Unit 6

Date:- / /
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Non Destructive Testing and Nanotechnology

Course objective :- To teach students basic concepts and principles of physics, relate them to laboratory experiments and their applications.

course outcome :- comprend use of concepts of physics for non-destructive testing. Learn some properties of nanomaterials and their applications.

Non destructive testing

All industrial products like automobiles, electronic devices, machinaries are made up from various components.

failure of any component is causes financial loss as well as threaten to human safety.

failure in Automobile & aircrafts components → human life in danger + financial losses.

To avoid such losses it is necessary to ~~not~~ test component" regularly.

Material Testing:- Material testing is the study of characteristics of behaviour of substances such as metals, ceramics or plastic under various conditions.

Material testing is essential because for human ~~safty~~ safety some rules and

regulation agencies are there (ISI, ISO ma
Material testing also describes properties of material with which we can find applications

Testing methods :-

Testing methods

Destructive method	Non-destructive meth
→ component is destroyed	→ component isnot destroy
→ All components cannot be tested	→ All component can be tested
→ Time consuming	→ Rapid (short time)
→ Testing during operat^n is not possible	→ Testing during opera is possible
→ Test results are quantitative	→ Test results are generally qualitative

Types of defects:-
In components defects can be external or internal which affects the performan of devices.

<1> Surface cracks
<2> Surface irregularies
<3> Internal cracks
<4> Impuries & air bubbles
<5> change in dimensions
<6> permanant deformation - creep
<7> failure of material due to repeated loading and unloading - fatigue
<8> Micro or axial segregation

Non destructive testing:- (NDT) :-

Non destructive testing is group of analysis techniques to evaluate the properties of a material without damage.

Defect can be detected without destroying material.

In NDT structural properties remains same

Objectives of NDT :-

1) To detect flaws during the manufacturing components, so that defective component can be detected, which save same money & time.
2) To detect flaws of ready components without destroying it to improve performance and reliability.
3) To detect flaws during operations, can overcome it without reducing rate of production.
4) To increase the safety by regular testing, can be defective components can be replaced.

Advantages of NDT :-

(1) Safety :- harmless and undamaged testing
(2) Reliability :- All components are tested, no risk
(3) Affordability :- affordable, can be used regularly
(4) Peace of mind :- knowing the accuracy & safety gives proper functioning

Methods of NDT

1) Magnetic methods
2) Electrical methods
3) Radiographic method
4) Ultrasonic method
5) mechanical method
6) Thermal method

Principle of physics in NDT

NDT is a testing and analysis technique used by industry to evaluate the properties of a material, component, structure or system for characteristic differences without damaging original part.

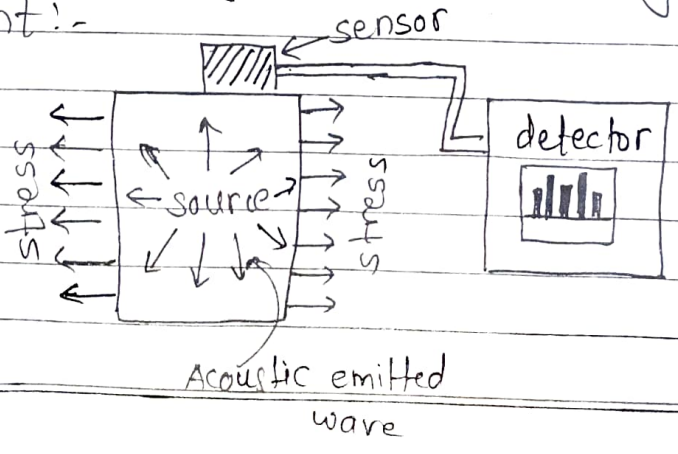
(1) Acoustic Emission testing

Acoustic emission is defined as the generation of an elastic wave due to rapid release of energy ~~without~~ within the material.

Elastic wave generated by released ene

Principle:- Higher force gives high deforma and higher elastic energy.

Arrangement:-



is reflected
In large sized structures several sensors are placed on the material surface leaving a space of some meters in between. the deformation information collected by each of the sensors is monitored through a computer.

If the defects exist in some areas the signal character from the sensor attached nearest to the discontinuity appears in different way.
By analyzing discontinuity, defects can be detected
It is used to inspect pipeline, pressure vessels, storage tanks. Also to detect flaws and irregularities in the materials

Advantages of acoustic emission testing

(1) Global testing
(2) Continuous monitoring can be possible
(3) Real time monitoring
(4) Shorter time than other NDT method.

Disadvantages of acoustic emission testing

(1) It gives only qualitative testing, not useful for finding exact size, depth & other defects.
(2) If more waves are produced, difficult to reduce noise from signals.

(2) Ultrasonic Method / Ultrasonic testing

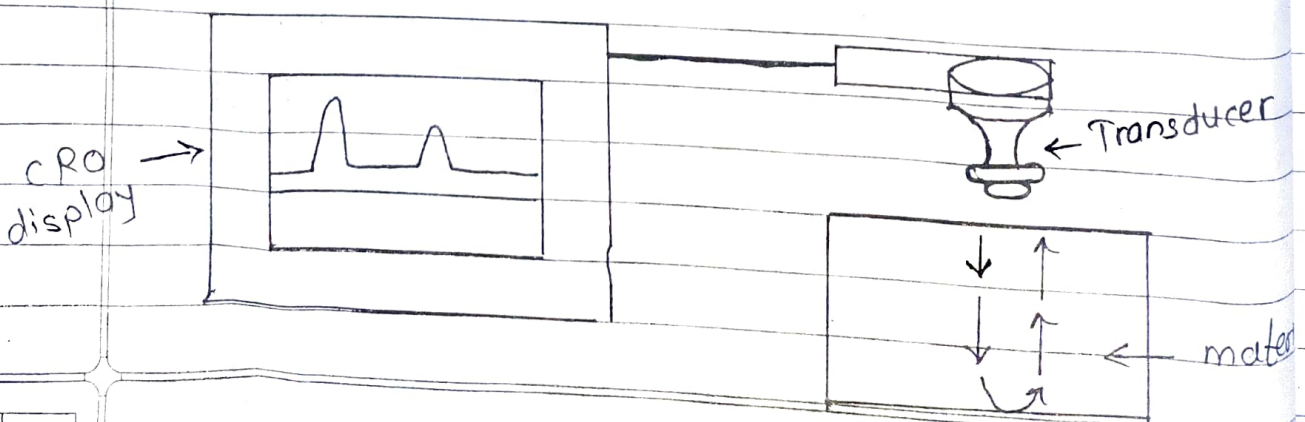
Sound waves / Acoustic waves

Infrasonic waves	Audible	Ultrasonic wa
f = less than 20 Hz	f = 20 Hz to 20 KHz	f = greater than 20k

Ultrasonic waves are highly directional, highly ~~energe~~ energetic and hence can travel large distances in air, liquid or solid.
Velocity of wave depends upon density and Young's modulus of the material.
If defect is there, velocity change is observed.

Principle:- It is based on the echo principle. Change in density of material gives partially reflected and transmitted waves.

Arrangement :-

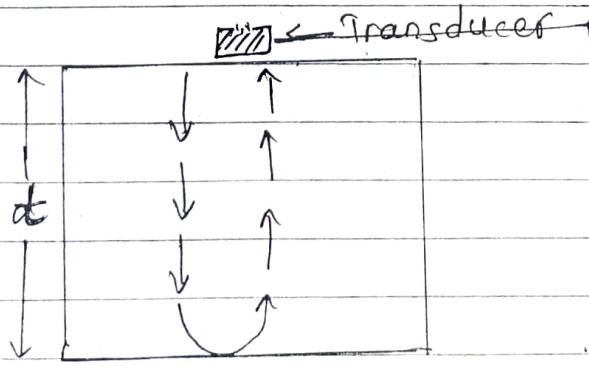


A piezoelectric transducer attached to the test piece converts the electric pulse into ultrasonic waves.
The waves travel through the test piece and reflected back from the opposite surface.

An ultrasonic pulse is transmitted into the specimen from one end by an ultrasonic transducer like quartz crystal which also use as receiver. Ultrasoni testing can be used for thickness measurement as well

Ultrasonic testing for thickness measurement:
Ultrasonic waves travel through metal block and gets reflected from its bottom.
The time required for reflection is calculated.
Speed of ultrasonic waves and reflection time is known, t distance i.e. thickness can be calculated.

$$v = \frac{\text{distance}}{\text{time}}, \quad \text{thickness} = \frac{\text{velcity} \times \text{time}}{2}$$

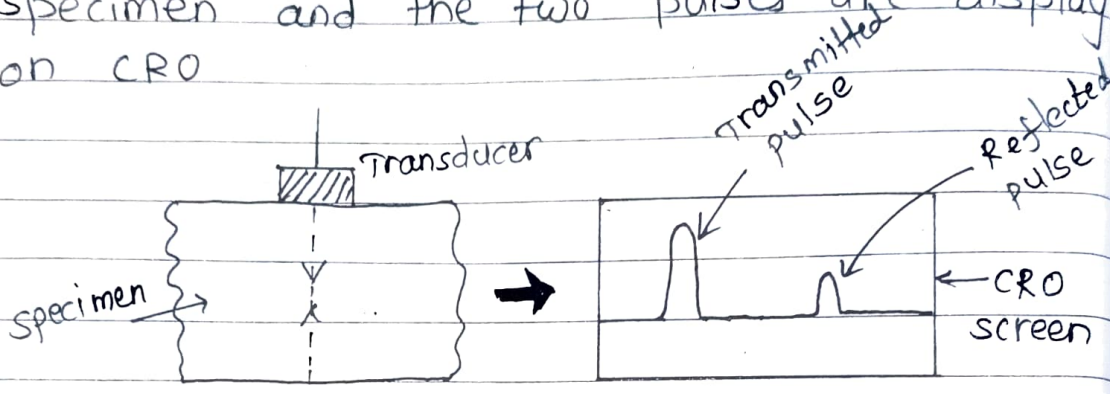


$$\therefore d = \frac{v \cdot t}{2}$$

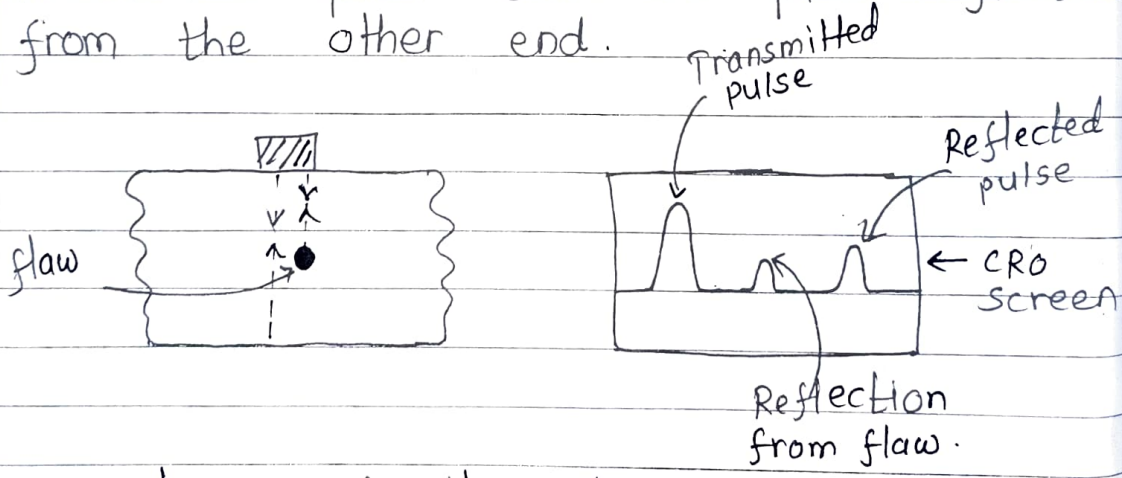
$$t = \frac{V \cdot T}{2}$$

Ultrasonic Testing for flaw detection:-

In absence of any flaw, the pulse is reflected from the other end of the specimen and the two pulses are displayed on CRO



If there is a flaw, an additional peak will be seen between the transmitted pulse and the pulse reflected from the other end.



Advantages of ultrasonic testing.

<1> ~~Hidden & internal~~ small flaws can be detected
<2> Inspection takes very little time
<3> Thickness can be calculated accurately.

Disadvantages of ultrasonic testing

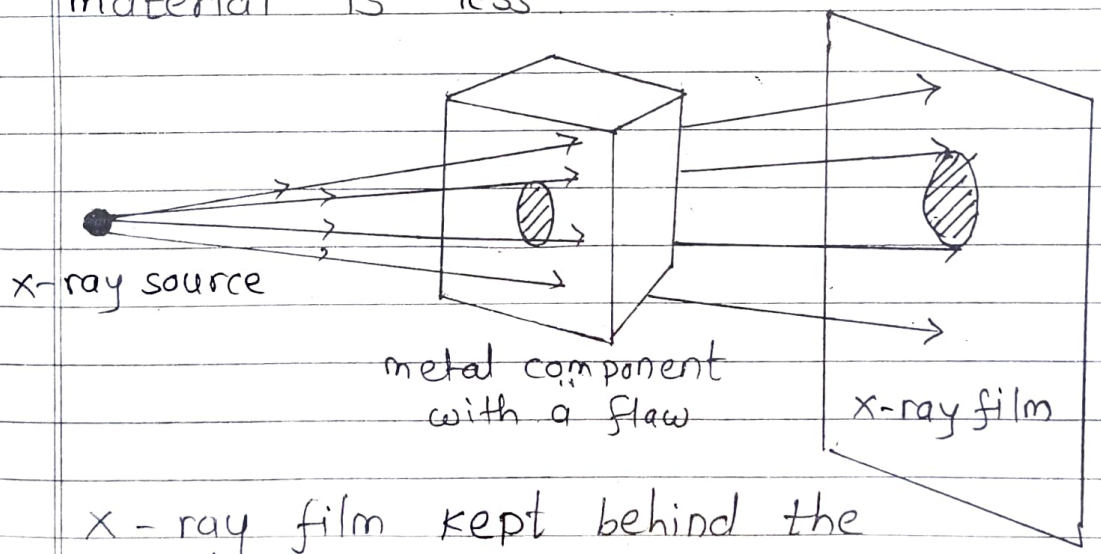
<1> more expensive than other method
<2> Difficult to use on very thin material
<3> Required smooth surface
<4> If defect is very close to surface cannot be detected.

X-ray Radiography testing:-

X-ray have high penetration power.
smaller the wavelength, larger is the penetration power.
When x-rays passing through metals, the intensity decreases due to absorption.

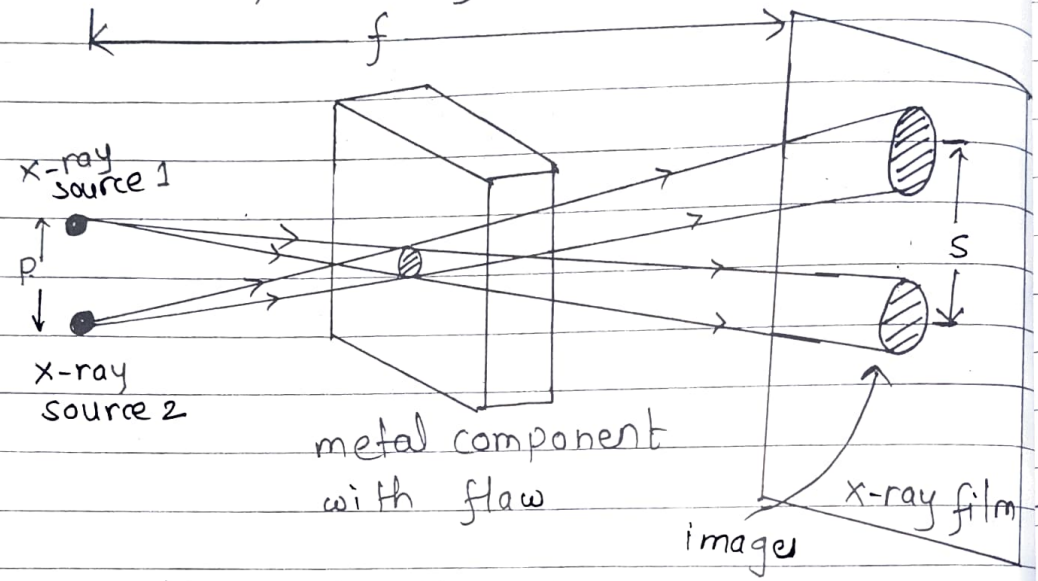
Principle:- Dissimilar transmission of x-ray through material creates a image of flaw.

Arrangement:- If x-rays are passed through a metal piece containing a flaw. the intensity of x-ray may vary because of flaw, where density of material is less



x-ray film kept behind the object.
The object will shows darker image on x-ray film metal absorbs x-ray which shows transparent and flaw represent darkness.
One can find internal defect of the body

with exact position by using x-ray or &
e.g. Human body x-ray scan shows transparent bones and remaing body is dark. Displacement method consists of two x-ray sources For finding exact position of the flaw, two position x-ray sources are required.



The depth of the flaw from upper surface can be find by displacement method. Two x-ray sources are used for incidence the x-ray on material & by using dissimilar transmission principle darkness and transparency is observed on x-ray film.

Flaw represents darkness and remaining part is transparent.

The depth of the transparent from surface

$$d = \frac{f \cdot S}{S + P}$$

d → depth, S → distⁿ betⁿ two
P → distance betⁿ sources, f → distⁿ betⁿ & scr

Advantages

(1) Hidden flaws can be detected
(2) Inspection takes very little time

3) A wide variety of materials can be tested

Disadvantages

(1) It is expensive compared to other NDT
(2) x-ray explosure for longer time is harmful to human being
(3) very small flaws can be detected.

(1) find the echotime of ultrasonic pulse which is travelling with the velocity 3.1×10^3 m/s in mild steel the correct thickness measured by gauss meter is 9mm.

→ Given data,

$v = 3.1 \times 10^3$ m/s

$t = 9\text{ mm} = 9 \times 10^{-3}$ m

$$\text{thickness} = \frac{vT}{2} = t$$

$$T = \frac{2t}{v}$$

$$T = \frac{2 \times 9 \times 10^{-3}}{3.1 \times 10^3}$$

$$\boxed{T = 5.8 \times 10^{-6} \text{ sec}}$$

$$\boxed{T = 5.8\ \mu s}$$

(2) An ultrasonic pulse is sent through a block of copper. The echo pulse is received after 4 μs. If velocity of ultrasonic in copper is 5000 m/s, calculate the thickness of copper block. If the reflection of pulse is recorded after 1.253 μs from the top, what is the location of flaw?

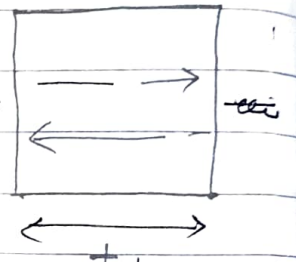
→ Given data,

$v = 5000$ m/s

$T_1 = 4\ \mu s$

$T_2 = 1.253\ \mu s$

Thickness



$$t_1 = \frac{v\,T_1}{2}$$

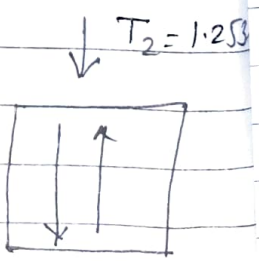
$$t_1 = \frac{5000 \times 4 \times 10^{-6}}{2}$$

$$t_1 = 10000 \times 10^{-6}$$

$$t_1 = 10^4 \times 10^{-6} = 10^{-2}\ m$$

$$\boxed{t_1 = 0.01\ m} \text{ or } \boxed{t_1 = 1\ cm}$$

Depth of the flaw,



$$t_2 = \frac{v\,T_2}{2}$$

$$t_2 = \frac{5000 \times 1.253 \times 10^{-6}}{2}$$

$$\boxed{t_2 = 0.003\ m} \text{ OR } \boxed{t_2 = 0.3\ cm}$$

Nanotechnology :-

Nanotechnology :-

It is the branch of physics which deals with the design, construction and utilization of functional structures with at least one dimension is in nanoscale.

nano → a billionth → 10^{-9}

$1\ nm = 10^{-9}\ m$

&

$1\ m = 10^{9}\ nm$

Nanoscience :- Study of fundamental principles for nanoscales.

Nanomaterials :- Material which having one of the dimension is in nanoscale i.e. ~~one~~ at least one of the dimension is very small i.e. less than 100 nm

Nanoscales can be 0D, 1D, 2D, 3D

It has high surface area to volume ratio.

Nanoscale materials having different properties than that of bulk material

When particle size is less than the characteristics length of some physical phenomenon, particle shows different properties.

characteristic length :- It is the dimension that defines the length scale of physical system.
It is generalizable to the other characteristic scales such as time, speed etc.

Classical mechanics can be useful for explaining the properties of the bulk material.
But it fails to explain the properties of nanoparticles.

When we are studying the properties of material in bulk form and nanoform, it is observed that properties of nanomaterials are different than that of bulk materials.

Development of technology is associated with smaller devices.
Now a days smaller devices represent technological growth & future prospects.

Factors affecting the properties of Nano-materials.

Properties of Nanoparticles are different from that of the bulk materials because of 1) Quantum confinement
2) Surface to volume ratio

(1) Quantum Confinement :-
When the size or dimension of a material is continuously reduced from a large or a macroscopic size (m, cm) to very small size (nm), dramatic changes in properties can occur.
Nanomaterials have properties that are different from those of bulk materials.

In the nanocrystals, the electronics energy levels are not continuous as in the bulk. they are discrete & having finite density of states because of the confinement of electronic wave function to the physical dimensions of the particles. This is quantum confinement.

Depending on the structures and confinements nanostructure named as
(1) Quantum well
(2) Quantum wire
(3) Quantum dot

1) Quantum well (2D)

Electrons are confined to one ~~dimension~~ in remaining two dimensions are ~~free~~, electr can move.

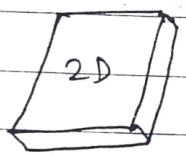
One of the dimension is in nanoscale.

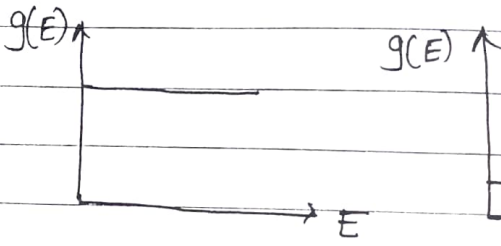
Density of the state is

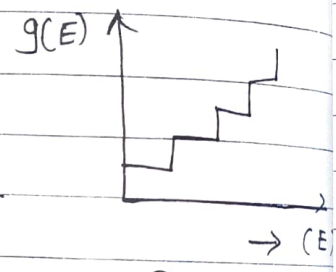
$$g(E) = \frac{4\pi m}{h^3} = \text{constant}$$

confinement is (because of) one dimensions

for different quantum state it shows different constant values.







for many states.

2) Quantum wire (1D)

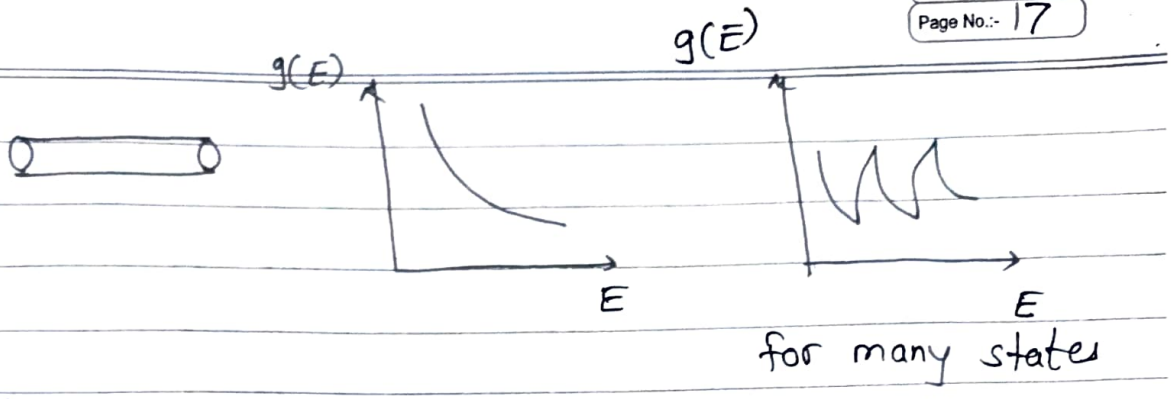
Two dimensions are in nanoscales

Electrons can move in one dimensions.

Two dimensions are confined.

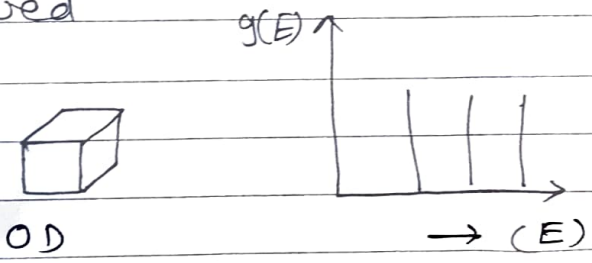
The density of states is,

$$g(E) = \frac{2\sqrt{2}\, m^{1/2}}{h^3} E^{-1/2}$$



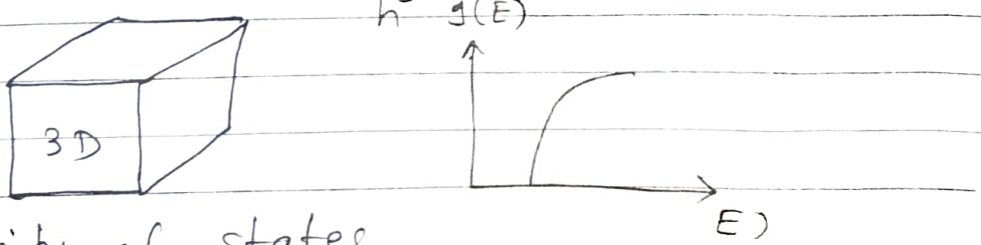
The density of states decreases with increase in energy.
For different quantum states it shows variations

3) Quantum dot (QD)
All the three dimensions are in nanoscales. all directions are confined. No free e⁻ Therefore for a quantum dot only some discrete energy states are allowed



* For Information:-
for Bulk material, density of the states is,

$$g(E) = \frac{8\sqrt{2}\,\pi\, m^{3/2}}{h^3} E^{1/2}$$



Density of states increases with energy.

Surface to volume ratio

When particle size decreases with the fraction of atoms on the surface to total number of atoms increases.

Nanomaterial have higher / ~~numl~~ larger fraction atoms at the surface than that of bulk.

surface energy per unit mass and is larger for nanomaterials.

Also surface to volume ratio is also larger for nanomaterials.

Properties of Nanomaterials.

Properties of nanoparticles are different from bulk particles.
properties can be vary with size and shape.

<1> Optical properties:
The colour of nanoparticle is different from corresponding bulk material.

When bulk material reduced in size energy band structure changes from continuous to a set of discrete energy levels.

e.g. gold in bulk form → yellow
gold in nano form → Red

In semiconductors blue shift in the absorption spectra is observed, as the particle size is reduced.

Atomic clusters of different sizes have different energy levels and hence size of the cluster can be altered to change the color of the material.

Due to metal nanoparticles, the glasses appear coloured.

In semiconductor nanoparticles which are used in quantum dots, there ~~sis~~ is significant shift in the optical absorption spectra towards blue as the particle size is reduced.

2) Electrical Properties :-

The resistivity in bulk matter is due to scattering of electrons by ions and crystal defects.

In nanomaterials, the resistivity is mainly depends on scattering from boundaries of nanoparticle when particle size becomes less than the mean free path between collisions.

The smaller particle size increases the resistivity.

Nanoparticles have very small defect as sizes are very small.
Confinement of conduction electrons is also responsible for conductivity.

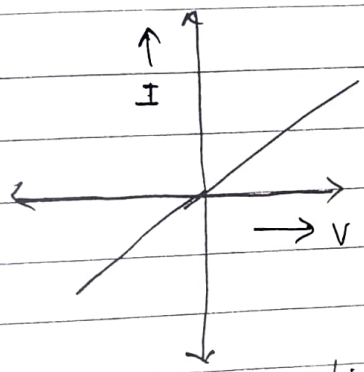
In quantum well,
The electron will be confined along one dimension, but freely moving along remaining two direction

In quantum wire,
If a conducting wire has a long length but very small diameter.
Electron can move in only one direction

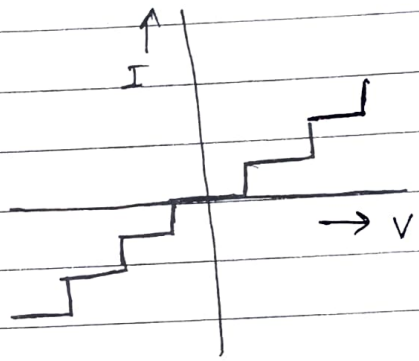
In quantum dot
Here all the three directions are in nanoscale.
so electron can not move along any direction. This confinement of electrons to small directions leads to quantization of energy.
Here around zero voltage and no current is observed,
for transferring electron, $\frac{\pm e}{2C}$ potential is required.
Because of added impurities in semicond
1 donor impurity atom in 10^8 atoms of semiconductor atoms.
10 quantum dot having one free electro

Here conduction is due to tunneling of electrons through the quantum dot. If voltage is less than $e/2C$, the electrons cannot be transfered. This gives zero current at low bias voltage and is known as "coulomb blockade".

The repeated tunneling of single electron produces coulomb staircase



metal properties
(IV characteristics)

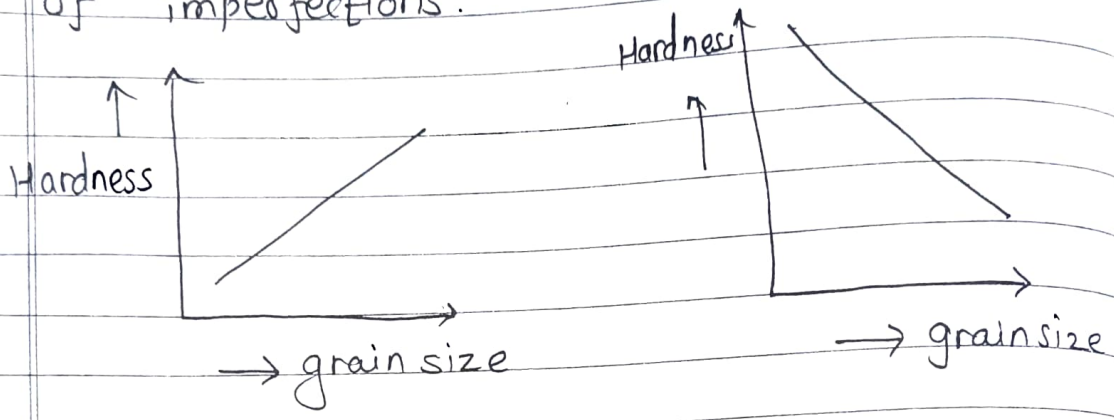


quantum dot
(IV characteristics)

The conduction is due to tunneling of electrons through the quantum dot. The electrons are blocked from tunneling except at discrete positions.

Mechanical properties :-
Mechanical properties like hardness, electricity and ductility depend upon the bonds between atoms.
crystal defect and impurities results in changes in these properties.

for a nanoscale materials the material tends to form a single crystal. The nanocrystals are highly pure and free of imperfections.



In Bulk form

for a bulk material the hardness increases with grain size, But in nanomaterials the hardness increases with decrease in grain size. e.g. Carbon nanotubes are stronger than Young's modulus of nanocrystalline material is smaller than that of the bulk form e.g. Mg nanocrystal,

Y in bulk form = 4100 N/mm^2

Y in nano form = 3900 N/mm^2

Applications of Nanoparticles :-

<1> Quantum dots as capacitance / Electronics appli.

The energy stored in capacitor is,

$$E = \frac{1}{2} QV \quad , \quad E = \frac{Q^2}{2C}$$

smaller dots are large enough to "block" the tunneling electron. Thus coulomb blockade can prevent unwanted

tunneling of electrons ($E_c >> kT$)
this function is used in single electron transistor (SET)

2) Medical applications (Targeted drug delivery)
Nanoparticles can be used for detection and treatment of cancers and tumours.
Encaspsuled nanoparticles are inserted in body (nanocapsules) guided towards specific ~~direction~~ part. It will be open by using magnetic field and infrared light, without damaging or affecting healthy organs.
Nanotechnology based tests are being developed for fast detection of viruses and antibodies.

3) ~~Electronics :-~~
3) Energy Applications :-
solar cell efficiency is improved by using nanotechnology, which advances renewable energy.
Hydrogen fuel has some drawbacks, like hydrogen is combustible and so cannot be stored easily. Carbon nanotubes are using to trap and store the hydrogen.

4) Automobile
Nanotube composites have better mechanical strength compared to steel.
Use of nanoparticles in paints provides smooth coating

(5) Computers appli.
Nanoparticles are also being used to increase the energy density of rechargeable batteries, which are used in laptops and mobiles.
Nanotechnology can also be used in computers for designing non voltatile memory.

6) Space and Defence
Aerogel are ~~porous~~ porous materials with nanosized pores.
They have very low density and are poor conductor of heat.
They can used in spacecrafts, light weight suits and jackets
satellite and spacecrafts we solar energy & nanotechnology.

(7) Environmental
Nanoparticle based on sensors are capable of detecting water & air pollutions.
Nanomaterial catalysts can be used as catalysts to convert the harmful emissions from industries and automobiles to less harmful gases.

(8) Textiles :-
With the help of nanotechnology water repellent and wrinkle free clothes can be prepared.

(9) cosmetics :-

zinc oxide and titanium oxide nanoparticles are used in sunscreen lotions which protect the skin from UV radiations.

These nanoparticles absorbs UV radiations.

Nanoparticles are also used in hair cream, hair gels & in hair dyes.

—x—x—x—x—x—

Date: 1 1
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Important Questions.

1) What are cooper pairs? Explain BCS theory [6]
2)

Important Questions : Unit 6

1) What is non-destructive testing? what are the objectives of NDT? [4]
2) Give the distinguish betn nondestructive & destructive testing [4]
3) What is principle of x-ray radiography? Explain the displacement method by using x-ray radiography [4]
4) What are the advantages & disadvantages of radiography? [4]
5) How pulse echo system is used to detect defect? [6]
6) Give advantages & disadvantages of NDT
7) Explain ultrasonic testing in detail [6]
8) Explain acoustic emission testing in detail [6]
9) What are the nanoparticles? Explain the factors affecting on nonomaterials [6]
10) Write a note on quantum dot [4]
11) Explain the optical & mechanical properties of material [6]
12) What is coulomb blockade? Explain electrical properties of nanoparticles [4]
13) Explain the effect of surface to volume ratio on properties of nanoparticles. [4]
14) Explain quantum confinement.
15) Give medical & electronics appli. of nanomaterial
16) Give Energy, cosmetics, textile & space appli. of nanomaterials.