Introduction to Metallurgy & Materials

(By Nitika Kundan)

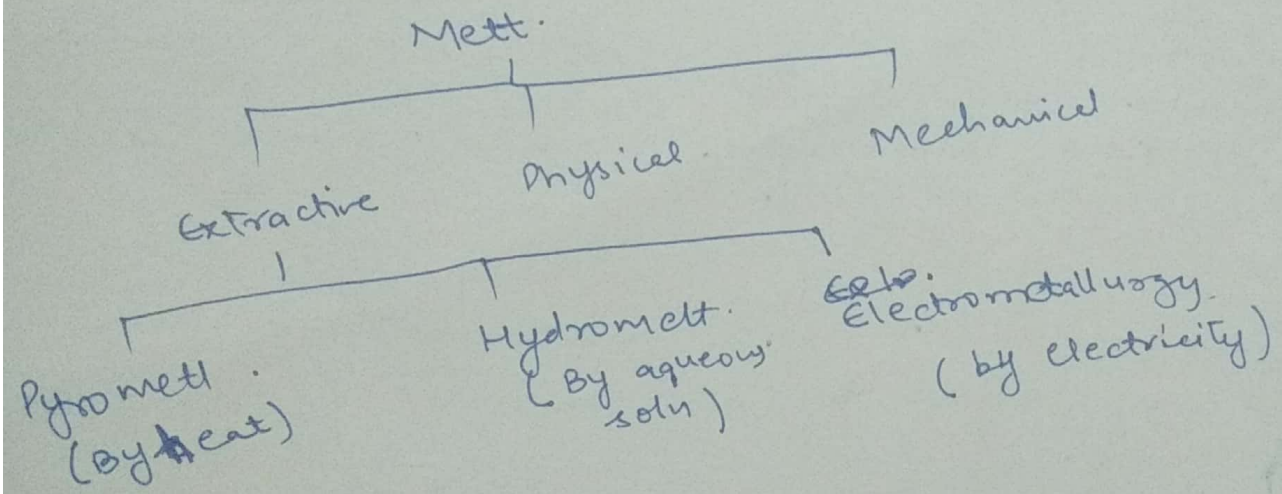
① An introduction to Mett. & Classification of Mett. Processes

→ Materials science → involves investigating the relations that exist b/w the structures & properties of materials.

Processing → structure → Properties → Performance

Material science is a branch of science that reveals the many diverse factors in materials.

Metallurgy (Mett.)
The branch of science & technology concerned with the properties of metals & their production & purification



Materials

→ That occupies space

Engg. materials

Universe
Matter
Elements

organic substances
inorganic substances

Classification of Engg. Material

- Metals
  - Ferrous Metals
  - Non-ferrous Metals
- Non-metals
  - Thermoplastics
  - Thermosets
  - Elastomers
- Ceramics
  - Glasses
  - Crystalline ceramics
    - Oxide, nitrides, & carbides
- Polymers
  - usually organic compounds that are chemically based on C, H & other non-metallic (O, N & Si)
- Composites
  - MMC
  - CMC
  - PMC

Advanced Materials
- Semiconductors
- Biomaterials
- Smart Materials
- Nanomaterials

→ Semiconductors

electrical properties are intermediated b/w electrical conductors & insulator.

electrical characteristics of these materials are extremely sensitive to the minute

Smart materials → able to sense changes in their environments & then respond to that changes in predetermined manner.

(2) Classification of Engineering Materials based on Engineering properties. A general discussion on other engineering materials plastics, rubber, polymers, ceramics, refractories, glasses, composites

Metals

- Metallic bonding
  - A metal is defined as an element with a valence of 1, 2 or 3

Alloy

- A substance having metallic properties & being composed of two or more chems
- An Alloy is usually defined as a combinati- -on of 2 or more elements out of which the major one should be a metal. The resultant pdt. must have metallic properties.

Ceramics

compounds formed by combination of metals & non-metals.

Polymers

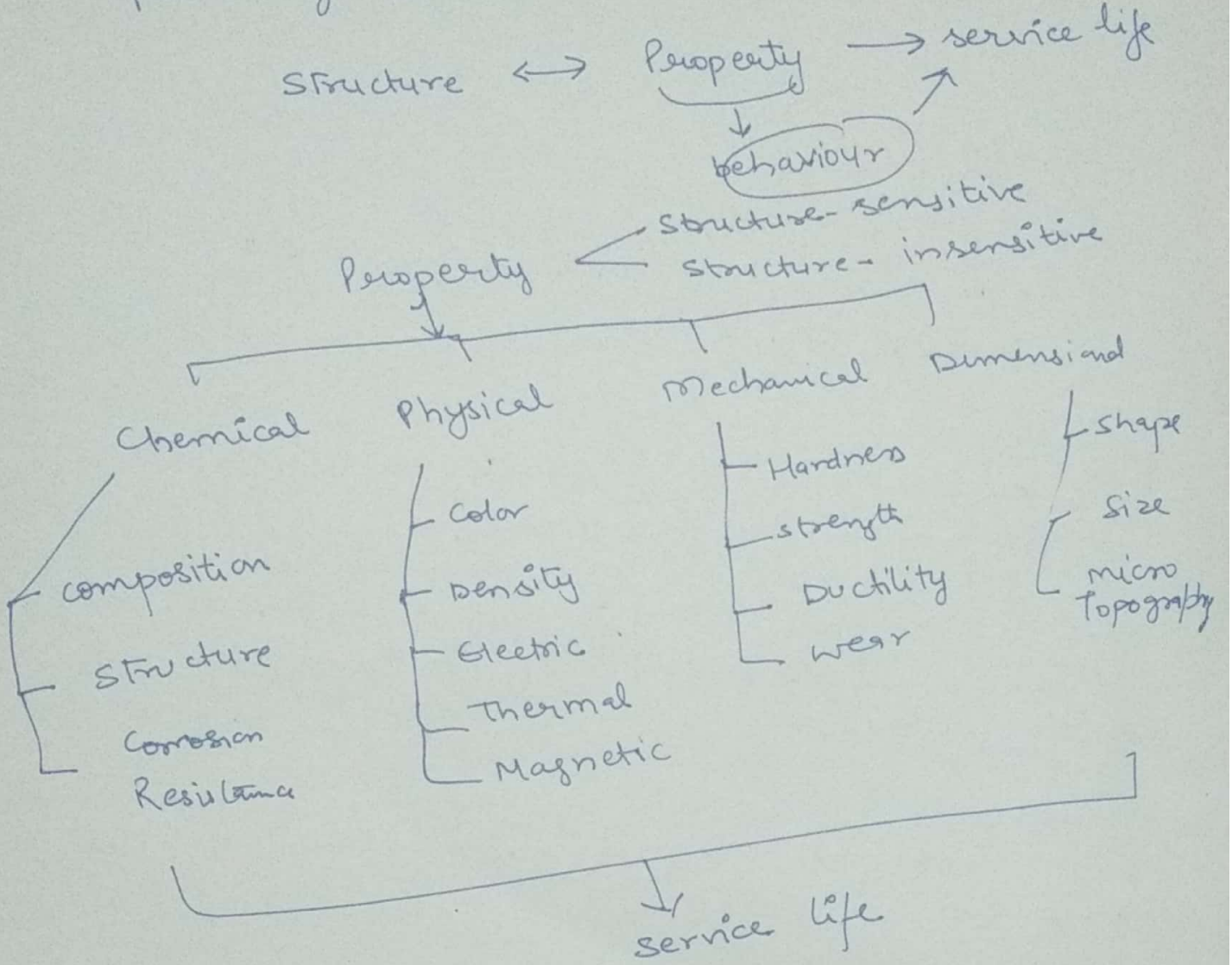
- Organic materials usually compounds of C with H or O

Composites

A composite materials is a ~~composite~~ combination of 2 or more materials that has properties different from its constituents. Composites provide almost unlimited potential for development of high strength, stiffness & corrosion resistance.

Properties of Materials

The properties of a material provide a basis for predicting its behaviour under various service cond.



Physical Properties

- characteristics of materials that are determined by nature

Chemical Properties

- material characteristics that relate to the structure of a material & its formation from the elements.

Mechanical

- material characteristics that are displayed when a force is applied to a material.

Wear

- Progressive loss or removal of the material from surface

Wear Resistance

- Resistance offered by material against removal of material

Fracture Toughness

- Fracture toughness is the ability of material to resist the growth of a crack of known size & geometry when subjected to tensile stresses.

Description of Some Physical Properties

Dielectric strength

- The min electric field that can be maintained b/w two conductor plates

Electrostriction

- The dimensional change that occurs in a material when an electric field is acting on it.

Dielectric loss

- The fraction of energy lost each time an electric field in a material is reversed.

Polarization

Alignment of dipoles in a manner that a charge is stored permanently.

Ferroelectricity

- The property by which a net polarization, due to alignment of domains, remains in the material after the removal of electric field

Ferromagnetism

- The behaviour of a material of retaining a net magnetization after removal of magnetic field

Dimensional Properties

- Imp in selection of material

Definitions of some Mechanical Properties

Tensile strength

↳ It is the ratio of max. load before rupture, which a material can withstand under tensile loading, to the original cross-sectional area of materials specimen.

Yield strength

↳ Yield strength is the stress reqd. to produce a small but definite plastic deformation

Ductility

- The ability of a material to deform plastically without fracturing under tensile stress.

Toughness

Ability of material to absorb energy prior to fracture

Hardness

↳ Resistance of material to permanent deformation by indentation

Fatigue

The phenomenon leading to fracture under repeated or fluctuating stresses having a max. value less than the tensile strength of the material.

Fatigue strength

Max. cyclic stress that a material can withstand for a specified no. of cycles before fatigue failure.

Creep

The permanent elongation of a material under a constant static load as a function of time is k/a creep

Creep strength

The stress that results in an average creep rate equal to an assigned creep rate is k/a creep strength.

Coercive strength

- strength of magnetic field reqd. to eliminate magnetization from a material

Curie temp:-

- Temp. above which ferromagnetic material ceases to behave like a ferromagnetic material

Reflectivity

- Fraction of incident radiation that is reflected by material

Refraction

The change in direction of light when it passes from one medium to another

Opacity

- characteristic of material that doesnot allow light to pass through it

Specific heat

energy reqd. to raise temp to one unit mass of a material by 1° of temp. scale

Thermal capacity

- Amt. of heat reqd to raise temp of material under consideration by 1° of temp scale.

Material selection

Fundamentals of material selection -

a) select class of engg. materials
b) select materials which can develop reqd. properties
c) select only those materials which can be manufactured or processed into desired shape & size
d) economical.

Structure of Materials

- Materials differ from one another because of the differences in their properties.
Differences in properties are due to difference in structure of materials

The solid materials structure can be expressed as -

- Atomic structure
- Crystal structure
- Microstructure
- Macrostructure

Atomic Structure

An atom has a very complex structure consisting of nucleus & the electrons.
(stationary mass) (-ve charge)

Nucleus consists of protons & neutrons
(+ve charge)

Electrons revolve around nucleus in definite orbits.

A moving electron is associated with a wavelength given by de-Broglie's equation -

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

where λ = wavelength of moving electron, p = momentum of the electron
m = mass of electron, v = velocity of electron

Crystal Structure

Properties of an individual atom are determined by its atomic structure.
These atoms combine together to form crystals and their arrangement in a crystals is referred to as crystal structure.

Materials, on the basis of structures, can be classified into three categories:-

- molecular structures
- crystal structure
- amorphous structures

Bondings in Solids

Many of physical properties of materials depends on the interatomic forces by which atoms are bonded together. Forces may be attractive or repulsive. The total interatomic forces is resultant of both forces

$$F_N = F_A + F_R$$

At equilibrium, $F_A = F_R$ or we can say

$$F_A + F_R = 0$$

The following are the different types of bondings found in solids:

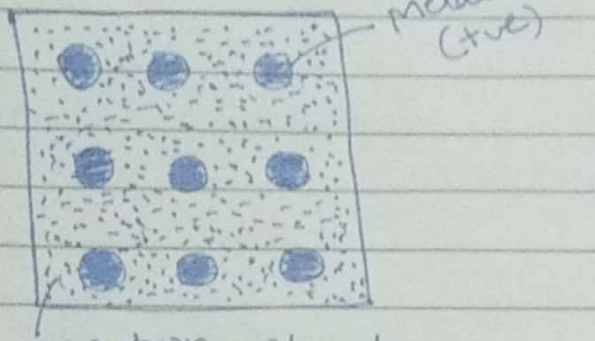
(i) Metallic Bond
(ii) Ionic Bond
(iii) Covalent Bond
} Primary Bonds

(iv) Van der Waals Bond } Secondary Bond

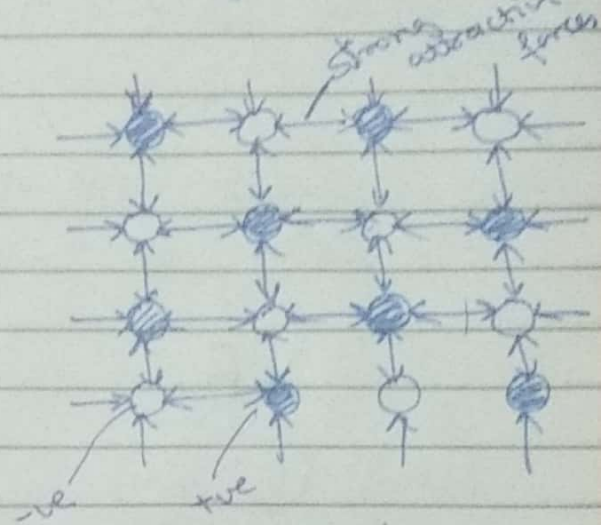
(i) Metallic Bond

- Primary type of bond found in metals & alloys

When each atom of the metal contributes its valence electrons to the formation of an electron cloud that spreads throughout the solid metal. A characteristic of metallic bond is that the conduction of electricity and heat are produced by movement of valence electrons through the metal.



[Metallic Bond]



Ionic Bond

(ii) Ionic Bond

- Composed of both metallic & non-metallic elements

If an electron is transferred from a metallic atom to non-metallic atom, the two resulting ions are held together by electrostatic attraction.

eg NaCl where sodium gave away its valence electron & chlorine takes it
(becomes +vely charged) (becomes -vely charged)

Ionic crystals have poor electrical conductivity, high

hardness & high melting point.

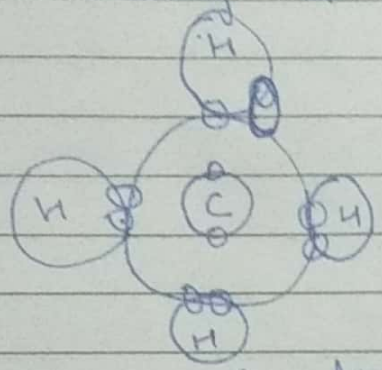
(iii) Covalent Bond

In this type of Bond, sharing of electrons between adjacent atoms forms a stable electron configurations.

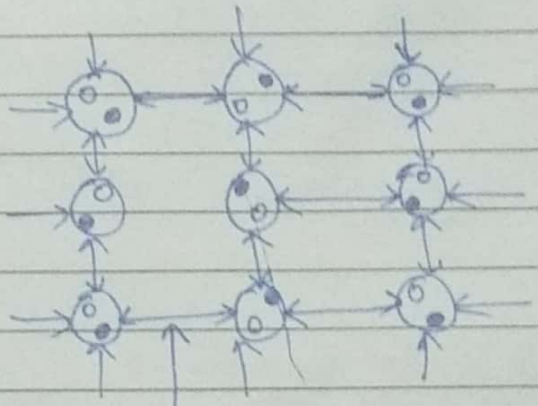
Covalently Bonded atoms have to contribute atleast one e^- to the bond, & the shared e^-s may be considered to both atoms.

eg Cl_2, CH_4, H_2, diamond, N_2 etc.

Covalent crystals have poor electrical conductivity & high hardness.



(CH_4) Covalent Bonding



Weak Attractive forces Between Polarized atom

Vander Waals

(iv) Vander Waals Forces

Inert gases & molecules like methane, which have no valence e^-s available for crystalline binding, obtain a weak attractive force as a result of polarization of electrical charges.

Polarization is displacement of centres of positive and negative charges in an electrically neutral atom or molecule when as it is brought close to its neighbouring atom.

- This force can be overcomed by disrupting the effect of thermal motion of atoms & molecules at higher temperature.