Classification of Engineering Materials.

Engineering Materials.

- Metallic Materials or Metals.
  - Ferrous (iron as main constituent)
    - Cast iron
      - Grey
      - White
      - Malleable
      - Ductile
      - Nodular
    - Wrought iron
    - Steel
      - Plain
      - Carbon
      - Alloy
  - Non-ferrous (Iron is not as main constituent)
    - Aluminium
    - Copper
    - Magnesium
    - Tin
    - Zinc
    - Lead
    - Nickel and their alloys.
- Non-Metallic Materials or Non-metals.
  - Organic
    - Plastics
    - Wood
    - Paper
    - Rubber
    - Leather
    - Petroleum
  - Inorganic
    - Minerals
    - Ceramics
    - Glass
    - Cement
    - Graphite.

* Engineering materials can be classified into two categories:-
1) Metals 2) Non-metal.

1) **Metals**:- • They are mostly opaque, shiny, Malleable, hard, heavy, ductile, lusture.
- They are good-conductor of heat and electricity.
- All metals are having high thermal and electrical conductivity.
- All metals are having positive temperature coefficient of resistance, means resistance of metals increases with increase in temperature.

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- Metals have a crystalline structure.
- Metals are normally solids at room temperature, except mercury and gallium.
- Metals are known as reducing agents as they easily lose electron due to their electropositive behavior in nature.
- Metals have ~~a~~ high density.
- Metals have high melting and boiling points.
- ~~It~~

2) Non-metals:- • They have generally soft, transparent, brittle, non-shiny, non-lustrous, Non-malleable, and Non-Ductile.

- They ~~ha~~ are bad conductor of heat and electricity.
- Non-metals materials are amorphous ~~amphorous~~ in nature.
- These are exist in both solid ~~liquid~~ and gases form.
- Non-metals have low melting and boiling point.
- Non-metals are known as oxidising agent as they are electronegative in nature.

* Metals are further divided into two groups:-
i) ferrous
ii) Non-ferrous.

i) ferrous metals:-

- All ferrous metal are having iron as common element.
- All ferrous materials are having very high permeability which makes these materials suitable for construction of core of electrical machines.
- eg:- cast iron, wrought iron, steel, silicon steel, High speed steel, spring steel etc.
- They have magnetic properties.
- It is less expensive.
- They are durable and strong.
- It has low resistance to corrosion.
- Its melting point is high

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ii) Non-ferrous metals:-

- All non-ferrous metals are having low permeability.
- They do not contain iron.
- They do not have magnetic properties.
- It is more expensive than ferrous metals.
- They are lighter.
- It has more resistance to corrosion.
- Its melting point is low.
- eg:- cobalt, Aluminium, zinc etc.

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* other classification of Engineering materials :-

1) Metals and Alloys
2) ceramic Materials.
3) organic materials.

- Alloys:- Alloys are the composition of two or more metals or non-metal together.

→ Alloys are having good mechanical strength, low temperature coefficient of resistance.

→ e.g:- Steels, Brass, Bronze, Gunmetal, Super alloys etc.

- ceramic materials:- Ceramic materials are non-metallic solids.

→ These are made of inorganic compounds such as - oxides, Nitrides, silicates and carbides.

→ ceramic materials possess ~~ext~~ exceptional ~~stru~~ structural, electrical, Magnetic, chemical and thermal properties.

→ e.g:- silica, glass, cement, concrete, garnet, MgO, ZnO etc.

- organic Materials:-

→ All organic materials are having carbon as a common element.

→ Generally, organic materials are having complex chemical bonding.

→ e.g:- plastics, PVC, synthetic, Rubbers etc.

Structure of metal-unit-cell, BCC, FCC and HCP structures:-

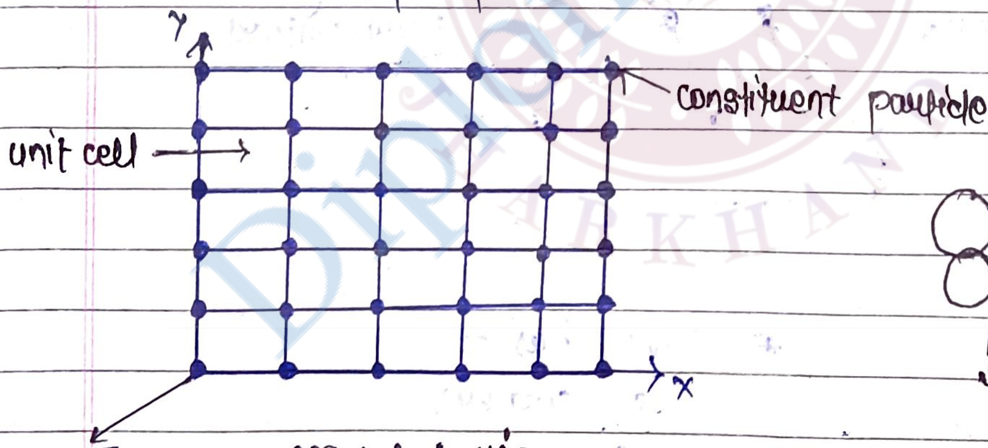
- **Crystal lattice or crystal structure:-** It is a 3-D arrangement of atom, ions or molecules in a crystalline solids.

→ The consituent particles are represent by point or sphere.

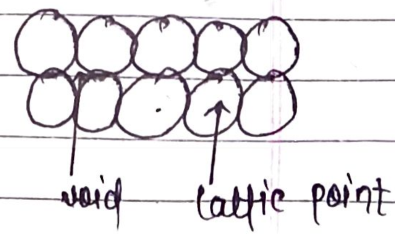
- **lattice point/site:-** The space occupied by the constituent particle is called lattice point.

- **void:-** The vacant space occupied by the which is surrounded by the constituent particle is called void.

- **unit cell:-** A unit cell is the smallest repeating structure that makes up a crystal lattice in a solid material.



crystal lattice



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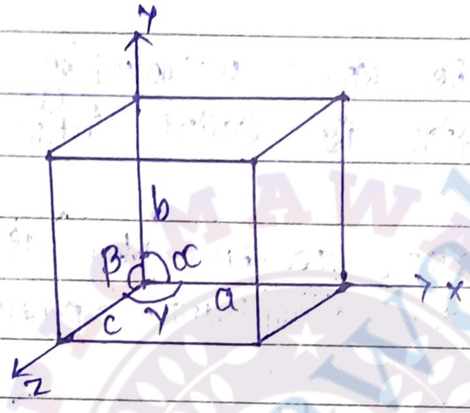
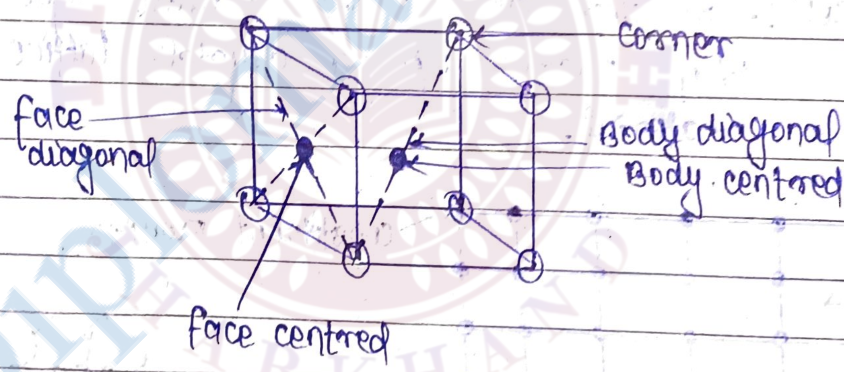
It means any crystal lattice is made up of large no. of unit cell arranged one over in different direction.

Any unit cell is characterised by its edge-length (a, b, & c) and interaxial angle (α, β & γ), which is called unit cell parameter.





A cube has —
8 corners
6 faces
10 edges.

Types of unit cell :-

→ It can be classified based on their geometry and symmetry.

(A) simple or primitive - unit cell
(B) centred or Non-primitive-unit cell.

(A) simple unit cell :-

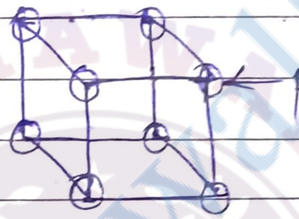
In such unit cell the particle are present at all the corners.

→ It is denoted by P.

→ No. of atoms = 1

→ C.N = 6, APf = 0.52

eg :- NaCl, $a = 2r$ or $r = \frac{a}{2}$



(B) centred unit cell :-

In such unit cell the particle are present at all the corners as well as centred of its body or face.

It is of three types -

i) Body centred cubic unit cell (BCC) :-

→ In such unit cell the particle / ~~Ato~~ Atom are present at all the corners and centred of its ~~face~~ body.

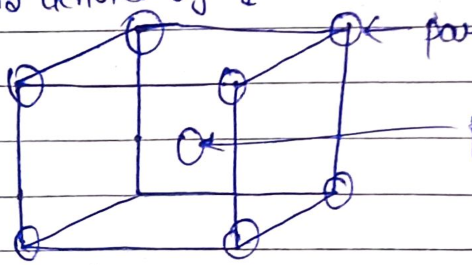
→ The coordination no. of each atom in the BCC structure is 8.

→ It is denoted by I

→ ~~CN~~ =

n = 2

APf = 0.68



$\sqrt{3}a = 4r$

$r = \frac{\sqrt{3}a}{4}$

e.g → α-iron, δ-iron, Molybdenum.

ii) face centred cubic unit cell (fcc) :-

→ In such unit cell the atoms are present at all the corners and centred of its faces.

→ It is denoted by f.

→ There are 8 atoms at each corner and of the cube and 6 atoms in the centre of each face.

→ The coordination no. of each atom in fcc structure is 12.

→ fcc is more density packed than BCC.

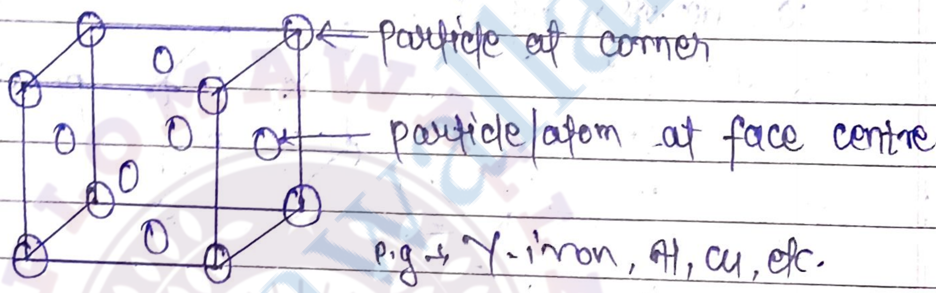
→ $n = 4$

→ C.N = 12

→ APF = 0.74

→ $\sqrt{2}a = 4r$

$r = \frac{\sqrt{2}a}{4}$

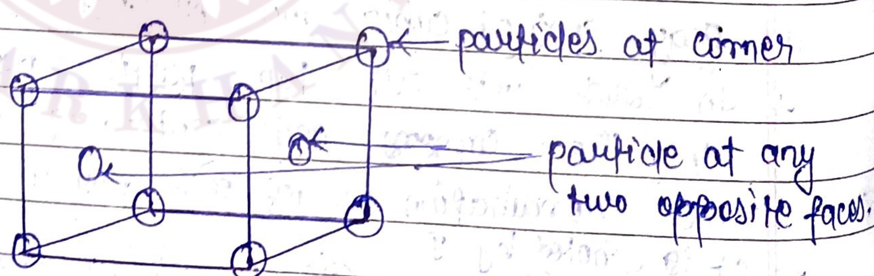


e.g → γ-iron, Al, Cu, etc.

iii) End-centred cubic unit cell (ECC) :-

→ In such unit the particles are present at all the corners and centred of its any two opposite faces.

→ It is denoted by C.



iv) HCP (Hexagonal close pack) :-

→ The hexagonal close packed structure also has a coordination no. of 12, but crystals of this type are hexagonally shaped rather than cubic.

→ 1 atom at each corner of hexagon and 1 atom at each centre of hexagon faces. → $a = 2r$, $r = \frac{a}{2}$, → APF = 0.74

→ n = 6, c.n = 12, eg- Titanium, zinchorium, Magnesium, cobalt.

Types of crystal :-

~~on the basis of unit-cell parameter the entire~~

There are 14 unique types of unit-cell, on the basis of unit-cell parameter the entire crystaline system are divided into seven fundamental crystal :-

S.No.	Types of crystal	edge-length	Interaxial angle	example
1	(C) Cubic (crystal lattice	$a=b=c$	$\alpha=\beta=\gamma=90°$	NaCl, KCl
2	(T) Tetragonal crystal lattice	$a=b\neq c$	$\alpha=\beta=\gamma=90°$	Sn, SnO_2
3	(O) Orthorhombic	$a\neq b\neq c$	$\alpha=\beta=\gamma=90°$	Rhombic sulphur.
4	(R) Rhombohedral	$a=b=c$	$\alpha=\beta=\gamma\neq 90°$	$CaCO_3$, HgS
5	(M) Monoclinic	$a\neq b\neq c$	$\alpha=\gamma=90$, $\beta\neq 90°$	
6	(H) Hexagonal	$a=b\neq c$	$\alpha=\beta=90$, $\gamma=120°$	Graphite, ZnO
7	(T) Triclinic	$a\neq b\neq c$	$\alpha\neq\beta\neq\gamma\neq 90$	H_3BO_3; $K_2Cr_2O_7$

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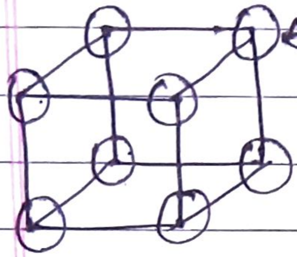
* Bravias lattice:-

on the basis of Mathematical calculation Bravias show that the atoms can be ~~arrag~~ arranged in 14 different ways in 7 fundamental of crystal, which is known as Bravias lattice.

S.No.	Types of crystal	variation
1	cubic	P, I, F
2.	Tetragonal	P, I
3.	orthorohmbic	P, I, F, C
4.	Rhombohedral	P
5.	Monoclinic	P, C
6.	Hexagonal	P
7	Triclinic	P.
		Total = 14

Calculation of no. of atoms/particles per unit cell :-

(1) In simple cubic unit cell :-

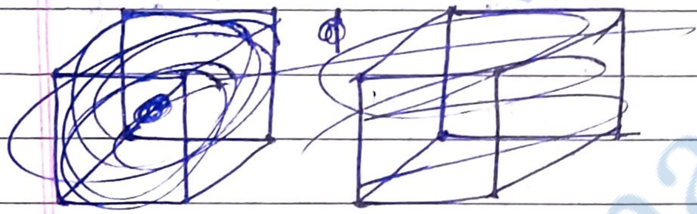


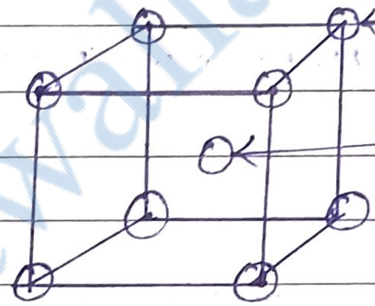
$\frac{1}{8}$ th part of particle at corner.

∴ Total no. of particles per unit cell $= 8 \times \frac{1}{8}$ (corner)

$= 1$

(2) In BCC unit cell :-



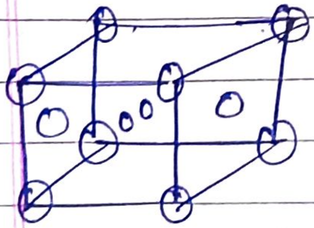


∴ Total no. of particles per unit cell $= 8 \times \frac{1}{8}$ (corner) + 1×1 (at body)

$= 1 + 1 = 2$.

(3) In fcc unit cell :-

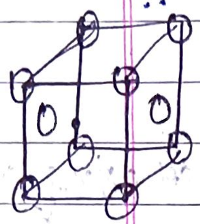
∴ Total no. of atoms per unit cell $= 8 \times \frac{1}{8}$ (at corner) + $6 \times \frac{1}{2}$ (at face centre)



$= 1 + 3$

$= 4$.

4. In ECC unit cell :-



∴ Total no. of atoms per unit cell = $8 \times \frac{1}{8}$ (at corner) + $2 \times \frac{1}{2}$ (at face centre)

= 1 + 1

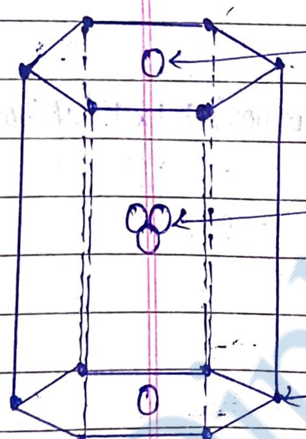
= 2.

5. In Hexagonal cubic closed (HCC) (CCP) crystal :-

∴ Total no. of atoms per unit cell = $12 \times \frac{1}{6}$ (at corner) + $2 \times \frac{1}{2}$ (at face centre) + 3×1 (body)

= 2 + 1 + 3

= 6.



#	unit-cell	No. of atom (n)
(i)	SCC	1
(ii)	BCC	2
(iii)	FCC	4
(iv)	ECC	2
(v)	HCP/HCC	6.

- **Atomic packing fraction (APF) :-**
  It is the ratio of volume of atom per unit cell to the total volume of unit cell.

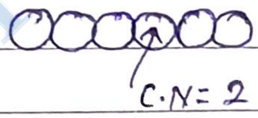
$$A.P.f = \frac{\text{volume of no. of atom per unit cell}}{\text{Total volume of unit cell}}$$

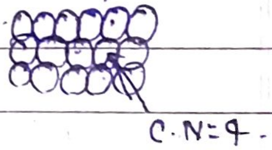
- **Efficiency of packing (EOP) :-**
  The % of the ratio of volume of atom per unit cell to the total volume of unit cell.

$$E.O.P = \frac{\text{volume of no. of atoms per unit cell}}{\text{Total volume of unit cell}} \times 100$$

- **coordination number :-** It is a no. of spheres touching at a particular spheres or atoms.

e.g :-





calculation of efficiency of packing (E.O.P) and Atomic packing fraction (A.P.f) in per unit cell :-

① calculation of E.O.P and A.P.f in scc unit cell :-

let, a = edge-length of unit cell
r = radius of atom (sphere)

Total no. of particles/atoms per unit cell = $8 \times \frac{1}{8} = 1$

∴ volume of no. of atoms per unit cell = $1 \times \frac{4}{3} \pi r^3$

∴ $a = 2r$

∴ Total volume of unit cell = a^3
$= (2r)^3$
$= 8r^3$

∴ A.P.f = $\frac{\text{volume of no. of atoms per unit cell}}{\text{Total volume of unit cell}}$

$= \frac{1 \times \frac{4}{3}\pi r^3}{8 r^3} = \frac{4}{3} \times \frac{3.14}{8} = \frac{1.57}{3}$

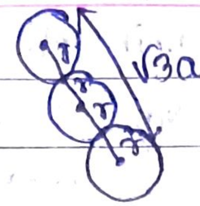
$= 0.523$

E.O.P = $\frac{\text{volume of no. of atoms per unit cell}}{\text{Total volume of unit cell}} \times 100 = 0.523 \times 100$

$= 52.3\%$

void = 47.7 %

② **BCC unit cell :-**



let, a = edge-length of unit cell

r = radius of atom

$\Rightarrow \sqrt{3}a = 4r$

$$\boxed{a = \frac{4r}{\sqrt{3}}}$$

∴ Total no. of atoms per unit cell $= 8 \times \frac{1}{8} + 1 = 1 + 1 = 2.$

∴ volume of no. of atoms per unit cell $= 2 \times \frac{4}{3}\pi r^3$

∴ Total volume of unit cell $= (\text{side})^3$

$= (a)^3$

$= \left(\frac{4r}{\sqrt{3}}\right)^3 = \frac{64r^3}{3\sqrt{3}}$

∴ A.P.f = $\frac{\text{volume of no. of atoms per unit cell}}{\text{Total volume of unit cell}}$

$= \frac{2 \times \frac{4}{3}\pi r^3}{\frac{64r^3}{3\sqrt{3}}} = 2 \times \frac{4}{3}\pi r^3 \times \frac{3\sqrt{3}}{64r^3} = \frac{3.14 \times \sqrt{3}}{8}$

$= \frac{3.14 \times 1.73}{8}$

$\boxed{= 0.67\%}$

E.O.f = 0.67 × 100

= 67.98%

$\boxed{\text{E.O.f} \approx 68\%}$

$\boxed{\text{void} = 32\%}$

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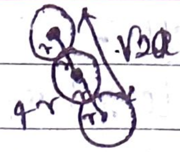
③ FCC. unit cell :-

Let, a = edge-length of unit cell.

r = radius of sphere



∵ $\sqrt{2}a = 4r$

$$a = \frac{4r}{\sqrt{2}}$$

∴ Total no. of atoms per unit cell $= 8 \times \frac{1}{8} + 6 \times \frac{1}{2}$

$= 1 + 3 = 4$

∴ volume of no. of of atoms per unit cell $= 4 \times \frac{4}{3}\pi r^3$

$= \frac{16}{3}\pi r^3$

∴ Total volume of unit cell = $(\text{side})^3$

$= (a)^3 = \left(\frac{4r}{\sqrt{2}}\right)^3 = \frac{64r^3}{2\sqrt{2}}$

A.P.F $= \dfrac{\frac{16\pi r^3}{3}}{\frac{64r^3}{2\sqrt{2}}} = \frac{16\pi r^3}{3} \times \frac{2\sqrt{2}}{64r^3} = \frac{3.14 \times \sqrt{2}}{6} = \frac{3.14 \times 1.414}{6}$

$= 0.74$

E.O.P = $0.74 \times 100 = 74\%$

void = 26%

4 In HCP unit-cell :-

let a = edge-length of unit cell
r = radius of atom.

$\therefore$ $\boxed{a = 2r}$

$\therefore$ Total no. of particles per unit cell $= 12 \times \frac{1}{6} + 2 \times \frac{1}{2} + 3 \times 1$

$= 2 + 1 + 3$

$= 6$

volume of no. of particles per unit cell $= 6 \times \frac{4}{3} \pi r^3$

$= \frac{24}{3} \pi r^3$

Total volume of unit cell $= a^3$ ~~$= \left(4\sqrt{\frac{2}{3}}\, r\right)^3$~~

~~$= (2r)^3$~~ $= 24\sqrt{2}\, r^3$

~~$= 8r^3$~~

$\therefore$ A.P.F $= \frac{24}{3} \pi r^3 \times \frac{1}{24\sqrt{2}\, r^3} = \frac{3.14}{3 \times 1.414} = \frac{3.14}{4.242} = 0.74$

E.O.P $= 0.74 \times 100 = 74\%$

void $= 26\%$

In a nut shell:-

	unit cell	n(atoms)	Relation betⁿ a & r	A.P.f	E.O.P	void
i)	SCC	1	$a = 2r$	0.52	52.3%	47.7%
ii)	BCC	2	$\sqrt{3}a = 4r$	0.68	68%	32%
iii)	FCC	4	$\sqrt{2}a = 4r$	0.74	74%	26%
iv)	HCP	6	$a = 2r$	0.74	74%	26%

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Types of Microscopes :-

(a) optical microscope

i) Binocular stereoscopic microscope :-

→ A microscope that allows easy observation of 3D object at low magnification.

ii) Bright Microscope :-

→ A microscope that uses different light transmission characteristic of materials, such as crystalline structures, to produce an ~~imag~~ image.

iii) phase contrast microscope :-

→ A microscope that visualizes minute surface irregularities by using light interference. → It is commonly used to observe living cells without staining them.

iv) polarizing microscope :-

→ A microscope that uses different light transmission characteristics of materials, such crystalline structures, to produce an image.

v) Differential interference contrast microscope :-

→ This microscope, similar to the phase contrast, is used to observe minute surface irregularities but at a higher resolution.

→ The use of polarized light limits the variety of observable specimen containers.

vi) fluorescence microscope:-

→ A biological microscope that observes ~~fluro~~ fluorescence emitted by samples by using special light sources such as mercury lamps. when combined with additional equipment, Bright field microscopes can also perform fluorescence imaging.

vii) Total internal reflection fluorescence microscope:-

→ A fluorescence microscope that uses an evanescent wave to only illuminate near the surface of a speciman. The region that is viewed generally very thin compared to conventional microscopes. observation is possible in molecular units due to reduced background light.

viii) laser microscope:-

→ This microscope uses laser beams for clear observation of thick samples with different focal distances.

ix) Multiphoton excitation microscope:-

→ The use of multiple excitation lasers reduces damage to cells and allows high-resolution observation of deep areas.

→ This type of microscope is used to observe nerve cells and blood flow in the brain.

x) Structured illumination microscope:-

→ A high-resolution microscope with advanced technology to overcome limited resolution found in optical microscopes that are caused by the ~~differe~~ diffraction of light.

(b) Electron - Microscope:-

i) Transmission electron microscope (TEM)
ii) Scanning electron microscope (SEM) etc.

→ These microscopes emit electron beams, not light beams towards targets to magnify them.

(c) Scanning probe microscope (SPM)

i) Atomic force microscope (AFM)
ii) Scanning near-field optical microscope (SNOM) etc

→ These microscopes scans the surface of samples with a probe and this interaction is used to measure fine surface shapes or properties.

(d) Classification by structure:-

i) Upright microscope:- observes targets from above. This type of microscope is used to observe specimen on slides.

ii) Inverted microscope:- observes targets from below. This microscope is used to observe, for e.g- cells soaked with culture in a dish.

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Specimen preparation procedure:-

preparation of metallographic specimens generally requires five major operations :-

1. sectioning
2. Mounting (which is optional)
3. Grinding
4. polishing
5. Etching

Advantages of well-prepared metallographic specimen are:-

(a) Represent sample
(b) Sectioned ground and polished so as to minimise disturbed surface metal caused by mechanical deformation.
(c) free from polishing scratches and pits and liquid staining
(d) polished so that inclusions are ~~preserved~~ preserved intact.
(e) It allows the true microstructure to be ~~revel~~ revealed by etching.
(f) flat enough to permit examination at high magnification.

① **Sectioning :-**

→ while preparing speciman we should ensure that we do not alter the microstructure or damage fracture features when cutting a specimen.

→ low-speed-cut-off wheels are utilized in cases where the heat created by standard abrasive cutters must be ~~ab~~ avoided or to avoid cold working a materials.

→ we ensure ample coolant (when allowable) and proper speed controls during sectioning operations.

② **Mounting :-**

→ The primary purpose of mounting is to make it convineement to handle specimens (of small of size) during various steps of metallographic ~~sample~~ preparation and examination.

→ second purpose is to protect and preserve extreme edges of surface (disfects) during metallographic preparation.

→ specimens are generally mounted in epoxy in 1 to 1.5 inch diameter molds of a hard polymer. Compression molding materials are typically either thermosetting or thermoplastic.

The mounting operation accomplishes important functions :-

i) It protects the specimen edge and maintains the integrity of a materials surface features.

ii) fills void in porous materials and

iii) Improves handling of irregular shaped samples, especially for automated specimen preparation.

iv) without damage to the specimen.

3. Grinding :-

→ Grinding is a most important operation in specimen preparation.

→ The purpose of grinding is to lessen (Reduce) the depth of deformed metal to the point where the last (mark) vestiges of damage can be removed by series of polishing steps.

→ During grinding the operator has the opportunity of minimizing mechanical surface damage that must be removed by subsequent polishing operations.

→ The purpose of grinding is to smooth the surface using progressively finer abrasive materials to remove any saw marks or deformations.

4) polishing :-

→ further refine the surface using ~~even~~ finer abrasives or polishing cloths ~~units~~ until it is free of scratches and has a mirror-like finish.

→ polishing is the final step in producing a surface that is flat, scratch free and mirror-like appearance.

x→ polishing involves the use of abrasives, suspended in a water solⁿ, on a cloth-covered electrically powered wheel.

→ In intermediate polishing, SiC paper of different grades are used], Again, the specimen is rotated while switching from one grade to another. The operation is carried out on a disc with the sandpaper stretched across it.

→ For fine polishing, Double Disc polishing Machine is used with a napped cloth fixed atop it.

5) Etching :-

→ Etching is the process that treat the specimen with a chemical reagent to reveal structural details, depending on the type of materials and the examination methods.

→ Etching is used to highlight and sometimes identify micro structural features or phase present.

→ The most common techinique for etching is selective chemical etching and numerous formulations.

→ The purpose of etching is to optically enhance micro-structural features such as grain size and phase features.

Advantages of Etching

- fast
- can be reproducible
- No mechanical deformation
- can be automated
- can produce excellent surfaces for examination.

Disadvantages

- conductive specimens only
- Not all alloys can be polished
- preferential attack or pitting can occur.
- No edge retention.
- limited polishing area.
- limited scratch & material removal.
- Hazardous electrolytes.
- Establishing correct conditions can be difficult

properties of metals :-

There are various ~~types of~~ properties of metals are:-

1. Mechanical properties.
2. Electrical properties
3. Thermal properties
4. Magnetic properties
5. Chemical properties.

i) Mechanical properties :-

- Mechanical properties of metal indicate the nature of its inherent behaviour under the action of the external force.
- Mechanical properties are the properties of metal which are associated with its ability to resist failure under the action of external forces.

Jitendra

- Some of the most important mechanical properties of the metals are -

i) Strength :-

- It is the ability of a materials to resist the external forces without breaking.
- The strength of materials depends on type of loading.
- Various types of strength like tensile, compressive, shear etc.

ii) Elasticity :-

- This property of metal by virtue of which it tends/ are able to regain its original shape and size after removal of deforming force / load is called elasticity.

iii) plasticity :-

- The property of metal by virtue of which ~~it~~ they doesn't tends / are able to regain its original shape and size after the removal of deforming force / load.

iv) Ductility :-

- The ductility may be defined as the property of metal by virtue of which they can be drawn into thin wires without breaking is called ductility.
- This property depends largely upon tenacity and to some extent on hardness.
- Ductility of metal is higher in cold than hot. hence, wires are drawn in cold condition.
- The following common metals have ductility in decreasing order :- Gold, platinum, silver, iron, copper, Al, nickel, zinc, tin and lead.

(v) Brittleness :-

- The brittleness may be defined as the property of metal by virtue of which it will fracture / broken suddenly or easily without any appreciable deformation.
- Metals that are less ductile will be brittle.
  e.g :- cast iron.

(vi) Hardness :-

- The hardness may be defined as the property of metal by virtue of which resist, abrasion, identation and scratch by relatively harder materials.
- Hardness is the ability of a materials to cut another materials.
- This property is used in selection of cutting tools materials.
  e.g :- Diamond, quartz, corundum etc.

(vii) Toughness :-

- The toughness may be defined as the property of metal by virtue of which has ability to absorb energy and resist fracture due to high impact loads or do not easily broken or damaged.
- Toughness decreases with an increase in temperature.
- It is a very important property that is considered while selecting the materials for power press, punch, pneumatic, hammer etc.

(viii) Stiffness :-

- Stiffness is also known as the rigidity of metal.
- It may be defined as the property by virtue of which the metal will not deform or ~~deflect~~ deflect when the load is applied.

(ix) Resilience / ~~Resistance~~ :-

- Resilience may be defined as the property of metal by virtue of which it stores energy and resists shock and impact loads.

(x) Creep :-

- The creep may be defined as the property of metal by virtue of which it deforms continuously and slowly under a steady load.
- Metals generally show creep at higher temperature.
- The creep is considered an important property while designing the part of the IC engines and turbine blades as they are subjected to high pressure at high temperatures.

(xi) Malleability :-

- Malleability is the property of metal by virtue of which metals can be beaten to form thin sheets.

- Thermal properties :-

The Thermal properties of the metals are the characteristics of metal which are influenced by the application of heat.

(a) Thermal conductivity :-

- Metals generally have high thermal conductivity, which means they can transfer heat efficiently.
- Higher the thermal conductivity, the greater will be the rate at which heat is conducted.
- pure metals show only small changes in thermal conductivity with temperature.
- Thermal conductivity of copper and Aluminium increases as the temperature decreases until a maximum reached.

(b) Thermal expansion :-

- Metals are expand when heated and contract when cooled.
- The amount of expansion and contraction will be proportional to the change in temperature.
- This property of metals will be useful in the application such as: shrink-fit and bi-metals alloys.
- This property is quantified by the coefficient of thermal expansion, which varies among different metals. for eg - aluminum has a higher coefficient of thermal expansion compared to steel.

(c) Melting point :-

- Metals generally have high melting points, ~~through~~ this varies widely among different metals. for e.g.- Tungsten has one of the highest melting points, whereas lead has a relatively low melting point.

(d) Specific Heat :-

The specific heat of a metal may be defined as the quantity of heat required to raise the temperature of a unit mass of a substance through 1°C.

(e) Heat Resistance :-

Some metal can withstand high temperatures without degrading, making them suitable for high temperature application e.g.:- stainless steel and titanium.

physical properties of metals :-

i) Metals are malleable and ductile
ii) Metals are good conductors of heat & electricity.
iii) Metals are lustrous (Shiny) and can be polished.
iv) Metals are solid at room temperature (except mercury).
v) Metals are tough & strong.
vi) Metals produce a ringing sound when struck, this property is known as sonority.
vii) Metals have high melting & boiling point & high density
viii) ~~Malleable, Ductile~~.

* **Electrical properties of metals:-**

The characteristic of a metal which enables the flow of electric current through it is called ~~therm~~ electrical properties.

The most important electrical properties of metals are Conductivity, Resistivity and Dielectric strength.

(a) **conductivity:-**

- The conductivity may be defined as the electrical property of the metal by virtue of which allows the flow of electric current.
- It is also defined as the reciprocal of resistance.
- pure metals have good conductivity at room temperature
- e.g:- Al and Cu are good conductors. They are used for making electrical transmission wires.

(b) **Resistivity:-**

- Resistivity may be defined as electrical property of the metal by virtue of which it resists the flow of electric current.
- It is also defined as the reciprocal of conductivity
- It increases linearly with an increase in temperature.

(6) Dielectric Strength :-

- The insulating materials will have the insulating ability up to a certain range of voltage.
- If the operating voltage is increased gradually, at some voltage it loses its insulating property.
- The minimum voltage can be applied to the insulating materials which results in the destruction of the ~~insulta~~ insulating properties of the materials is defined as dielectric strength.

- Dielectric strength is defined as the maximum voltage required to produce a dielectric ~~d~~ breakdown through a material.