Chapter – 1 :- Semiconductor theory

1.1. Atomic Structure.

- Every element is made of the atom and each atom has the nucleus and electron. Nucleus is the center of the atom and it is surrounded by the electron.
- Electron is negatively charged particle. An electron has the charge of (e)1.602×10^{-19} Coulomb and its rest mass is $9.109 \times 10^{-31} kg$.
- Nucleus is constituted of proton and neutron. Proton is a positively charged particle and neutron is neutral.
- Atom as a whole is electrically neutral and therefor it has same number of electron and proton (same number of negative and positive charge).
- Total number of neutron (N) and proton (Z) is called the mass number (A = Z + N). Z is called the atomic number.
- The electron surrounding the nucleus in an atom occupies different orbit. Valence orbit is the last orbit of an atom(farthest).
- When an atom loses an electron it becomes the positive ion with net charge of +1. If it gains an extra electron it becomes the negative ion with net charge of -1.
- *Ionization potential* is energy required to remove an electron from the outer orbit of the atom
- *Electron affinity* is the work done by a system, when an extra electron is attracted from the infinity to the outer orbit of the neutral atom.
- *Electro negativity* is tendency of an atom to attract electron to itself during the formation of the bond with other atom.
- In semiconductor device *electron volt(eV)* is used as the energy unit. 1eV = $(1V) \times (1.602 \times 10^{-19}C) = 1.602 \times 10^{-19}J$
- If an electron is accelerated through a potential of 1 V, then the energy is e.V = $(1V) \times (1.602 \times 10^{-19}C) = 1.602 \times 10^{-19}J$

$$Electron\ volt = \frac{joule}{charge\ of\ one\ electron\ (in\ coulomb)}$$

- According to Bohr model total energy of electron in nth orbit of the hydrogen atom is given by

$$E = -\frac{me^4}{8\epsilon_0^2 h^2 n^2}\ joules = -\frac{13.6}{n^2} eV$$

Where m = mass of electron in kg
e = charge of an electron in Coulomb
h = plank constant in joule-second.

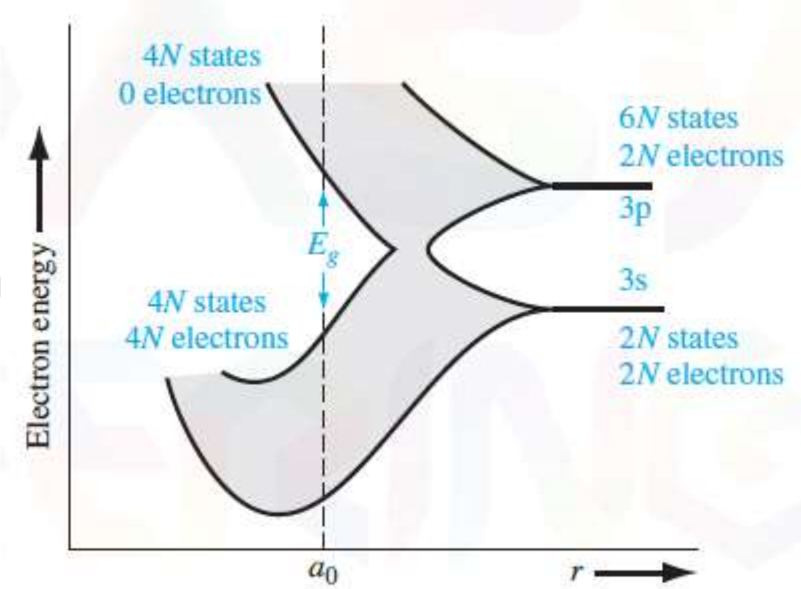
- To remove the electron from first orbit (n = 1) of the hydrogen atom to outside the atom (ionization) the energy required is 13.6eV
- Energy associated with an electron in nth orbit is given by $-13.6/n^2$ eV. Thus the energy E_1, E_2, E_3,…………of the first, second, third …………∞ orbits are respectively -13.6eV,-3.4eV,-1.51eV,……..0eV. Energy required to raise the atom from n= 1(ground state) to n=2 states is (13.6-3.4) = 10.2eV. Energy required to raise the atom from n= 1(ground state) to n=3 states is (13.6-1.51) = 12.09eV.
- When electron jumps from higher states to the lower states then it radiates the energy. Wavelength of the radiated energy when electron jump from n= 2 to n = 1 is given by

$$\lambda = \frac{12400}{E_2 - E_1} \text{ in angstroms}$$

- When monochromatic light is incident on the surface of a metal plate in a vacuum. The electrons in the metal absorb energy from the light, and some of the electrons receive enough energy to be ejected from the metal surface into the vacuum. This phenomenon is called the *photoelectric effect.*

1.2. Energy band theory of crystal

- As isolated atoms are brought together to form a solid, various interactions occur between neighboring atoms, the forces of attraction and repulsion between atoms will find a balance at the proper interatomic spacing for the crystal. In the process, important changes occur in the electron energy level configurations, and these changes result in the varied electrical properties of solids. One of them is the formation of the energy band.
- An energy gap exists between two energy bands. This energy gap is called as the forbidden energy gap E_g no electron can occupy this gap.



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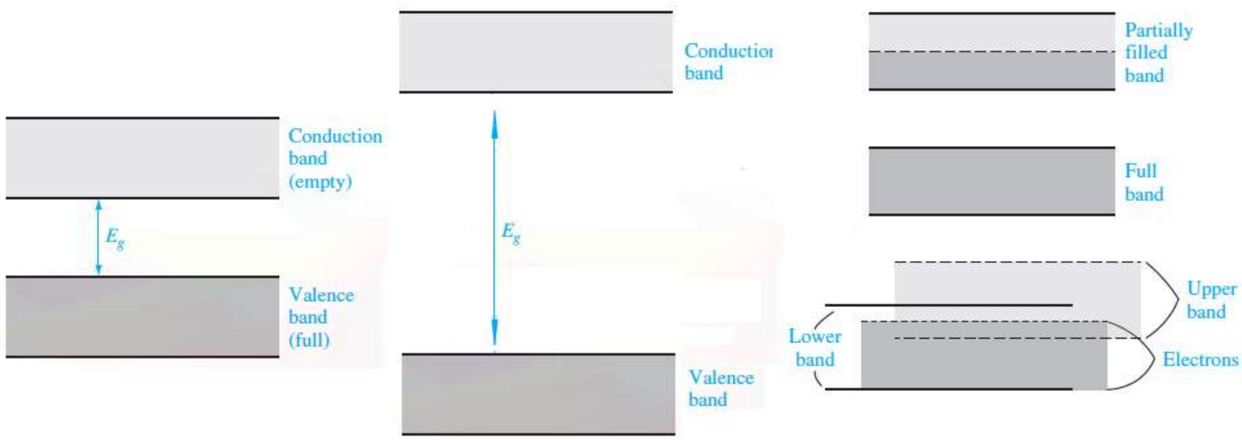
- The band above the forbidden energy gap is called the conduction band and the band below the forbidden energy gap is called the valence band. Conduction and valence band consist of infinitely large number of closely spaced energy states that electron can occupy.
- Electron in the valence band would not move under the action of the applied voltage because of the completely filled energy states. So valence electrons do not conduct.
- Electron in conduction band can gain momentum under the action of applied voltage, and move since there are empty states available.
- Lowest portion of conduction band is denoted as E_C. Upper most portion of valence band is denoted as E_V.

1.3. Metals, Semiconductors, and Insulators

- If the energy band is completely full or completely then there will not be any current when we apply the electric field across the material. Such a material is called insulator.
- The resistivity of an insulator is very large or, conversely, the conductivity of an insulator is very small.
- The bandgap energy *Eg* of an insulator is usually on the order of 3.5 to 6 eV or larger, so that at room temperature, there are essentially no electrons in the conduction band and the valence band remains completely full. There are very few thermally generated electrons and holes in an insulator.



(a)semiconductor (b) Insulator (c)Metal

- The energy-band diagram for a metal may be in one of two forms. Figure(c) shows the case of a partially full band in which there are many electrons available for conduction, so that the material can exhibit a large electrical conductivity
- Figure(c) shows the another case in which two band are overlapping with each other there are large numbers of electrons as well as large numbers of empty energy states into which the electrons can move, so this material can also exhibit a very high electrical conductivity.
- In case of semiconductor bandgap energy *Eg* is usually 1eV or smaller. So carrier requires very small thermal energy to jump from Valence band to Conduction band. But this thermal energy is not possible to get at ~0^oK. So at ~0^oK semiconductor behaves like an insulator.