UNIT III Ferrous and Non-ferrous Metals

- Effect of alloying additions on Steel
- α and β Stabilisers.
- Stainless and tool Steels
- HSLA, Maraging Steels
- Cast Iron, alloy Cast irons
- Copper and Copper alloys
- Brass, Bronze and Cupronickel
- Aluminium and Al-Cu
- Precipitation Strengthening treatment
- Bearing alloys, Mg-alloys, Ni-based Super alloys and Ti alloys.

High Strength Low Alloy Steels (HSLA)

- They are refered to as Micro-alloyed steels.
- Low Carbon Content (0.07 - 0.18 %C) with low alloying elements (< 0.5 %)
- Alloying elements include V, Ti, Nb and Al.
- alloying elements added form Carbide, nitride and Carbonitride Precipitate that provide Strength and hardness to Steel.
- Low Carbon Content enemes good ductility, malleability, toughness and weldability.
- These Steels have better Strength to weight ratio
- High hardness is obtained by fine grain size, Solid Solution Strengthening
- Its tensile Strength ranges from 50 to 80 kg/mm^2

Maraging Steels (Martensitic ageing - Superior Strength & toughness)

They are low carbon steels (< 0.03% C) containing 18 to 25% nickel and other alloying elements in small proportion.

Additional alloying elements - Mo, 3 to 5%, Co - 3 to 8%, Ti 0.2 to 1.6% and traces of Al.

Maraging steels are subjected to air hardening followed by aging, hence the name maraging steels.

The heat treated steel is then age hardened at about 500°C for three or more hours.

The aging treatment results in precipitation of intermetallic compounds such as Ni_3TiAl and Ni_3Mo in the matrix of martensite.

They have tensile strength upto 220 MPa

They also have excellent fracture toughness.

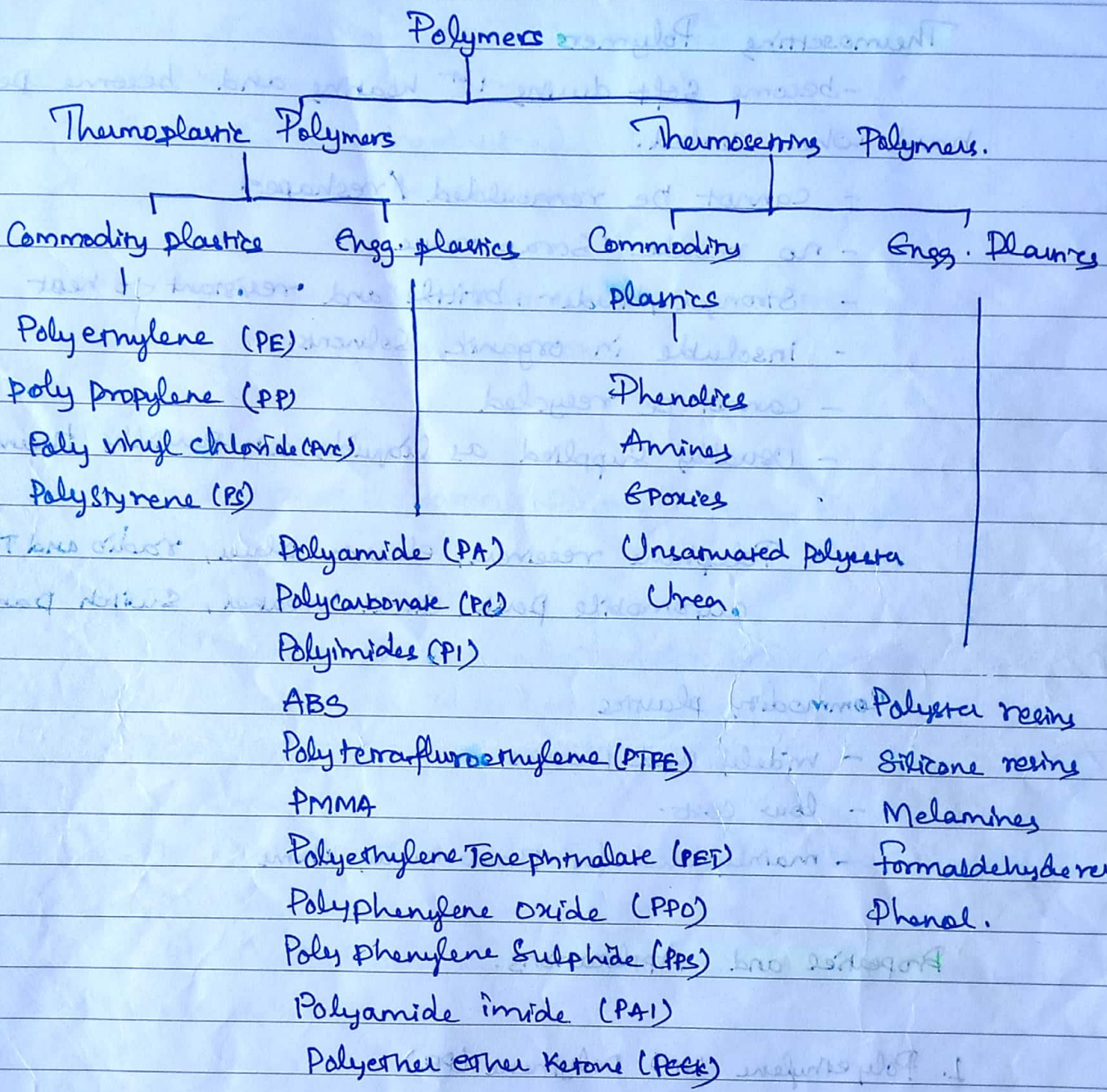
They are used for special applications such as rocket casing, pressure vessels, engine components, injection moulds and dies.

Stainless Steels:-

These steels have high corrosion resistance and hence do not corrode under normal environmental conditions.

The high corrosion resistance is due to the presence of alloying elements namely chromium.

When chromium is present in excess of 13%, a thin film of chromium oxide is formed on the surface that is exposed to air.



Thermoplastic Polymers:

- Soften when heated and harden, when cooled
- Soft and ductile
- low melting point, repeatedly moulded and remoulded
- Can be recycled
- Soluble in organic solvents.
- Supplied as granular material.
- Toys, Combs, toilet goods, photographic films, insulating tapes, hoses, electric insulation, etc.

Thermosetting Polymers

- become soft during 1st heating and become permanently hard when cooled.
- cannot be remoulded / reshaped
- no resale / Scrap value.
- Stronger, harder, brittle and resistant to heat
- Insoluble in organic solvents.
- cannot be recycled
- Usually supplied as liquids or Partially thermoplastic solids.

Telephone receivers, electric plugs, radio and TV cabinets, automobile parts, circuit breakers, switch panels, etc.

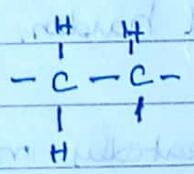
Commodity plastics

- widely used plastics.
- low cost.
- mainly used for throw away items

Properties and Applications:

1. Polyethylene (or) polythene (PE)
2. Polypropylene (PP)

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



Properties :-

1. Low cost, made for petrochemical raw materials.
2. Higher strength and stiffness.
3. Light weight.

4. Good Chemical and thermal resistance.
5. Poor resistance to UV rays.
6. Good surface hardness and dimensional stability.
7. Brittle at low temperatures.

App :- Housewares, Car interior Component, bottle caps, extruded pipes, ropes, bags, etc.

3) PVC

Trade names: Saron, Plavic, Tygon, Vinylite, etc...

Prop :-

1. Products of chemical reaction blw acetylene gas and HCl in presence of a catalyst.
2. Strong and brittle.
3. Low cost
4. Originally rigid, made flexible using plasticizers.
5. Susceptible to heat distortion.
6. Good flame, electrical, chemical, oil, abrasion and weather resistance.

App :-

Pipes, valves, floor tiles, fittings, toys, etc..

Types :-

(i) Unplasticised PVC (UPVC) doors, windowframes,
(ii) plasticised PVC (PPVC) gasket, garden hoses,
(iii) Chlorinated PVC (CPVC) hot water piping
(iv) Polyvinylidene chloride (PVDC) pipes.

4) Polystyrene (PS)

Trade names: Lustrex, Reyolite, Styron, Ceresex, Loralin

Prop:-

(i) made from ethyl benzene.
(ii) Excellent moldability.
(iii) Good electrical, heat and strain resistance.
(iv) Poor chemical and corrosion resistance.
(v) Good dimensional stability

App:

CD cases, ball point pens, disposable food containers, automobile parts, etc.

Types:-

(i) High impact Polystrene (HIPS)
(ii) Styrene acrylonitrile copolymer (SAN)

Commodity Thermosetting Plastics :-

(i) Phenolics Or Phenol-formaldehyde (PF)

Trade Name : Bakelite, Resinox.

Prop :-

High hardness, rigidity and strength because of highly crosslinked aromatic structure.
Good heat and electrical insulating properties.
Low thermal conductivity.

App. :-

Electrical Plugs, Sockets, Switches, door knobs and handles, binder material for sand and for abrasive

(ii) Amines : Urea formaldehyde and melamine formaldehyde are the two most important amino resins.

(i) Urea formaldehyde (UF)

Prop :-

Hard and rigid
Good strength and impact resistance
resistance to most chemicals.
Good electrical insulator.
Pigments can be added to give variety of colours.

App. :-

Urea-water soluble resins are used as adhesives in wood board, plywood, boat hulls and furniture.
Used for bottle caps, cup and saucer.

(ii) Melamine formaldehyde (MF)

- Made by Condensation polymerisation of melamine with formaldehyde with water as a byproduct.
- Due to interpenetrating network, this polymer has good rigidity, toughness, abrasion resistance and high temperature resistance.
- It is a non-toxic and low cost polymer.

Applications :-

- Food handling utensils such as dishes and dinner ware.
- cellulose filled MF is used in control buttons, knobs and other electrical devices.

(3) Epoxides :-

Trade Name : Epon, Epirez, Araldite.

Prop :-

Hard and rigid
Excellent mechanical properties and corrosion resistance.
Good dimensional stability.

App :-

Used as adhesives, as rigid moulded parts for electrical applications, ckt. boards, Sporting goods, automotive components

(4) Unsaturated Polyesters :-

Trade Name : Paraplex, Laminac, Selectron,

3) Urea i.e. Polyurethanes (PUR)

Prop :-

Very good wear resistance
Highly resistant to grease, oil and petrol.

Applications :-

Hose, Shoe heel tips, Car bumpers, etc...

Engineering Plastics :-

- Plastics that are used in engineering applications.
- costlier than commodity plastics.
- have great env. resistance, high strength and better physical properties as compared to commodity plastics.

(1) Polyamides (PA)

Trade names : Nylon, Plaskon.

Prop :-

(i) One of the first engg. plastics.

(ii) They are crystalline thermoplastics with good mechanical properties.

(iii) They have high lubricity, low surface friction and good abrasion resistance.

(iv) Strong, tough, flexible and high impact strengths.

(v) Major drawback is that they tend to absorb water, thereby reducing its strength.

Apps :- Rope, extended hose, wiper gears, automobile Speedometers, etc.

(2) Poly Carbonates (PC)

Trade name : Lexon, Merlon.

Prop :-

- Linear heterochain polymer made from condensation of bisphenol A and Carbonic acid.
- High tensile strength and heat resistance.
- Excellent mouldability, good insulating property and transparency.

Applications :-

- Helmets, Shield and goggles, lenses, glazing, automotive parts like dashboard, boat propeller, headlamp moulding, Kitchenwares.

(3) Polyimides (PI)

Trade Name : Vespel.

Prop :-

- Excellent Mechanical Properties.
- Excellent resistance to temperatures upto 250°C.
- Good resistance to organic solvents but are attacked by alkalies and concentrated acids.
- Transparent to microwaves and are not affected by radiation.

App :-

- PCB, high temp. electrical cable insulations.
- Composite with PI matrix are used in Space Shuttle applications.
- Used as adhesives.

(4) Acrylonitrile butadiene Styrene (ABS)

Trade name: Carbon cycolac, Luerron

Prop:-

- ABS is a polystyrene terpolymer of three monomers Acrylonitrile, Butadiene and Styrene.
- Excellent strength and toughness.
- Good electrical properties, resistant to heat distortion and chemicals are contributed by Acrylonitrile.
- Butadiene provides impact strength to the polymer.
- Styrene provides rigidity and processability of polymer.

App:-

Telephone receivers, helmets, bathroom fittings, automotive parts, etc....

(5) Poly tetra fluro ethylene (PTFE)

Trade name:- Teflon, Halon, Fluorothene

Prop:- Small size of fluorine atoms and regularity of carbon chain, make it a highly crystalline structure.

Chemically inert in all environment and insoluble in almost all organic solvents.

Very low coefficient of friction; hence has self lubricating and non-sticky properties.

Low tensile strength and creep resistance.

PTFE is processed similar to powder metallurgy technique.

App.:-

- chemically resistant coatings.
- non-sticky coatings for cooking utensils.
- anticorrosive seals,
- chemical pipes and valves.
- high temp. electronic parts, etc...

(b) Polymethyl Metha acrylate (PMMA)

Trade names: Perplex, Lucite, Flexiglass, Acrylite.

Prop:

- obtained by reacting methyl acrylic acid with an alcohol.
- Hard, rigid and high impact strength.
- Highly transparent to visible light.
- Can be readily colored and has excellent decorative properties.
- Good chemical and weather resistance.

App.:

- Good optical properties, hence used as lenses in cameras, flash-lights, safety glasses, etc..
- Weather proof coatings.

(4) Polyethylene Terephthalate (PET)

Trade Name: Polyester, Mylar, Dacron.

Prop:

- Made by condensation polymerisation of ethylene glycol and terephthalic acid.

Ceramics

Ceramic is a Compound formed by combination of inorganic and non-metallic materials.

Ceramics are hard and brittle materials used for high temp. applications.

Common Properties of Ceramics :-

- Due to the presence of strong ionic or covalent bonds, Ceramics, in general, possess high hardness, brittleness, high M.P, chemical resistance, electrical and thermal insulation properties.
- They have high abrasive resistance.
- They are crystalline in structure but due to different chemical groups and different-sized atoms coming together, their structure becomes more complex than metals

Classifcation of Ceramics :-

Production method	Application	Structural Arrangement
• Natural Ceramics	• Abrasives	• Crystalline Ceramics
• Manufactured Ceramics	• Fired-clay products	• Non-crystalline "
	• Glasses	
	• Cement	
	• Rocks	
	• Refractories	
	• Insulators.	

1) Natural Ceramics
   eg: Clay minerals, Silica SiO_2, Silicates

2) Manufactured Ceramics.
   eg: Al_2O_3, Silicon Nitride, Various Oxides, borides, nitrides, Carbides etc.,

1) Abrasives

- It is a hard and wear resistant material.
- eg: Emery - Used as emery paper for polishing metals.

Carborundum (SiC) - Used in grinding wheels and as refractory material in furnace.

Aluminium Oxide (Al_2O_3) - Used for polishing cast iron and some non-ferrous metals.

2) Fired-clay products.

- They are made from natural ceramics and hence inexpensive.

clay - • They are produced by chemical changes during weathering of rocks.

- They have characteristic flaky structure.
- plasticity of clays is its ability to form a plastic mass with water.

3) Glasses

- It is an inorganic product of fusion of one or more oxides of silicon, boron, magnesium, calcium, sodium, etc...
- It is a transparent silica product which may be amorphous or crystalline, depending on the heat treatment it undergoes.
- Glass is manufactured by mixing raw materials like soda ash, limestone, sand, sodium sulphate, etc.. according to the final requirements.

Glass Manufacturing processes

(1) Flat mould - Sheet glass
(2) Extrusion - Tubes and rods.
(3) Blow molding - Bottles
(4) Casting & Grinding - Lenses and mirrors.
(5) Melting & Spraying - Glass-lined tanks.

4) Cements

- Cements can be organic such as rubber cements or inorganic such as Portland cements.
- Portland cement consist of SiO_2, Al_2O_3, Calcium oxide, magnesium oxide, etc..

5) Rocks

- Natural ceramic
- Consist of minerals and polycrystalline in structure.

6) Refractories

7) Insulators.

Engg. Ceramics

- Ceramics that are specifically used in engg. applications.
- There are mainly oxides, carbides, sulphides and nitrides of metals.
- Sintering, Vitrification.

Alumina (Al_2O_3) :

- One of the oldest engg. ceramic
- It is obtained from the fusion of bauxite ore ($Al_2O_3 \cdot 2H_2O$), iron fillings and coke in electric furnace.
- It has a hexagonal structure with very strong ionic and covalent bonds.

Props. :-

- have high hardness and moderate tensile strength.
- excellent wear resistance and chemically inert.
- Stiffer than steels because of high E (3.65×10^5 MPa.
- Finding applications in nuclear equipment

Apps. :-

- Used as refractory material for high temp. apps.
- High voltage insulators . eg: Spark-plug insulators.
- Used as abrasive material in grinding wheels.
- Used for pump liners, Check valves, rocket nozzles etc.
- medical applications.

Partially Stabilised Zirconia (ZrO_2):

PSZ is a Zirconium Oxide, that is blended and Sintered with Other Oxides such as those of Mg, Ca, and Yttrium, to control Crystal structure transformations.

The Oxide of Zr exists in 3 different crystalline modifications.

(i) It has a Cubic Structure at elevated temp,

(ii) During cooling, it transforms first into terragonal structure.

(iii) At room temp., it transforms into a monoclinic structure.

It is difficult to fabricate a pure ZrO_2 ceramic.

A fully stabilised Zirconia contains 18% of stabilising Oxide whereas a PSZ contains Only 5% of Stabilising Oxide.

Props :-

- better tensile strength than alumina
- better toughness than other ceramics.
- Coefficient of Thermal Expansion similar to steel.
- Low friction coefficient
- Transformation Toughened Zirconia (TTZ) is the newer developed Zirconia that has higher toughness.

Apps.:

- Superalloy rotor blades in jet turbines.
- Die material for hot extrusion.
- Zirconia beads are used for grinding applications.
- PSZ are environment friendly in human bodies, hence they are used in manf. of artificial hip joints.
- Dispersion media for aerospace coatings and automotive primers and top coats.

Silicon Carbide (SiC)

- Made from Silica Sand, Coke, Small amount of NaCl and Saw dust.
- There are 2 types of SiC.

1) Hexagonal - α-SiC
2) Cubic - β-SiC

According to the method of manf., they are classified as,

- Sintered SiC
- Clay bonded SiC
- Reaction bonded SiC
- Nitride bonded SiC

Props.:-

- more expensive
- low coefficient of friction.

Apps.:-

- abrasive for grinding wheels.
- wear resistant coatings.
- Refractory tubes and Containers.

Sialon ($Si_3Al_3O_3N_5$)

- derived from Si, Al, O_2 and N_2.

Props.:

- Extremely hard
- Stronger than steel and light in weight than aluminium.

Apps.:

- Used for cutting tool materials, wire and tube drawing dies, rock and coal cutting equipments.

Silicon Nitride (Si_3N_4)

- Fully resistant to strong acids and other low M.P metals.

types :-

- Reaction bonded silicon nitride (upto 20% porosity)
- Hot pressed silicon nitride (100% density theoretically)

Props:-

They have low density and hence, low weight.

Apps.:-

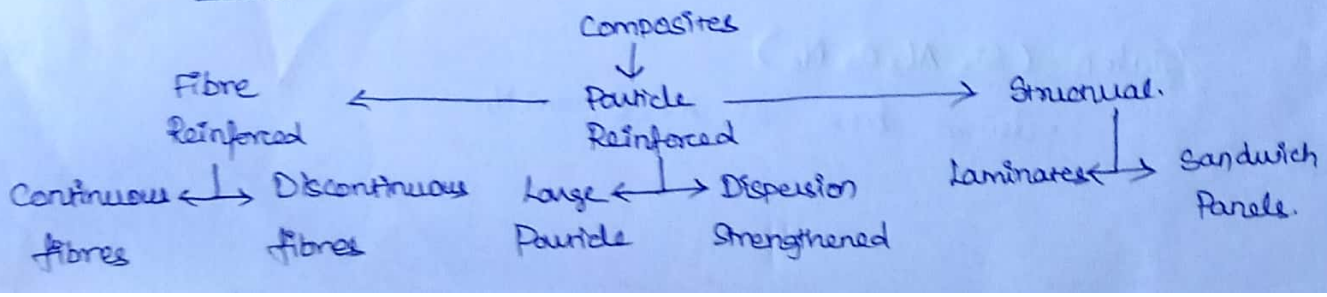
- Used as cutting tool material.
- Sand blast nozzles, spindle bearings, etc.

COMPOSITES

- Composite material is defined as a material formed by the combination of two or more chemically dissimilar materials with distinct boundaries between them.

- The base material (soft phase) is called the matrix and other material (hard phase) is called the additive or reinforcing phase.

Classification



Fibre - reinforced Composites:

A number of factors influence the strength of fibre - reinforced Composite, such as:

- The distribution and Orientation in between the fibres & matrix
- % of fibres and matrix mixed in the composite.
- Mechanical properties of fibres and matrix.
- Bonding at the fibre - matrix interface.

- for effective strengthening of composite mix, the critical dimensions of fibres are defined.

- The Critical length of fibre (L_c) is given by:

$$L_c = \frac{\sigma_f \times d}{\tau_c}$$

where,

σ_f - ultimate strength ; d - dia. of fibre ; τ_c - Shear strength.

- Depending on the length of actual fibres, the fibre-reinforced Composites are classified as,

(1) continuous fibres ($L > L_c$)
(2) Discontinuous fibres ($L < L_c$)

eg:-

- One of the popular example of fibre-reinforced Composite is the FRP (fibre-reinforced plastic)
- It consist of fibres of glass (mix of SiO_2, Al_2O_3, CaO, MgO).
- The matrix is made of different types of plastics such as polyester, nylon, etc...

Particle - Reinforced Composites.

(1) Large - Particle Composites eg:- Cement

(2) Dispersion Strengthened particle reinforced Composites. Eg: Thoria dispersed Nickel

Structural Composites

(1) Laminated Composites

(2) Sandwich panel composites.