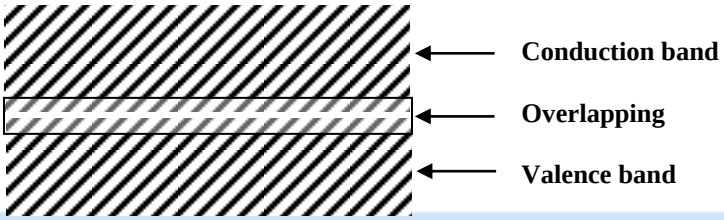
Lecture-2

1.3 Metal, Insulator and Semiconductor:

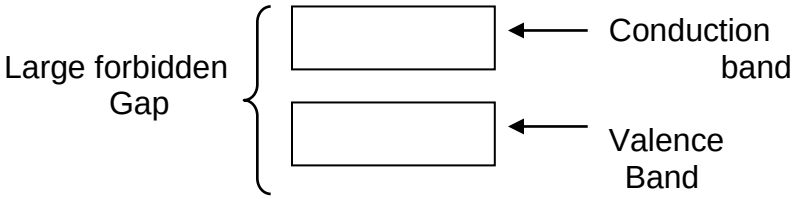
The electrical properties of the materials can be expanded by the concept of energy bands. Depending on the nature of band occupation by electrons and on the width of forbidden gap, all solids can be classified as conductors, insulators and semi-conductors.

Metal (Conductors): In conductors, there will be no any forbidden gap between valence band and conduction band. Valence band and conduction band will be overlapping. Hence the valence band itself is also the conduction band.



Conductor

Insulator: In insulator there is a full valence band and an empty conduction band. There will be large energy gap (of several ev) between them.



Semiconductor: Semiconductor have a forbidden gap (energy gap) between filled valence band and vacant conduction band which is small as compared to the gap in case of insulators. The narrow energy gap imply that some electrons from the completing filled lower valence band can be thermally excited to the empty conduction band where they are able to conduct small current on the application of electric field to the crystal.

1.4.0 Phenomenon of conductivity of semiconductor:

As we have seen in above discussion there is a small energy gap between valence band and conduction band. All valance electrons of material will be available in valence band and conduction band will be totally vacant. But due to small energy gap it is easy to move electrons

from valence band to conduction band to increase conductively of material. It means conductivity of semiconductors can be changed by providing free electrons in conduction band. If number of free electrons in conduction band increase, conductivity will increase. And if number of free electrons decrease in conduction band conductivity will decrease. So one thing is now conform that the conductivity of semiconductors materials can be varied between conductor and insulator by providing free electron in conduction band or holes in valence band conductivity can be varied by (i) temperature(ii) Doping

1.4.1By temperature: On increasing temperature of a semiconductors material, some bonds can be broken in valence band and electrons can move from valance band to conduction band. So by increasing temperature some free electron will be available in conduction band and in respect of that holes will be available in valance band. Here hole means vacant position of electron, vacant position created due to breaking of bond is called hole and it signify positive charge.

1.4.2 By Doping: As we have discussed the conductivity of a semiconductor material can increase by increasing number of free electrons in conduction band or by increasing holes in valence band. Free electrons in conduction band can be increased by adding some atoms in the semiconductors material having extra free electrons. Means we add a Gr V atom in a semiconductors material to increase free electrons in conduction band.

Similarly if we add Gr III atoms in a semiconductors material number of holes in valence band will be increased.

Adding an impurity atom to a semiconductors material is called doping. So finally we can say by doping Gr V atoms in semiconductors material number of free electrons in conduction band can be increased. Similarly by adding Gr III atoms in semiconductor material number of holes can be increased in valance band.

Actually in semiconductors material like Si, and Ge there are four valence electron in an atom. Atoms are bonded by covalent bond as shown in fig. 1.3

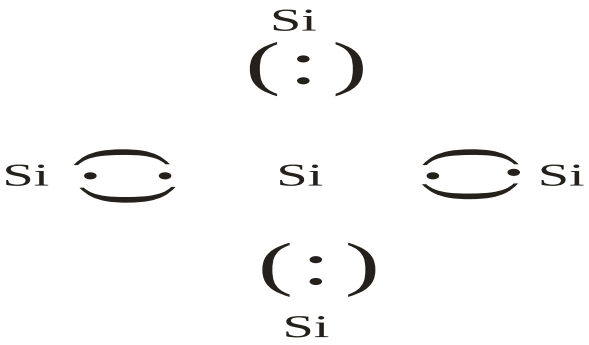


Fig 1.3

In above figure we can see Si atom is bonded with other four Si atoms by covalent bond.

Now if we add a Gr V atom in place of Si atom, four valance electron of Gr V atom will be attached with four Si atoms but its fifth valence electron will be free as shown in figure below.

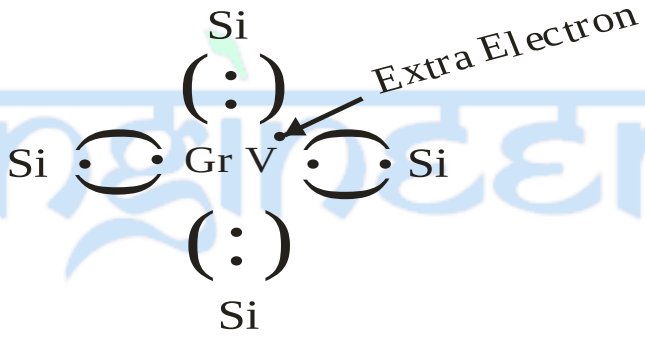


Fig1.4

So on increasing doping of Gr V the number of free electrons in conduction band will be increased and so conductivity will be increased.

Similarly if we dope Gr III atom in a semiconductor material there will be a vacant position for fourth electron as shown figure below.

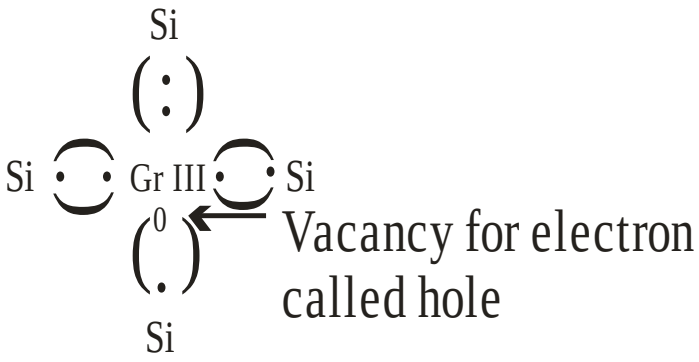


Fig1.5

From figure it is conform that for every doping of Gr III atom a hole will be created in valence band. It means by doping GrIII atom conductively of a semiconductors material can be increased.

1.4.2.1Donor Impurity: When we add Gr V atom in a semiconductors material, as we have discussed a free electron is created in conduction band means doped Gr V atom is donating a free electron to the parent semiconductor material. So Gr V atom is called donor ion or donor impurity and this ion is shown by positive charge.

1.4.2.2Acceptor Impurity: When we dope Gr III atom in a semiconductor material a hole is created in valance band and the doped Gr III atom is always ready to accept electron. So Gr III atom is called acceptor ion or acceptor impurity and this ion is shown by negative charge.

- **The semiconductor material doped with impurity atoms like Gr III or Gr V is called impure or extrinsic semiconductor material**.