PHYSICS

SEMICONDUCTOR

* On the basis of electrical conductivity or electrical resistance materials can be broadly classified into 3 categories: metals, semiconductors & insulators.
* Metals have electrical resistivity as low as $10^{-6}\ \Omega\ cm$ & the insulators have electrical resistivity as high as $10^{20}\ \Omega\ cm$.
* Semiconductor have resistivity in between these two extremes, but the speciality about the resistivity of semiconductor is that it is very much temp. dependent.
* At absolute zero temp. it behaves as a perfect insulator and at high temp. it can compete with metals.
* Semiconductor materials are very important from technology point of view. Devices made from semiconductor materials form the necessary parts of all instruments & gadgets eg. diodes, transistors & ICs.
* Some points regarding semiconductors:

(a) Materials used as semiconductors
(b) band gaps of "
(c) whether the band gaps are direct or indirect
(d) band structure of semicond.

(a) Materials used as semicond. →

* Materials used are mostly silicon (Si) & germanium (Ge). Other materials are made from the combination of elements of 2 different groups in periodic table. For ex.

AlSb, ZnSe, PbSe, CdSe etc.

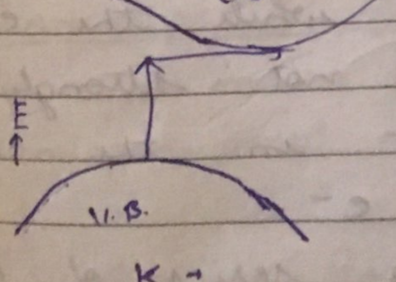
(b) <u>Band Gaps</u> -

Si	1.1eV
Ge	0.7eV
GaAs	1.43 eV

Materials with band gaps less than 3eV are considered semiconductors. Materials with band gaps greater than 3eV generally do not exhibit semiconducting behaviour.

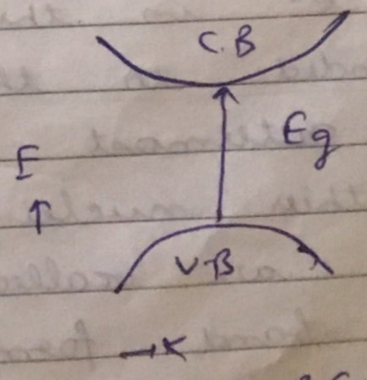
(c) <u>Direct & Indirect Bandgap</u>:-

* Band gap is defined as the minimum energy difference b/w the top of valence band and the bottom of the conduction band.
* In semiconductor physics, the bands are represented by E (energy) versus K (wave number) curves in Brillouin zones.
* If the K value corresponding to the minimum energy state in the conduction band & the 'K' value corresponding to the maximum energy state in the valence band are the same, the band gap is said to be <u>direct</u>.
* If these two 'K' values are not same, the bandgap is said to be indirect.



Indirect B.G

(a).



Direct B.G.

(b)

(a) Energy vs momentum for a semiconductor with an indirect B.G., showing that an e- can not shift from the highest energy state in the valence band to the lowest energy state in the conduction band without a change in momentum. Here almost all of the energy comes from a (vertical) photon, while almost all of the momentum comes from a photon (horizontal)

(b) 'E' vs 'k' for a D.B.G., showing that an e- can shift from the highest energy state in the V.B. to the lowest energy state in the C.B. without a change in crystal momentum.

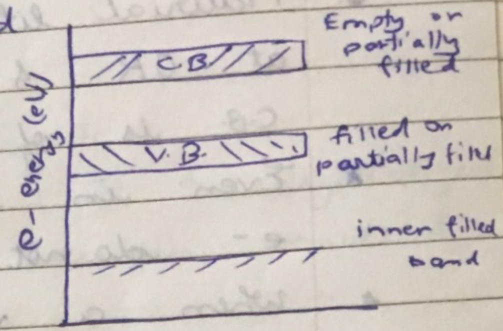
Example of D.B.G - GaAs, GaSb, InAs
" " I.B.G. - Si, Ge, GaP

<u>Valence Band, Conduction Band & Forbidden Band</u>-

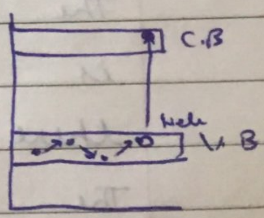
* We know that atoms of a solid are arranged in a regular repeated pattern & the e- of the atoms rotate around their nuclei in certain energy levels.
* The e- in the inner shells are strongly bounded to their nuclei while the e- in the outermost shells are not strongly bounded to thier nuclei. The e- in the outermost shell are called <u>valence e-</u>.
* The band formed by a series of energy levels containing the valence e- is known

as Valence band. It may be defined as band which is occupied by the valence e- or a band having highest occupied band energy.

* The next higher permitted band is the conduction band. The e- occupying this band are conduction e-. It is defined as the lowest unfilled energy band. In conduction band the e- can move freely.



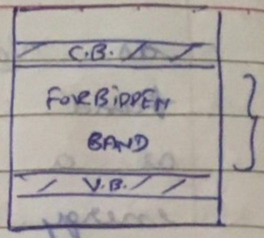
* The two bands i.e. conduction & valence band are separated by a region or gap known as forbidden band. No e- can exist in this band. When an e- in the valence band absorbs enough energy, it jumps the forbidden gap & enters the conduction band.
* When an e- jumps from V.B to C.B., a covalent bond is broken. So a positively charged hole is created.
* This hole is filled by the e- from the adjacent ~~atom~~ atoms. This process repeats as if the hole moves from one place to another.



Conductors, Semiconductors & Insulators -

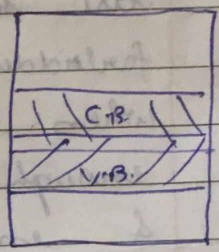
On the basis of forbidden band, the insulators, semiconductors & conductors can be classified.

Insulators - Forbidden energy band is wide. Due to this fact e- can not jump from



V.B to C.B

* In insulators the valance e- are bound very tightly to their parent atoms.
* Material like glass, V.B. is completely filled at 0K & the energy gap between V.B. & C.B. is of the order of 10 eV.
* Even in the presence of high electric field, e- do not move from V.B. to C.B.
* When a very large energy is supplied, an e- may be able to jump across the F.G.. Increase in temp. enables some of e- to go to the conduction band.

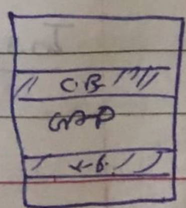


Conductors -

* There is no forbidden band & the V. & C. B overlap each other. Hence a plenty of free e- are available for electric conduction.
* The e- from V.B. freely enter in the C.B. The most important point in conductors is that due to the absence of F.B., there is no structure to establish holes. The total current in conductors is simply a flow of e-

Semiconductors -

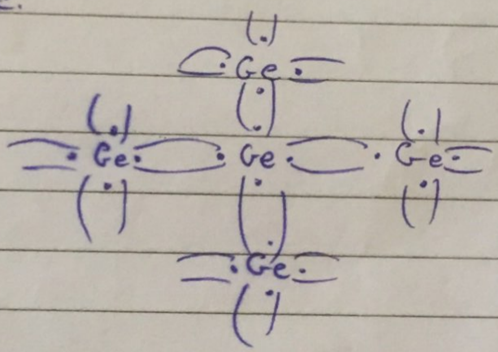
* S.C are materials which have electrical conductivities lying between those of good conductors & insulators. for ex. Ge, Si, C etc.
* S.C is a substance which has resistivity (10^{-4} to $0.5\ \Omega\ m$) in b/w conductors & insulators.



- F.B. is very small. In Ge 0.7 eV & in Si 1.1 eV.
- In S.C. bonds are formed by sharing of V. e-. Such bonds are called covalent bonds.
- Commonly used S.C are Ge & Si.

Germanium (32) = Z = 2, 8, 18, 4

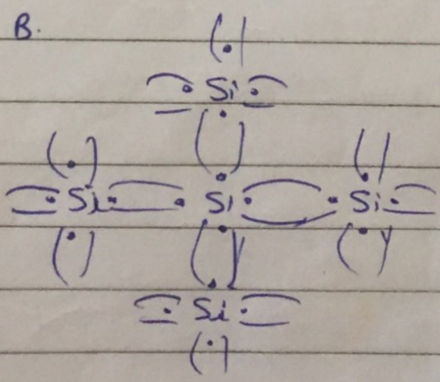
- Ge can be purified relatively well & crystallized easily. Recovered from ash of certain coals & from dust of zinc smelters.
- Generally, recovered Ge is in the form of germanium dioxide powder which is then reduced to pure Ge.



- 4 e- in V.B. ie. it is tetravalent

Silicon (Si) - Z = 14 = 2, 8, 4

- 4 e- in V. B.



Above absolute 0 -

- The energy needed to liberate an e- from 'Ge' atom is very small ie of the

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order of 0.7 eV. Thus even at RT an e^- of one atom or the other can get detached from its bond by thermal agitation.