Section - A

Miller Indices :- The spacing b/w the successive plane and density of lattice point is diff for diff. set of planes. There is an useful method to design these planes by a set of three integers known as miller Indices.

Steps :- 1) find the intercepts made by the plane along the coordinate axes x, y & z in terms of lattice parameters.

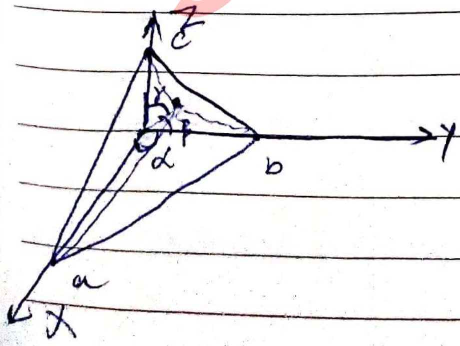
2) Express the intercepts as the multiples of primitive vectors.

3) Take resiprocals of these numbers.

4) If fraction results, then convert them into smallest possible set of integers.

5) Put the resulting integers h, k, l into (hkl). By taking reciprocals, we bring all the planes in a single unit cell.

formula for the distance b/w two adj planes :- Consider a single unit cell in which the co-ordinate axes are orthogonal.



Origin O is taken at any lattice point. The next plane cuts the intercepts a/h, b/k, c/l at x, y and z axes resp. A normal ON = d is drawn to the plane ABC from the origin, d is the length from origin.

$$d = \frac{a}{h}\cos\alpha = \frac{b}{k}\cos\beta = \frac{c}{l}\cos\gamma$$

where α, β & γ are the angles b/w the normal to the plane and x, y & z axis resp.

According to law of direction Cosines

$$\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$$

Putting the values of $\cos\alpha$, $\cos\beta$ & $\cos\gamma$, we get

$$d^2\left(\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}\right) = 1$$

$$d = \frac{1}{\left(\frac{h^2}{a^2} + \frac{k^2}{b^2} + \frac{l^2}{c^2}\right)^{1/2}}$$

for cubic system, $a = b = c$

$$d = \frac{a}{(h^2+k^2+l^2)^{1/2}}$$

Q (2b) (223) (234)

$$d_{hkl} = \frac{a}{\sqrt{h^2+k^2+l^2}}$$

$$d_{223} = \frac{a}{\sqrt{(2)^2+(2)^2+(3)^2}} = \frac{a}{\sqrt{4+4+9}} = \frac{a}{\sqrt{17}}$$

$$d_{234} = \frac{a}{\sqrt{(2)^2+(3)^2+(4)^2}} = \frac{a}{\sqrt{4+9+16}} = \frac{a}{\sqrt{29}}$$

Q-(C) for first order reflection $(n) = 1$
Bragg's angle $(\theta) = 60°$
Wave length $(\lambda) = 1.8 \times 10^{-10} m$

$$\therefore \boxed{2d \sin\theta = n\lambda}$$

$$d = \frac{n\lambda}{2\sin\theta} = \frac{1 \times 1.8 \times 10^{-10}}{2 \sin 60°}$$

$$= 1.039 \times 10^{-10}$$

$$= 1.039 \text{ Å}$$

1) Space lattice :- It is a parallel ~~space~~ net like arrangement of points such that environment about any point is identical to that about any other point.

2) Unit Cell :- The region of crystal formed by three primitive vectors a, b & c along crystal axes is called the unit cell.

3) Translation vectors :- The act of displacing a crystal parallel to itself by an

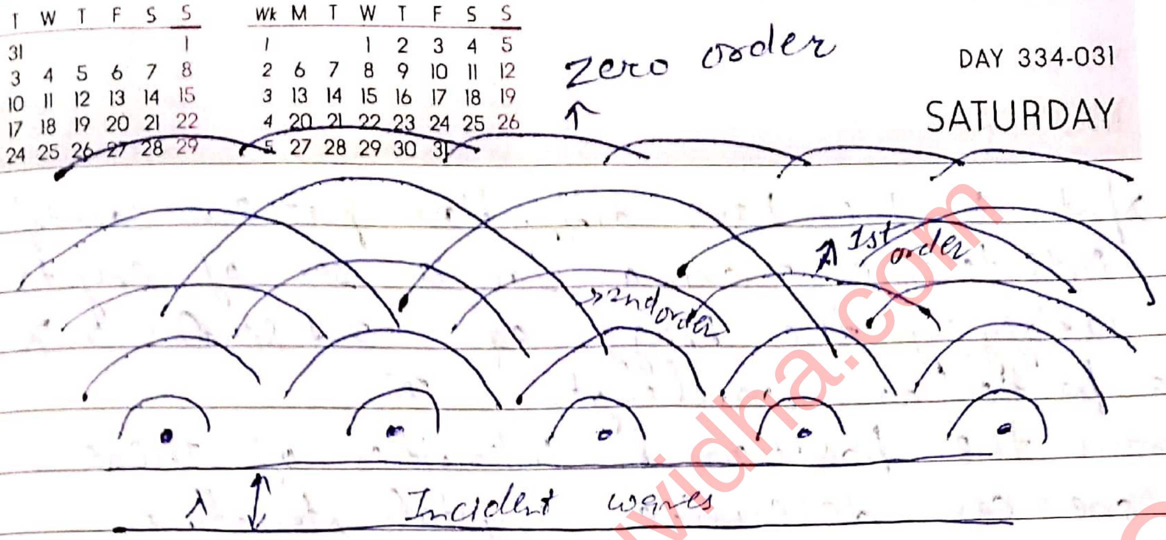
Intigral multiple of each of the primitive vectors is called translation operation. And vector representing the lattice point relative to its initial position is translation vector (T).

$$T = n_1a + n_2b + n_3c$$

X-ray diffraction :- Let's consider an e^- in an atom, subjected to a mono-chromatic beam of x-rays. The electric field vector of the radiation forces it to carry out the vibration of frequency equal to that of the incident beam. It will emit radiation of the same wave length in all directions. Thus all e^- in the atom contributes to scattering of x-rays in this fashion. When the wavelength of incident x-radiation is large as compared with the dimensions of an atom, the wavelets emitted by the e^- in atoms are nearly all in phase.

But x-ray used in difference have a wavelength of same order of magnitude as the atomic diameter because it is necessary condition to obtain diffraction pattern. Thus the wavelets emitted will partially cancel each condition to obtain a diffraction pattern.

In Crystals we are concered with the scattering by a large no. of atoms arranged according to a particular pattern.

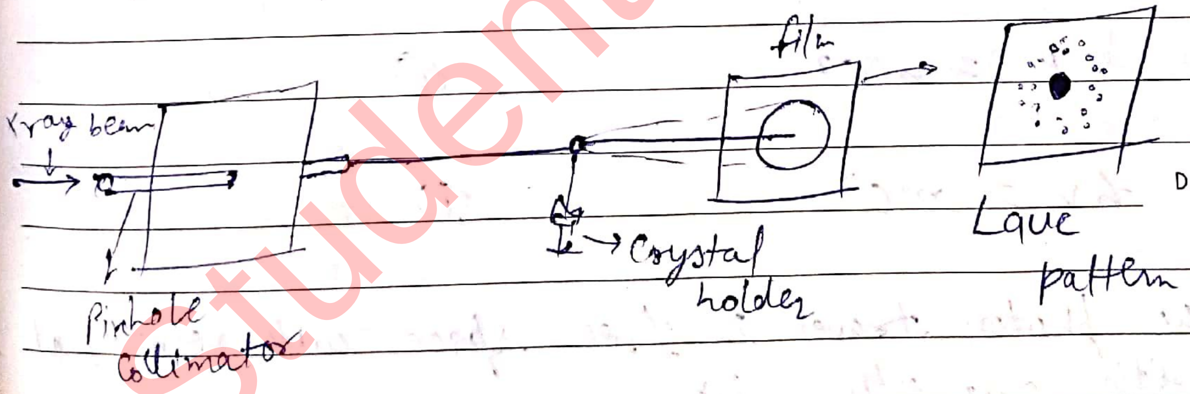


Reinforcement of scattered waves.

Laue's method :- This method is used to determination of crystal structure and the details of electrons charge distribution within the solids.

Requirements :-

1) A continuous X-rays beam, well collimated by a pin hole.
2) A single crystal held stationary.
3) A flat film to receive transmitted diffraction beam



Working :- When X-ray beam falls on the crystal, the beam is differected. The transmitted beam forms a series of spots on the film called Laue spot which are characterize of crystal structure.

Each spot in the Laue diffraction pattern corresponds to an interference maxima for a set of crystal plane satisfying the bragg's eq^n $2d\sin\theta = n\lambda$ for a particular wavelength.

from the position & intensities of these spots one can determine crystal structure.

(3) Compton effect:- when high frequency radiations are scattered by the electrons, then frequency of scattered wave is smaller then the freq. of incident wave. This is compton effect.

Derivation of de-Broglie eq^n:- first case:- Consider a photon.

$$E = h\nu \quad \text{--- (1)}$$

w.k.t.

$$E = mc^2 \quad \text{--- (2)}$$

So,

$$h\nu = mc^2 \quad \text{--- (3)}$$

If all the photon travel in free space with velocity of light, c, it's momentum is:-

$$p = mc \quad \text{--- (4)}$$

from 3 & 4

$$\frac{h\nu}{p} = \frac{mc^2}{mc} = c$$

$$p = \frac{h\nu}{c} = \frac{h}{\lambda}$$ $\left(\frac{c}{\nu} = \lambda \right.$ the wavelength of radiation $\left. \right)$

$$\therefore \lambda = \frac{h}{p}.$$

So,
from here we got that if m is the mass of parti(cle) with velocity v, then its momentum $p = mv$.
The wavelength

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

Crystal defects → 1) Point defect
2) Line defect
3) Surface defect

Point
→ Vacancy
→ Schottky defect
→ Interstitial defect
→ Substitutional defect
→ Frenkel defect

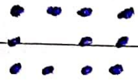
Line
→ Edge dislocation
→ Screw dislocation

Surface
→ Grain boundaries
→ Tilt boundries.
→ Twin boundary.

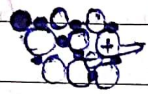
1) **Point defect** :- Lattice errors at isolated lattice point is point defect.

they may be reffered as zero dimensional imperfection

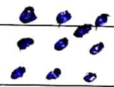
1) Vacancy :- Missing of an atom from a regular lattice site



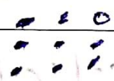
2) Schottky defect :- when pair of +ve / -ve ions are missing And crystal stays neutral.



3) Interstitial defect :- when foreign atom occupied the void space in crystal.



4) Substitutional defect :- when a foreign atom replace with parent atom.

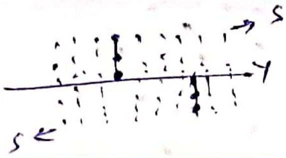


5) Frenkel defect :- where cation & anion are present and cation displaced from their regular location to interstitial location.

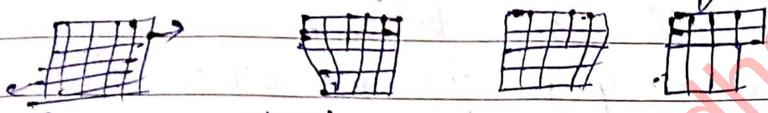
⇒ Line defect :- Dislocation / distortion of atoms along a line in same direction are called line defect.

1) Edge dislocation :- Edge dislocation lies perpendicular to its Burger's vector. It involves an extra row of atoms ; either above (+ve) or below (-ve).

This presence of extra row are displaced elastically under a shear stress → a (+ve)



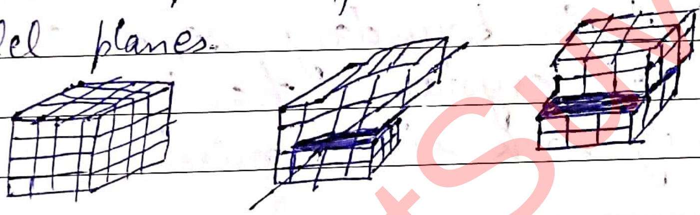
dislocation moves to the right and a (-ve) to left.



As the dislocation glides out the crystal completely, it produces a slip step of one width at the edge of crystal.

→ Edge dislocation is useful in explaining ~~the~~ slip in plastic flow during mechanical working.

Screw dislocation :- It lies parallel to Burger's vector. A screw dislocation is a continuous helicoidal plane of atoms rather than a series of parallel planes.



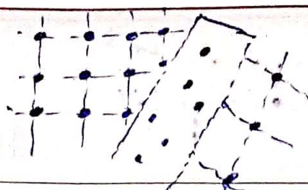
∴ Speed of movement of a screw dislocation is less than edge.

∴ Screw dislocation explain crystal growth as well as slip in plastic deformation.

→ **Surface defect** :- Surface defects are either internal or external.

External defects are represented by boundary. The external surface of the material having imperfection itself, because atomic bonds do not extend beyond it. An internal defect is present in the interior of the crystal.

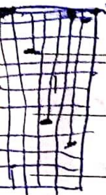
Grain boundaries :- Those planer imperfection



ions in polycrystalline material that separate crystal (grains) of diff. orientation.

A grain boundary is formed when two growing grain surface meet. It is a three-dim. surface.

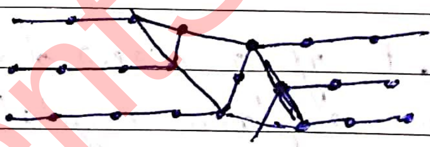
In grain boundaries the atomic packing factor is imperfect.



Tilt boundaries:- It's a surface imperfection, but also be regarded as array of edge dislocation.

Tilt boundary is a class of low boundaries.

Twin boundary:- A twin boundary separate two parts of crystal having the same orientation. And they look like mirror image of each other.



Bravais lattice:- The crystal lattice representing various arrangement of points are called bravais lattice.

There are 14 types of Bravais lattice and 7 " " Crystal.

2D bravais lattice:- There are five bravais lattice in 2D one oblique lattice and four spatial lattice.

$2\ell/n$ ($n = 1 \ldots 6$)

1) Oblique ⊢ $|a| \neq |b|$; $\gamma \neq 90°$
2) Square ⊢ $|a| = |b|$; $\gamma = 90°$
3) Hexagonal ⊢ $|a| = |b|$; $\gamma = 120°$
4) Rectangular ⊢ $|a| \neq |b|$ $\gamma = 90°$
5) Centered rectangular ⊢ $|a| \neq |b|$; $\gamma = 90°$

3-D bravais Lattice

1) Triclinic ⊢ Single lattice, Primitive (P) unit cell, three axes of unequal length & angle.

2) Mono clinic ⊢ Two lattice, one Primitive & other non primitive conventional cell.

3) Orthorhombic ⊢ four lattice, one primitive, one base centered, body centered and one face centered.

4) Tetragonal ⊢ Right square prism.

5) Cubic ⊢ 3 lattice, Primitive cell, Body Centered cubic, Face Centered Cubic

6) Trigonal ⊢ A rhombohedron is usually choosen as unit cell.

7) Hexagonal ⊢ The conventional cell chosen in a right prism, based on a rhombus with an angle of 60°. The Lattice is primitive.

Section B

→ Quantum dots :- If all the three dimensions of the material are reduced to nano range, the structure is called quantum dots.

→ Quantum Size effect :- The splitting of energy levels is called quantum size effect.

Applications of Quantum dots :-

1) Computing :- Q.D. technology is best candidate for use in solid state quantum computing. By applying small voltage to leads one can control the flow of e^- through the quantum dot and make precise measurements of the spin and other properties. It also helps in detection of Tumors.

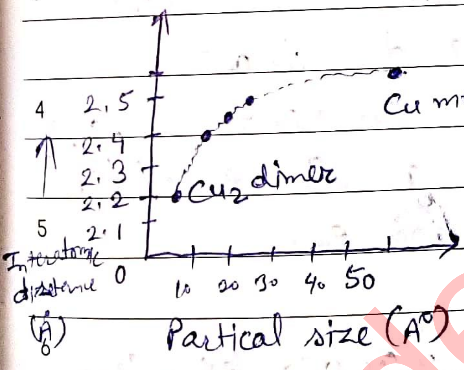
2) Quantum dot lasers :- Laser operation requires the presence of discreate energy levels. Hybrid type lasers have been constructed using "dots in well".

3) Biology :- In modern biological analysis, various kinds of organic dyes are used and the traditional dyes are often unable to meet the expectations. To this end quantum dots have quickly filled in the role, being found to be superior to traditional organic dyes.
For single particle tracking, the irregular blinking of quantum dots is a minor drawback.

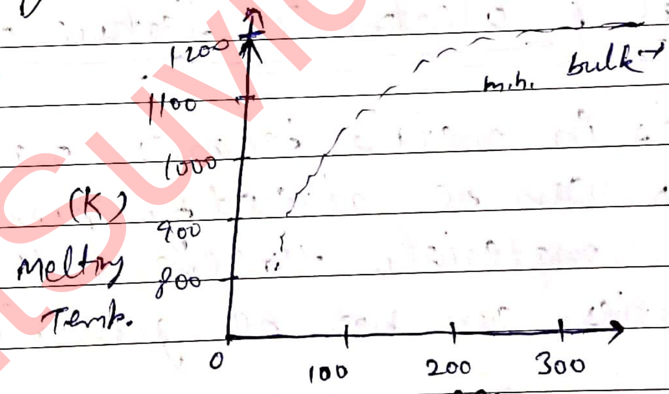
iv) Photo-voltic Cell devices (PVCs) :- QD may have the potential to increase the efficiency and reduce the cost of today's typical silicon photovoltaic cells.

Features of Nanoparticles

1) Physical feature :- i) With decrease in particle size, surface to volume ratio increases. It changes the surface pressure and hence it leads to change in the interatomic distance.
The interatomic spacing increases with increase in diameter of the particle.



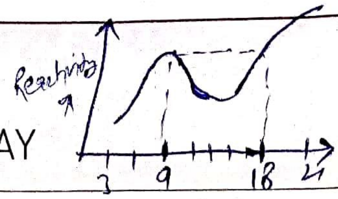
(i)



(ii)

ii) The change in interatomic distance and large surface to vol. ratio have a combined effect on material properties. The melting point decreases with dec. in particle size.

2) Chemical & Catalytic feature :- The relatively surface to volume ratio have a combined effect on catalytic and chemical properties. Many features of nanosystem changes with cluster size.



i) The reactivity of small clusters has been found different when the cluster size is changed by changing only a few no. of atoms.

In fig. reactivity of diff. cluster sizes first inc. upto a peak value and then decreases. When cluster size is greater than 18 atoms, then nanosystems are more reactive.

ii) Insoluble materials like gold becomes soluble at nanoscale.

iii) The stable materials like Al becomes combustile.

Electrical & Electronic features :- Due to quantum confinement the electronic bands in metals becomes narrow and those bands can be altered by passage of current through these materials. However, the change in electrical properties can not be generalized. For ex,

i) In nanoceramics and magnetic nanocomposites, the electrical conductivity increases with reduction in particle size. Whereas in metals electrical conductivity decreases.

Optical feature :- The optical properties of nanosystem are very much diff from those of bulk. But the observed changes are diff for diff. materials.

→ Depending on the size of particle, diff color are seen in case of nanoparticle suspension.

exs Gold → 100nm → orange
" → 50 nm → Green

→ Opaque bulk substance become transparent when the size is reduced to a few nm.

exs Bulk copper is opaque but copper nanosystem is transparent.

Magnetic features :- Magnetic nanosystem show many new magnetic properties when compared with the bulk materials. This is mostly due to surface effects, electronic charge transfer and magnetic interactions.

→ The strength of magnets is measured by value of coercivity and saturation magnetization. These values increases with a decrease in particle size and with increase in relative surface area. So, nano systems have good novel magnetic properties also.

Mechanical features :- Surface atoms of nanosystem experience diff potentials in diff directions.

→ Most of the nanosystems are brittle and show reduced ductility under tension.

→ Because of nanosize, many properties like toughness, fatigue strength, hardness modified.

Applications of nanotechnology – Nanotechnology has wide applications in every field of Science & Tech.

1) Electronics – The electronic devices with typical dimensions of few nanometers in either of three directions display, not just minimization but unique properties.
Single Electron Transistor (SET), Magnetic Tunnel Junction (MTJ) are conceptually new devices based on nanotechnology.
Such devices are faster, compact and relatively cheaper.
The quantum computers using nanotechnology will be more powerful then existing computers. The flat panel TV or comp. monitors are the products of nanotech.

2) Energy – Nanotech is very imp. to fulfill the growing need of energy. Natural resources are ~~going~~ ~~too~~ depleting very fast. Researchers are trying to make efficient solar cells using nanomaterial.
Attempts are being made to tap hydrogen fuel by splitting water using sunlight in presence of nano-materials (Photocatalyst).

3) Sports & Toys – Robots, & movement of dolls etc.
Pores of tennis balls filled using nano clay so ~~to~~ maintain air pressure inside.

4) Automobile – A nanotube composite have better mechanical strength than steel. Cars are painted with spray of fine particles. Nanoparticle

paints provide smooth and thin attractive coating.

5) Textile :- NP plays a imp. role in textile industry. Clothes consisting of nanoparticles of some material would give pleasent look of synthetic fiber but comfort of cotton.

6) Cosmatics :- Zink oxide and titanium oxide nanoparticles of uniform size are able to absorbe UV light & protect the skin. Nanoparticle based creams are being preffered because of their use in small amount and not leaving any gap.

7) Domestic Appliances :- Silver has antibactorial properties. Silver nanobased refrigerators can keep the food fresh and prevent food. The clothes washed in nanobased washing machine remains germfree for a long t

In addition to these nanotechnology has imp. use in medical field to detect and destroy cancer cells. In space and defence for better performance and better fatigue strength of space vehicles and safety from solar radiations.

NOV '19							
Wk	M	T	W	T	F	S	S
44					1	2	3
45	4	5	6	7	8	9	10
46	11	12	13	14	15	16	17
47	18	19	20	21	22	23	24
48	25	26	27	28	29	30	

Tools for making nanostructures:-

1) **Scanning Probe Instrument** :- Used to see and manipulate structures. Here ~~atoms are~~ materials are assembled atom-by-atom or molecule-by-molecule.

(ii) **Nanoscale Lithography** :- Lithograph is an image that is produced by carving a pattern on the stone, inking the stone, and then pushing the inked stone onto the paper.

In this lithography, a master mask is made using chemical methods and light passes through the mask to produce the actual chip structure.

Nanoscale lithography can't use visible light because wavelength of visible light is 400–900 nm. So, structure smaller than that are difficult to make directly using it. Hence making smaller objects at the nanoscale required entirely new prepration methods.

(iii) **Dip Pen Nanolithography** :- DPN is based on the principle that, in a lithography, a reservoir of "ink" is stored on the top of scanning probe tip. This "ink" is composed of atoms or molecules and so, it is also called atomic or molecular ink. The scanning probe tip is then manipulated (or drawn) across the given surface.

(iv) E-beam lithography :- In this technique, electrons are used instead of light and hence it is called e-beam lithography. The E-beam lithography can be used to make structures at the nanoscale.

Resistivity (ρ) $\quad m = 9.1 \times 10^{-31}$ kg

No. of e^-/m^3 (η) $\quad e = 1.6 \times 10^{-19}$ C

Electric field (E)

Relaxation time $(\tau) = \dfrac{m}{\eta e^2 \rho}$

Drift velocity $(v) = \dfrac{eE}{m} \times \tau$

Mobility of e^- $(\mu_e) = \dfrac{e\tau}{m}$