Unit-I

Lecture-1

1. Semiconductor

1.0 Introduction :

Different material has different properties. We shall consider the property of conduction of electricity by any material, certain material like Copper, Silver , Gold are good conductors of electricity; whereas material like glass, wood, paper etc. are bad conductor or insulators for electricity. Both the conductors and the insulators find wide applications in engineering industry.

There is another category of material whose conductively lies in between conductors and insulators. Such materials are known as semiconductors. Germanium and silicon are two of the well known semiconductors. Further down in this chapter we shall see how the properties of these semiconductors materials can be improved further by a technique called 'doping'. For proper understating of the phenomenon of semiconductors, we shall review the atomic structure of materials.

1.1 **Atomic Structure**:

The atomic structure of materials, as conceived by Bohr, has a nucleus at the center around which the electron moves in orbits. This can be understood to be similar to planets around the sun. The nucleus comprises of protons which are positively charged and neutrons having no electrical charge. The electrons are negatively charged with $1.6x10^{-19}$ C. All the electrons do not belong to the same orbit (or shell). Further, within each shell. There are subs shells. The maximum number of electrons which can be present in any shell is given by $2n^2$, where n is the orbit number.

The electrons fill up the first-shell first, and then the second shell and so on, the number of electrons will be the same as the number of protons in the nucleus.

Let us take example of Ge, atomic number is 32.

32 =2, 8, 18, 4 = $1s^2$, $2s^2$, $2p^6$, $3s^2$ $3p^6$ $3d^{10}$, $4s^2$ $4p^2$

Here outermost shell has 4 electrons. So it is called Gr IV atom.

1.2 Formation of Energy Band:

In case of a single isolated atom, there are discrete energy levels, 1S, 2S, 2P, 3S, ………. That can be occupied by the electrons of the atom, as shown in Fig. 1.1 (a)

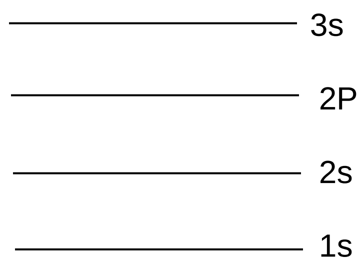


Fig. 1.1 (a) for isolated atom

All the atoms of a solid, if assumed isolated from one another, can have completely identical electronic schemes of their energy levels. Then the electrons fill the levels in each atom independently.

As isolated atoms are brought together to form a solid, various interactions occur between neighboring atoms. As a result of this interaction, the higher energy levels are considerably affected i.e. the energy levels of the outer shell are slightly changed without violating Pauli's exclusion principle. There will be splitting of a single energy level of isolated atoms into a large number of energy levels as shown in fig 1.1 (b)

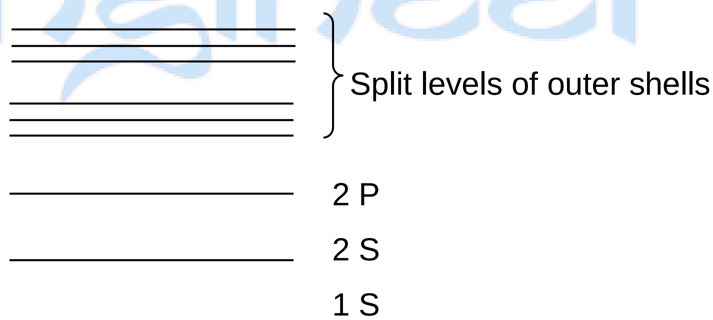
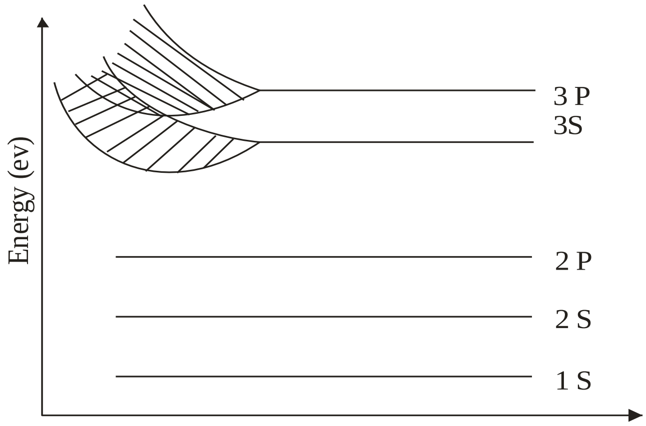


Fig 1.1(b)

Since in a solid, many atoms (N=10^{23} atoms /cm^3 are brought together, the separation between N sub levels (in to which each discrete energy level splits due to interaction) is very small.

For example, if there are 50 atoms in a piece of solid material, then there will be 50 levels of slightly different energies i.e. 50 energy level diagrams would be superimposed on each other consequently, the split energy levels are almost continuous and said to from an energy band.

Fig. 1.2 shows the formation of energy levels for higher energy levels of isolated Silicon, atoms whose ground state configuration is $1s^2$ $2s^2$, $2P^6$, $3s^2$ $3p^2$



Interatomic Distance (A^0)

Fig. 1.2

It may be seen that lower levels, 1s and 2S, do not split at all because electrons in lower levels are the 'inner ' electrons of the atoms which are not significantly affected by the presence of nearby atoms. The 2P level does not begin to split until the inter atomic distance becomes smaller than actually found in silicon. The 3s level is the first occupied level to be spitted into a band. It is due to the fact that electrons in higher levels are the 'valence' electrons whose wave functions overlap appreciably.

Now, the energy bands in a solid correspond to the energy levels in an atom. An electron in a solid can have only those discrete energies that lie within these energy bands. These bands are therefore, called allowed energy bands. These (allowed) energy bands are in general separated by some gaps which have no allowed energy levels. These gaps (regions) are known as fabrication energy bands. Energy bands occupied by the valence electrons is called valance band and is obviously the highest occupied band. Electrons which have left the valence band are called conduction electron and are only weakly bound to the nucleus. The band occupied by these electrons is called the conduction band. Thus the band beyond forbidden band is called conduction band in to which, when the electrons pass, they can move freely.