Q12.2 Discuss about modern engineer materials.

UNIT-II

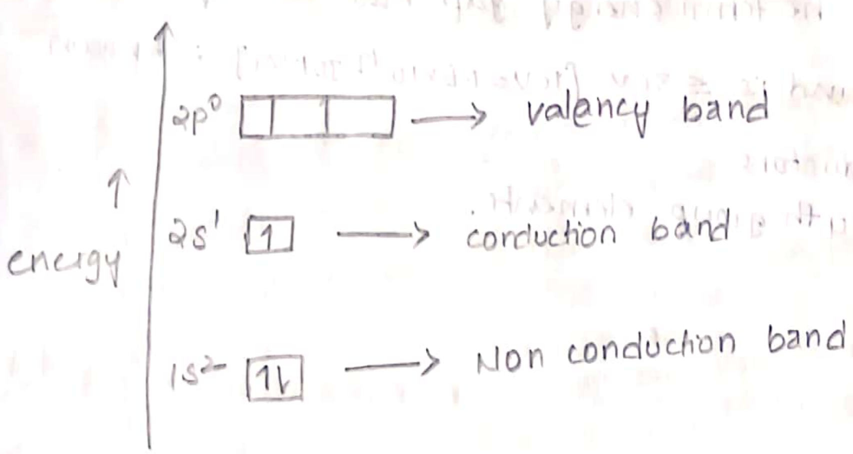
MODERN ENGINEERING MATERIALS

Band theory of solids :

Felix bloch proposed band theory of solids to explain conductors, semiconductors and insulators in 1928.

In our periodic table lithium is first solid state element

$Li \rightarrow 3 \rightarrow 1s^2 2s^1 2p^0$



Non conduction band

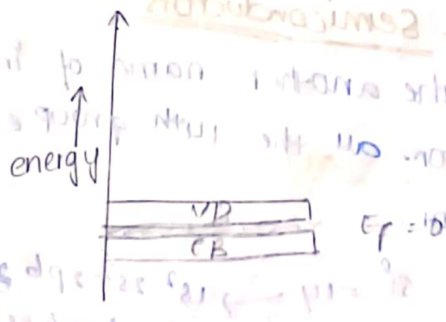
The completly filled orbitals produce non conduction band in lithium element $1s^2$ orbital produce. non condiction band

conduction band :- the partially filled orbitals produce conduction band in lithium element $2s^1$ orbital produce conduction band

valency band :- the empty orbitals present in valency level in lithium element $2p^0$ is vacant orbital produce valency band. in lithium element $2p^0$ is vacant orbital produce valency band.

Conductors :- the fermi energy gap b/w valency band and conduction band is '0' that means both bands are overlapped.

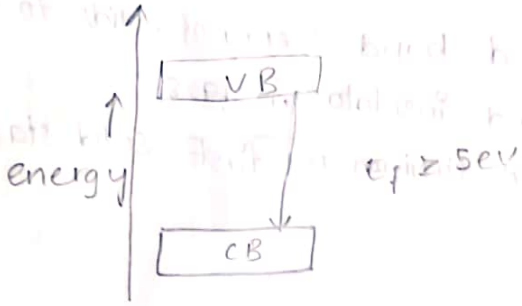
ex: all metals.



Insulators :

The fermi energy gap between valency band and conduction band is $\geq 5eV$ [$1eV = 1.6 \times 10^{-19}$ Joules] is known as Insulators.

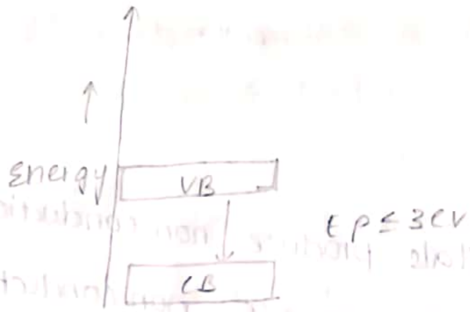
Ex: nonmetals, plastic, wood, paper etc.



Semiconductors :

the fermi energy gap b/w valency band and conduction band is $\leq 3eV$ [$1eV = 1.6 \times 10^{-19}$ Joules] is known as semiconductors.

Ex:- 14th group elements.



Note:- 13th group elements – Beta Alpha Gamma In Triangle
B Al Ga In Tl

14th group elements – Classlo sita Geetha Sneha Pubg Adu
C Si Ge Sn Pb

15th group elements – Navya party lo asalu sabulu Bismilla
N P As Sb Bi

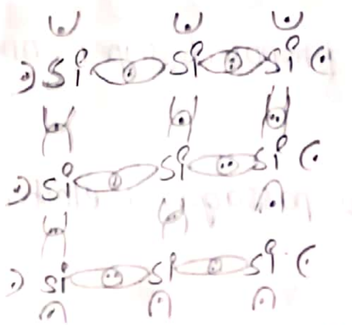
Types of Semiconductors

Intrinsic semiconductors

The another name of Intrinsic semiconductors is pure semiconductor. all the 14th group elements acts as (incr) intrinsic semiconductor.

$Si^0 = 14 \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$ (Ground state)

$1s^2\ 2s^2\ 2p^6\ 3s^1\ 3p^3$ (excited state)

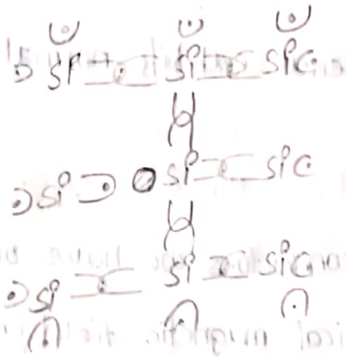


Extrensic Semiconductor.

On the based ~~on~~ upon addition of impurities extensic semiconductors are divided into 2 types those are. 1. p-type semiconductor or p doped semiconductors.

p type semiconductors :- the addition of 13th group elements has a impurities to the semiconductor material which forms p type semiconductor.

Here 13th group elements have three valency electrons but our requirement is 4 electrons, so, that 4th valency should be balanced by positively charged hole.

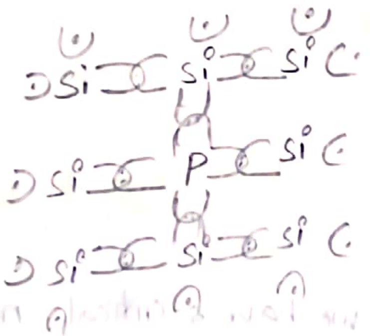


p type
It is extrensic semiconductor
Impurities are 13th group elements
holes are majority carriers
electrons are minority carriers

n type
It is also extrensic semiconductor
Impurities are 14th group elem
electrons are majority
holes are minority

n type semiconductor :- the addition of 15th group element has a impurities to the semiconductor material to form n type semiconductor

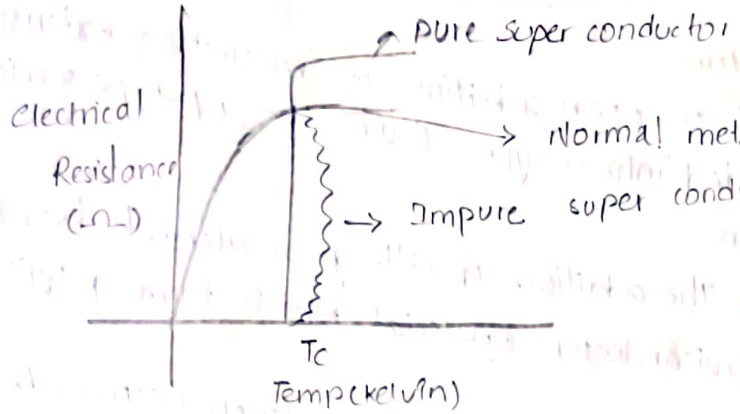
Here 15th group elements have 5 valency electrons but our requirement is 4 electrons so we have one excess electron i.e., sureplus electron moves entire the semiconductors



Superconductors :

A Dutch physicist kammerlingh onnes proposed super conductors in 1911.

A solid which offers no resistance to passage of electricity through it is known as "superconductors."



Critical temperature

At which temperature super conductor materials convert into normal metal state is known as "critical temperature".

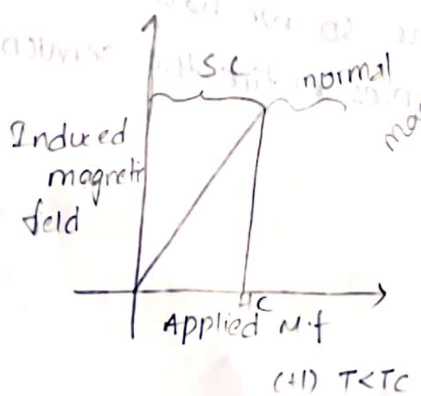
Below the critical temperature that material exhibits super conducting state

Above the critical temperature that material exhibits normal state of metal.

Classification of superconductors.

Type 1 superconductors :- In type 1 super conductors we have one critical magnetic field, below the critical magnetic field which acts as Super conducting state, above the critical magnetic field which acts as normal metal state. It is also called soft superconductor

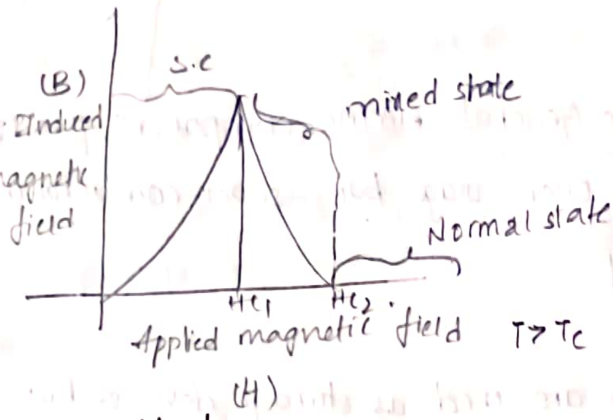
Type 1 super conductor exhibits "miessner effect"



Type 2 super conductors

In type 2 super conductor we have 2 critical magnetic fields (H_{C_1}, H_{C_2}). Below the H_{C_1} that material exhibit super conducting state in b/w H_{C_1} & H_{C_2} that material exhibit mixed state, after

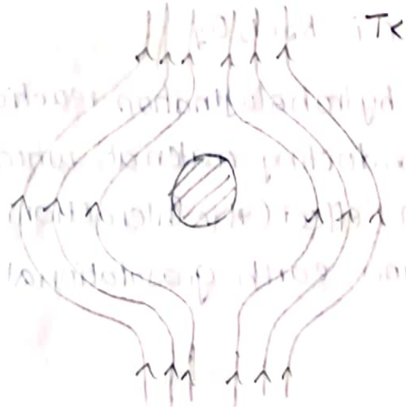
H_{C_2} which acts as normal state of metal. It is also known as Hard s.c
In type super conductor does not have missioner effect.



miessner effect
the complete explusion of magnetic field. by the super conducting material is known as miessner effect.

1. In case of critical temperature is high when compared to normal temperature ($T < T_c$) which obeys miessner effect.

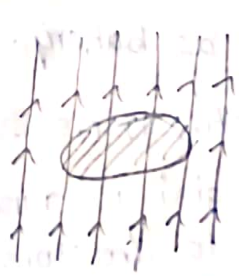
$T < T_c$



Effect of dopping (IOT)

2. In case of critical temperature is low when compared to (low t) normal temperature ($T > T_c$) which does not obeys miessner effect.

$T > T_c$



Properties of superconductor:-

① Brittle nature - which forms very thin sheets when compared to normal metal.

② $I^2R = 0$ (the copperloss equation is always '0' because of input of current is equals to output of current)

3, miessiner effect

4, strong magnetic field

5, Diamagnetic nature.

6, thermoelectric effect - The General electric component produce heat Energy to over usage but super conductor material there is no heat energy.

applications

1, Generally silicon chips are used as storage devices. but we use super conductor chips. These are 1000 times effective than normal silicon chips

2, Super conductors are used to manufacturing "MRI scanning equipment (Magnetic Resonance Image)

3, It is used to find out alchoal content in drunk and drive cases.

$(La_{2-x}\,Sr_x\,Cu_3\,O_{7-x})$ chemical substance is $K_2Cr_2O_7$

4, It is used as industrial catalyst in β. dehydrohalogination reactions

5, Maglev trains are made up of a superconducting material which moves very fast in the presence of levitation effect (the interaction forces b/w superconducting material and earth gravitational forces.

Super capacitor:

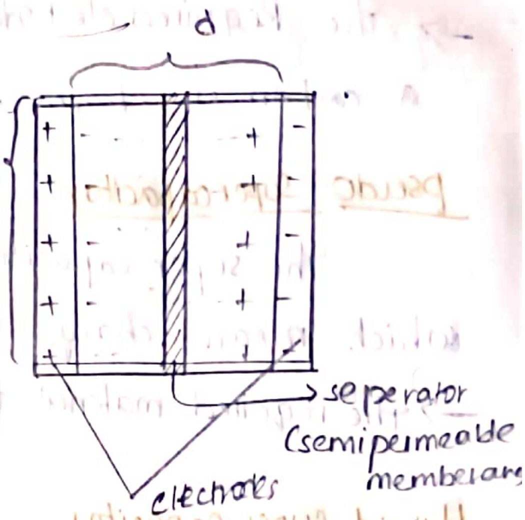
leyman example: In 200m running race we require more energy to reach destination it is known as super capacitors.

In 20km running race we require less amount of energy to reach destination is known as battery.

Becker proposed supercapacitors in 1957. Supercapacitor used electrical buses developed in shanghai in china

definition:- The matrial which is used to ~~stro~~ store maximum amount of electrical energy when compared to battery is known as super conductor.

Principal of supercapacitors



In the constuction of supercapacitors we take a equal lenght of plates acts as anode and cathode. these 2 plates are seperated by semipermiable p memberane and electrolyte substance

→ In supercapacitors positive charge cell terminal attracts negatively charged ions from the electrolyte solution .which forms one layer.

→ In super capacitors negative cell terminal attracts the positively charged ions fom the electrolyte to form another layer.

→ the two layers present in supercapacitors which produce some electrode potential which is known as directric constant (x-law)

$$c = \frac{\varepsilon l}{d}$$

where c = capacitance
ε = directric constant
l = lenght of the electrode
d = distance b/w the electrodes.

Classification of super capacitors

on the based upon attraction forces and material taken for electrodes supercapacitors are divided into 3 types those are :

1. Double layer supercapacitor
2. pseudo capacitors
3. Hybrid super capacitors

diagrame fram Cheyali

1. Double layer super capacitors :

the supercapacitor undergoes electrostatic forces which means no the charge transfer b/w electrodes.

→ The Required electrodes for the super capacitors made up of a carbon or charcol powder (CNTS, graphane)

Pseudo Super capacitor

The super capacitors which exhibits electrochemical process which means charge transfer b/w electrode and electrolyte.

→ the required material for the electrodes made up of a Ceramics or conducting polymers)

Hybrid super capacitor :

the supercapacitor which have the properties of double layer and pseudo capacitors is known as hybrid supercapacitors.

The super capacitors which undergoes electrostatic and electro chemical process.

Properties

→ long life

→ large storage

→ low cost

→ more effective.

Applications :

→ used in laptop computers

2, used in preparation of laser medical equipment.

3, These are used in ups system in Engineering colleges.

4, Industrial catalyst.

5, It is used in electronic digital switching devices

Nano chemistry

It is a branch of chemistry which deals preparation properties and applications of nanomaterials.

one nanometer is equals to 10^{-9} m = $\frac{1}{}$ one billionth of meter

In human air 10000th portion is equals to 1nm.

~~one~~ the hydrogen atom size = 0.1 nm

Classification

Nanomaterials :-

The material which exhibit atleast one dimension b/w one nm to 100nm is known as nanomaterials.

Nanolayer :-

The nano material which exhibits one dimension b/w one nanometer to 100nm is known as nano layer.

Nanotube :-

The nanomaterial which exhibits two dimension b/w one nanometer to 100nm is known as nanotube.

Nano particle :

The nanomaterial which exhibits three dimension b/w 1nm to 100nm. these known as nanoparticles.

Quantum dots :

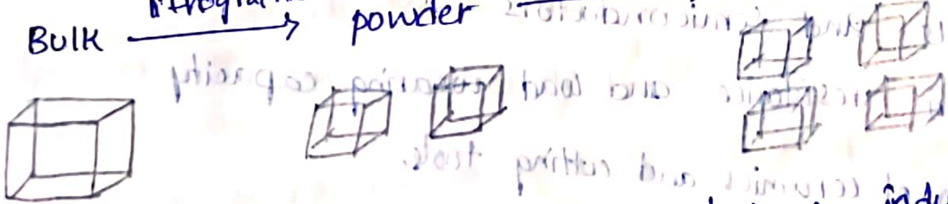
The semiconductor meterial which have one dimension b/w one nm to 100nm is known as Quantum dot.

General methods for preparation of nanomaterials.

Topdown approach method

In this method bulk material undergoes lithographic method (stone crushing technique) to form powder state further powder undergoes lithographic method to form nano materials.

Bulk $\xrightarrow{\text{lithographic}}$ powder $\xrightarrow{\text{lithographic}}$ Nano materials.



eg:- This method is used in microelectronic industries.

Bottom up approach method

In this method atoms are aggregated to form clusters further clusteres are aggregated to form nanomaterials.

eg:- In this method fullerins, graphine, nano particles prepared

Atoms $\xrightarrow{\text{Aggregated}}$ Clustures $\xrightarrow{\text{Aggregated}}$ nanomaterial

properties of nanomaterials

(1) Based upon size
- (1) magnetic property — nanomaterial has strong magnetic property
- (2) colour — bulk material has yellow & nano has blood colour
- (3) solubility, (5) melting point — high melting point
- (4) Transparacy.

(2) composition
- colloidal → co-ercing colloids
- chemical reactivity
- Reaction Rate

(3) Surface
- conductivity
- dispersibility
- catalytic.

Applications

1. electronic digital switching devices like environmental sensors and LED's
2. Industrial catalyst like cerium oxide (CeO_2), Nickel
3. Drug delivery, to control HIV virus
4. Agriculture field like Genetic improvement
5. solar cells and semiconductors
6. corrosion resistance and load wearing capacity
7. fabrication of ceramics and cutting tools.

Fullerenes : Richard swalley et al proposed fullerene material in 1985 a trice university in USA. He awarded noble prize for this concept in 1996. The fullerene name coined by "buck minister fuller"

Definition:

"It is an allotrophy of an carbon element which having ellipsoid, so tube, spherical structure is known as fullerenes."

Classification of fullerence (types)

1, Buky ball clustures :- this type of fullerenes consists of sperical structures in ball shape

ex: C_{20} · C_{60} — high — low

2, Carbon nano tubes :- this type of fullerenes, having hallow tube structures with small dimensions

Ex.. SWCNT's (single wall carbon nano tube)

MWCNT's (multi wall carbon nano tubes)

3, Mega tubes :- This type of fullerence having large dimensions.

4, Polymers :- the two dimensional and three dimensional polymers generates fullerens in the prensence of high temperature and pressure.

5, Nano onions : the fulleren's which exhibits multiple layers like onions is known as nano onions.

6, linked ball and chain dimers: The soccer ball shape of fullerens connected in chainwise manner to form linked ball and chain dimers.

C_{60} fullene (or) Buck minister fullerene

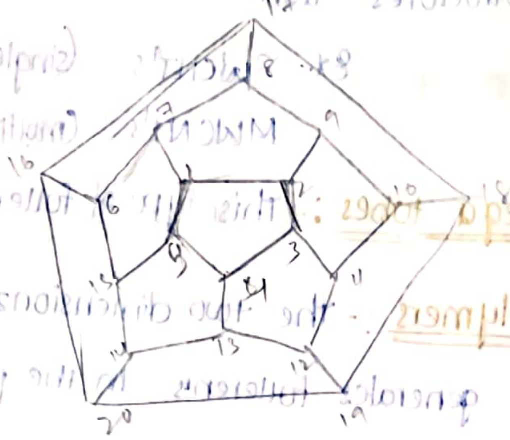
→ The IUPAC name of C_{60} fullerene is truncatedicosahedran

In this carbon element undergoes sp_2 hybridisation with bond lenth 1.4A°

→ In C_{60} fullerenes we have 12 pentagonal rings and 20 hexagonal rings.

C_{20} fullerene

The IUPAC name of C_{20} fullerene is unsaturated ~~do~~ dodecahedran It is very smallest fulleren molecule



properties :

1, Endo hedral fullerenes :

whenever the atoms tapped into inside of the fullerence which gives inclusion compound like egg shaped

Ex: $Tb_3 Ne C_{84}$

2, chirality :

In fullerence carbon element exhibits chirality which means different functional groups attached to carbon element

Ex:

3, sculpture property :

According to Quantum mechanics fullerance exhibits dual nature that's why these are used to sculptoring of ceramics

4, solubility :- fullerenes are sparingly soluble in organic solvents like carbon disulphide(CS_2) and toulene &

5) Halogenation :- the addition of halogens like flourine, chlorine bromine to the fullerence which forms halogenated fullerence

Ex: $C_{60}Br_8$, $C_{60}Br_{24}$ (Bromin is preferable)

6. Hydrogenation :- the addition of hydrogens to the fullerens which forms poly hydro fullerence.

7. Addition of Hydrogen the addition of oxygen, ozone to the fullerenes which forms epoxide state of fullerenes

Ex: $C_{60}O$.

(epoxide: $\overset{O}{\triangle}$ If one 'c' is exchanged by oxygen atom) is called epoxide structure.

Applications

→ It is used to prepare hydrogen fuel with the help of polyhydro fullerenes.

→ In medical field fulleren materials are used to control HIV (Human Immuno deficiency of virus)

→ fullerene are used to prepare solar cells

Carbon Nano tube (CNT's)

Sumio Iijima proposed carbon nanotubes in 1991 for arc discharge method

" It is an allotropy of carbon element which consists continuous un breakable hexagonal rings in tubical structure with 0.4 nm is known as carbon nanotubes"

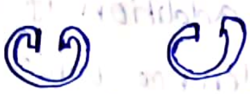
Types of carbon nanotubes:

① SWCNT's : This type of carbon nanotube have monolayer of hexagonal ring sheets is known as SWCNT's

② MWCNT's (multiwall carbon nano tubes)

In this carbon nanotubes two or more hexagonal ring sheets are attached.

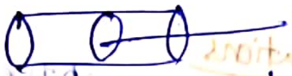
MWCNT's
- Russian doll model (No edges)
- perchman model (edges)

3) Torus : Doughnut shape 

4, Nanobud :- The fullerence are attached either top side or bottom side to the carbon nano tubes.

5, N-dopped CNT's :- The addition of 15th group elements to the carbon Nano tubes is known as N-doped carbon Nanotubes.

6, Peapod CNT's : The internal attachment of fullerene to the carbon nanotube is known as peapod



7, Graphenated CNT's

8, cup-stacked :- Arranged in cupwise manner. 

properties

1. tensile strenght
2. Hardness —
3. Telescropic
4. Semiconductor
5. Toxicity
6. Electro magnetic radiation
7. thermal conductivity. electrical cond

Applications of CNT's

Ankr

1, These are used in preparation of space elevators, stab proof, Bullet proof clothing. rocket wing

2, solar cells

3, Food storage containers. Prevent the rancidity (oxidation)

④ paper batteries mixing of cellulose derivatives.

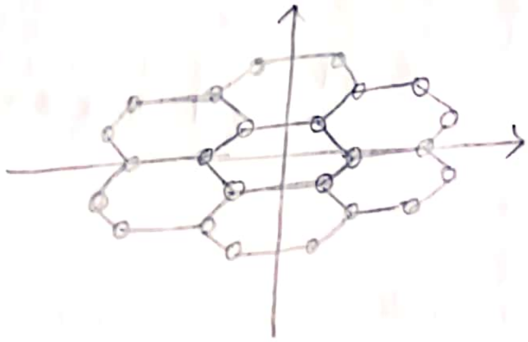
⑤ Antibacterial fabrics

Graphine nanoparticles : A

Andewgain & koustantin novosolov prepared graphine nanoparticles in 2003 during cleaning of graphite wastage.

- They awarded nobel prize in 2010.

" It is an allotropy of carbon element which having unbreakable monolayer of hexagonal ring. with Honeycome lattice structure is known as graphine nano particles.



Graphene nanoparticles are zero band gap conductors because of valency band condution band connected at one advance specific centre which is known as dirac point

preparation of Graphene

i. Top down approach — mechanical exploitation / Chemical exploitation.

a) mechanical exploitation: During this process we apply mechanical Energy after that we get nanoparticles

→ our Scientist prepared Graphene nanoparticles by using mechanical exploitation method.

b) chemical exploitation: During this process we use alkali metals as a chemical

2. Bottom up approach — CVD / Atomic layer deposition

a) <u>Chemical vapour deposition</u>:

The carbon element compounds undergoes cooling phase in the presence of nickel metal as substrate. we get graphine nano particles.

b) <u>Atomic layer deposition</u>:- It is the one of the type of chemical vapour deposition.

<u>Properties of Graphene</u>:

1, Strongest material (0.2TPa)
2, thinnest material. Steel young's mo... is (1TPa)
3, young modulus
4, Transmitted is 98%.
5, high conductivity
6, thermal stability (5000 $W m^{-1} K^{-1}$)
7, flexible
8, zero band gap
9, little scattering bending movement
10, Semi conductor
11, Transparency.

<u>Applications</u>:

Integrated circuits (electrical components), transisters, desalination (the removal of salt from water), gas sensors, Solar cells, flexible mobiles, pollutant gases