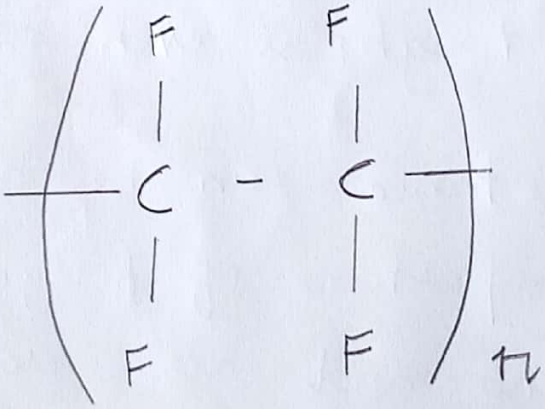
It is a terpolymer made by polymerization of styrene and acrylonitrile in the presence of polybutadiene. The polybutadiene, a rubbery substance provides toughness even at low temp.

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

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.

consisting wholly of carbon and fluorine. It is ishydrophobic: neither water nor water-containing substances wet PTFE.

It 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.

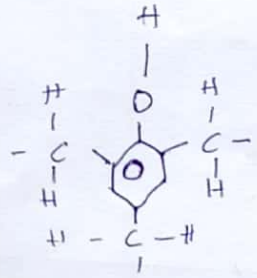
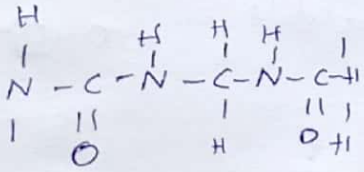
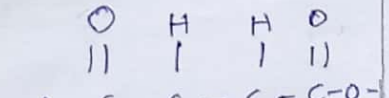


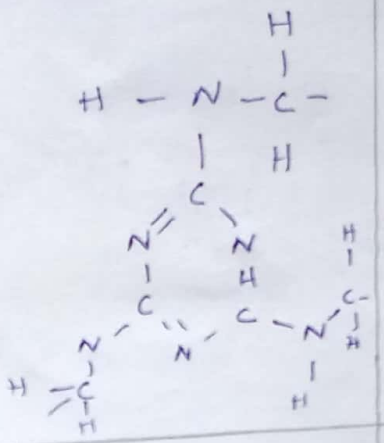
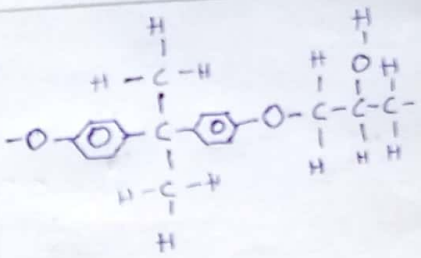
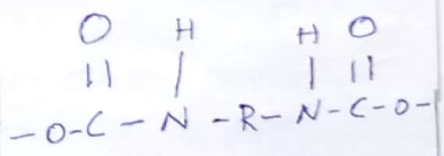
PTFE gains its properties from the aggregate effect of carbon-fluorine bonds, as do all fluorocarbons. The only chemicals known to affect these carbon-fluorine bonds are reactive metals like alkali metals.

Applications.

+ Wiring for aerospace and computer application.

(*) Trade names, Repeat unit structures, properties and typical applications for a number of thermosetting polymers.

S.No	Abbreviation	Name	Trade names	Repeat unit structure	properties	Typical applications
1.	PF	Pheonal formaldehyde	Bakelite, Durez, Resinox		* Hard, rigid and stable upto 150°C. * Low thermal conductivity	Electrical plugs, sockets, switches, door knobs and handles, adhesives coating and laminates
2.	UF	Urea formaldehyde	–		* Hard and rigid * Good electrical insulators. * Good resistance to most chemicals	Electrical devices, circuit breakers, switches, and the like. Used in the manufacture of laminates, used for bottle caps etc.
3.	–	polyesters	Selectron Laminac, paraplex		* Excellent electrical properties * Low cost	Safety helmets, fibre glass boats, machine covers, structural panels

S.No	Abbreviation	Name	Trade names	Repeat unit Structure	Properties	Typical application
4	MF	Melamine formaldehyde	–		As same as of urea formaldehyde	As same as of urea formaldehyde
5	EP	Epoxides	Epon, Epi-rez, Araldite		* Very hard and rigid * Dimensionally stable	Used as adhesives, as rigid moulded Parts for electrical applications, automative components, circuit boards, sporting goods etc.
6	PVR	polyurethanes	–		* Very good wear resistance * Resistant to oils greases and petrol	Hose, car bumpers, shoe heel tips, hammer heads etc.

(*) Types of engineering ceramics.

S.No	Class	Material types	Applications
1.	Single oxides	Alumina (Al_2O_3)	Electrical insulators
		chromium oxide (Cr_2O_3)	Wear coatings
		Titania (TiO_2)	Thermal insulation
		Zirconia (ZrO_2)	
2.	Mixed oxides	Kaolite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$)	Clay products
3.	Carbides	silicone carbide (SiC)	Abrasives
		Vanadium carbide (VC)	Wear coatings
		Tantalum carbide (TaC)	Cutting tools
		Boron Carbide (B_4C)	Abrasives
4.	Nitrides	Silicon nitride (Si_3N_4)	Wear parts
		Boron nitride (BN)	Insulator
5.	Sulphides	Molybdenum disulphide (MoS_2)	Lubricant
		Tungsten disulphide (WS_2)	Lubricant

(*) Types of Ceramics

S.No	Class	Material types	Applications
1.	Engineering ceramics	Oxides, carbides, nitrides, cermets	Dies, seals, bearings, spark plugs, diesel and turbine engine components
2.	whitewares	Porcelain, china, Stoneware	Tableware, wall tiles, sanitary ware
3.	Refractories	Acid, intermediate, base	furnace lining.
4.	Stone	Granite, Sandstone, limestone	concrete aggregate building Stone
5.	Glass	Various glasses, glass ceramics	Containers, Flate glass.
6.	Abrasives	Diamond, carborundum, corundum	Grinding wheels, abrasive cloth.
7.	cements	Portland cement, alumina	Concreate, Structural products.
8.	Nuclear ceramics	Oxides carbides of Uranium	Nuclear fuel elements.

Al_2O_3 [Aluminium oxide Alumina]

It is 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.

Application:

- Used in high temperature furnace, 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.

SiC [Silicon Carbide]

- Oldest ceramic material
- Used for abrasive 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 °C.
- Reaction bonding - Silicon powder react with Carbonaceous gases at high temperature.
- Hot pressing - powder by uniaxial pressure at 2150 °C. (pressure 30 MPa)

Properties:

- Increase strength, stiffness and hardness
- Increase thermal conductivity.
- Increase dimensional stability and polishability
- Resistant to bra ion and wear
- Increase chemical resistant.

Applications:

- Optical mirrors because of dimensional stability and polishabiling
- Used in nuclear reactor fuel elements.
- Used for mech seals, bearings and engine components.

Sialon [$Si_3 Al_3 O_3 N_5$]

- It is formed by blending and Sintering Silicon nitride, alumina-silical and aluminium nitride.
- Presennce of Aluminium oxide in sialon increase hardness because of presence in Silicon nitride increase toughess.

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

Application:

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

Application	Materials / Properties
1. Bush	Polyamides
2. Furnaces heating element	Ferritic stainless steel
3. Lathe bed	Cast iron
4. Coins	Gliding metal or bronze
5. Big end Bearing	Aluminium base bearing
6. ~~Big end~~ Girders for Airship	Aluminium / austenitic stainless steel
7. Turbine Blade	Valloy / monel metal
8. Conduit Pipes	PVC
9. Knobs	Styrene acrylo-nitrile Copolymer SAN
10. Windshields	Acrylic Plastic
11. Touch Screens	Indium tin oxide ITO
12. Furnace lining	Refractories / ceramics
13. Grinding (abrasive) wheels	Abrasives / Ceramics
14. Coating on cutting inserts	Diamond
15. Cutting inserts for ferrous alloy	Cemented Carbides

Si_3N_4 [Silicon Nitride]

Two main types of reaction bonding.

a) 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 0% theoretical density.

Properties:

- Brittle and react with atmosphere.
- No loss of strength at temp 1000°c.
- Decrease thermal expansion.
- Better toughness than Sic and Al2O3.
- Stiffness than steel.

Application:

- Cutting tool materials
- Used in heat exchangers, furnace components and crucibles.
- Used in automobile industry.
- Used for gas turbine parts, resist thermal cycling.

Zirconium Oxide [ZrO_2]

- Otherwise known as partially stabilized zirconia.
- It is blended and sintered with other oxide such as magnesium oxide or Calcium oxide to control crystal structure transformation
- It has monoclinic crystal structure at room temperature.
- Tetragonal 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
- Softer 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

Composites:

* Particle reinforced.
  - Dispersion strengthened.
  - Large particle.
* fibre reinforced.
  - Continuous
  - Discontinuous
* Structural.
  - Laminates,
  - Sand which panels.

Particle reinforced Composites:

They consists of particles of one material dispersed in a matrix of second material.

Dispersion strengthened Composites:

In Dispersion strengthened Composites, particles are normally much smaller, having diameters between 0.01 and 0.1 μm the volume concentrations are 1 to 15%.

SAP Composite:

The important example of dispersion strengthened Composite is SAP. is Sintered aluminium powder Composite.

we can significantly increase the high Temp properties of alluminium alloys since the composite does not overage.

Large Particle Composites.

In this type of Composites particle diameters are greater than 1 μm and volume concentrations are greater than 25%.

These Composites are designed to produce unusual combination of properties rather than to improve strength.

Different Cermet Materials and their applications.

Cermet Group.	Ceramic	Bonding Matrix	Applications.
* Carbides.	Tungsten Carbide	Cobalt.	cutting tools.
	Titanium Carbide	Cobalt	
	molybdenum Carbide	molybdenum(or) tungsten.	
	chromium carbide	Nickel.	gear gauges. dies.
* Oxides.	Aluminium oxide.	Cobalt or chromium	Rocket motor, Jet Engine parts.
	magnesium oxide.	magnesium or Al or cobalt.	
	Chromium oxide.	Chromium.	
* Borides.	Titanium boride.	Cobalt or nickel.	cutting tool tips.
	Chromium boride.	Nickel.	
	molybdenum boride.	Nickel.	

* Application of composites :-

* Composites find a wide variety of application in many field some of the important application are listen

1. Commercial air craft :-

* used for air conditioning duct, radar dome, landing gear door, seats, flooring, window panel, wiring panels, propeller blades, nose, wing body, elevator, ailerons, air brake, etc.

2. military air craft :-

* used for speed brake, rubber trunnion, forward fuselage, elevator, airlerons, gear door, etc.

3. missiles :-

* used for remote piloted vehicles, filament wound rocket motor, wings, rotor vane, etc.

4. Space hardware :-

* used for antennas, struts, support truss, storage tank for gases and fluids at cryogenic

5. Automobile and truck :-

used for microphone housing miniature - electronic board holder, ribs to protect printed circuit board, etc.

6. Electrical and electronics :-

used for microphone housing, miniature electronic card holder, ribs to rocket printed circuit boards etc.

7. marine application :-

used for small boat hulls, sonar dome, masts, tanks, decks, submarine masts, plates in nuclear submarine lead acid batteries, etc.

8. sporting equipment :-

used for tennis rackets, golf club shaft, bicycle components such as wheels, frames, forks, pedal crank arms racing etc.

9. other application :-

other application include bridge building, joint implants, heart valve, lab coating, chemical industries application in reinforced wood product, etc.

Review and summary :-

in this unit the non metallic material - polymer, ceramic and composite in detail

polymer have large, high- molecular - weight molecules produced by joining smaller molecule called monomer

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

* Two polymerisation mechanisms used are :-

1. Addition polymerisation
2. Condensation polymerisation.

1. Addition polymerisation :-

* It also known as addition polymerisation or chain reaction polymerisation, is a process by which two or more chemically to form long chain molecules.

2. Condensation polymerisation :-

* Also known as step-growth polymerisation is the formation of polymer by step wise intermolecular chemical reaction.

* polymer are various additives to improve their properties and performance. some of the polymer additives are : filler material, plasticizer, flame retardants and lubrication.

* A plastic may be defined as an organic polymer, which can be moulded into any desired shape and size with the help of heat.

* There are two broad group of plastic

1. Thermo plastics
2. Thermo setting.

* Thermo plastics :-

also known as thermo plasts, are the plastics whose plasticity increase with the increase in the temperature desired shape and hence they have a good recall / recap value.

* Thermo setting plastics :-

are also known as thermo sets, are plastics which become permanently hard when heat is applied and do not soften upon subsequent heating.

* The characteristics and typical application of some important thermo plastics such as PE, PP, PS, PVS, PTEF, PMMA, PAN, PA, POM, PC, PET.

* Ceramics :-

are non-metallic and inorganic solid that are processed and used at high temperature. typical ceramic are electrical and thermal insulator with good chemical stability.

* Engineering ceramics :-

also known as industrial ceramics or advance ceramic, are those ceramics that are specially used in engineering application

* Composites :-

* are produced when two or more material are joint to give a combination of properties that cannot be obtained

* the unit give a summary of the particulate - reinforced and fibre - reinforced composite.

* engineering ceramic are mainly oxides, carbides, sulphides and nitrides of metal.

* in this unit the properties and typically application of some important engineering ceramic such as Al_2O_3 SiC, Si_3N_4, PSZ, and silicon have been presented.

* composites and composed of two phase : matrix phase and dispersed phase.

* Also it may be noted that most of the thermoplastics are formed by addition polymerisation whereas most of the thermosetting plastics are formed.