Midterm Question and solution 19-11-2016

Question (1)

What is the main factors affecting the mobility of charge carriers in semiconductors?

Solution

There are three main factors affecting the mobility of charge carriers in semiconductors, they are:

Temperature: As temperature increases, the thermal kinetic energy increases the vibration of atoms and the charge carriers suffer from Collisions, the dependence of mobility in temperature given by:

$$\mu_L = KT^{-3/2}$$

Impuritites: The scattering of charge carriers results from the presence of ionized donors or acceptors or impurities. This charged centers will deflect the motion of carriers by the electrostatic forces between two bodies, so the density of such centers affect the velocity; it is also being noted that, the impurity scattering decreases as temperature increases.

$$\mu_I = \frac{KT^{3/2}}{N_I}$$

Dislocations:

Dislocation is atomic misfit, where atoms not probably arranged, so it has a considerable role of scattering carriers. For example, in germanium, the dislocations behave as acceptors, and the mobility affects by:

$$\mu_D = KT$$

Now if we combine these three parameters, we have a general expression to determine such effects in mobility of charge carriers.

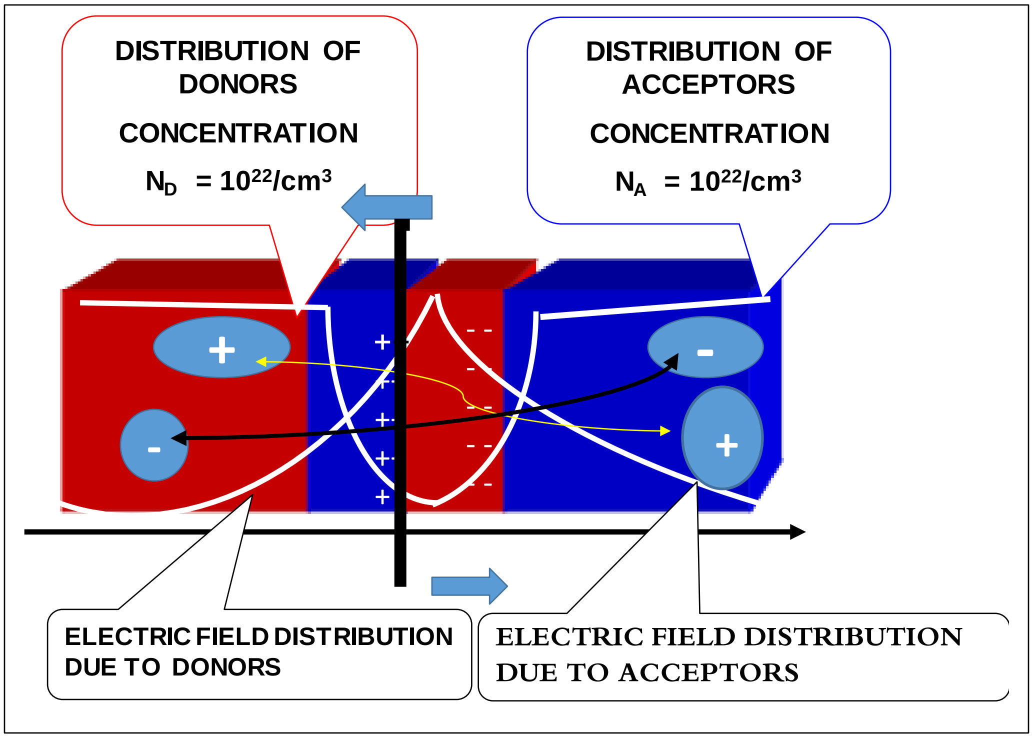
$$\frac{1}{\mu} = \frac{1}{\mu_L} + \frac{1}{\mu_I} + \frac{1}{\mu_D} = \alpha_L T^{3/2} + \alpha_I T^{-3/2} + \alpha_D T^{-1}$$

Question (2)

How pn junction comes in equilibrium statement?

Solution

If two pieces of semiconductor materials with different conduction type are brought together in a contact, a junction is formed. Before contact there is a large electron concentration in the n-side and a large hole concentration in the p-side. After the two sides are brought into contact, electrons are diffused from the n-side to the p-side and holes are diffused from the p-side to the n-side. However, each electron that diffuses into the p-side leaves a positively charged donor atom behind in the n-side, likewise the holes that diffuse into the n-side leaves a negatively charged acceptor atom behind in the p-side. An electric field is built-up between the ionized donors and acceptor atoms in such a direction as to oppose further diffusion of electrons and holes and the system comes into equilibrium statement.



Question (3)

How we can express such expressions, Applied voltage (V_o), built – in or , barrier voltage (V_T) , forward voltage (V_F) , reverse voltage (V_R) , cut-in or offset or break point or threshold voltage (V_γ) , Zener or breakdown voltage (V_Z)?

Solution

- **Applied voltage (V_o), is the battery voltage applied to in semiconductor diode circuit, it can be positive or negative to be forward or reverse.**
- **built – in or, barrier voltage (V_T), is the voltage that be built – up during the pn contact construction to hinder more diffusion of both charge carriers and bring the system in neutral electric mode.**
- **forward voltage (V_F), is the applied voltage to pn device, it decreases the barrier voltage and increase charge carrier concentration and bring the diode in forward bias mode.**
- **reverse voltage (V_R), is the applied voltage to pn device, it increases the barrier voltage and decrease charge carrier concentration and bring the diode in reverse bias mode.**
- **cut-in or offset or break point or threshold voltage (V_γ), is greater than the barrier voltage, it is in forward bias mode but below which forward current is very small, less than 1% of its maximum.**
- **Zener or breakdown voltage (V_Z), is in reverse bias mode , when reverse voltage increases for a certain value , rush of reverse saturation current can damage the diode.**

Question (4)

Calculate the intrinsic carrier density in silicon at 300, 400, 500 and 600 ^oK. if the effective density of electrons in conduction band is $2.81\ x\ 10^{19}$ and the effective density of holes in valance band is $1.83\ x\ 10^{19}$.

Solution

The intrinsic carrier density in silicon at 300 ^oK equals:

$$\begin{aligned} n_i(300K) &= \sqrt{N_c N_v}\, exp\left(\frac{-E_g}{2\,KT}\right) \\ &= \sqrt{2.81\ x\ 10^{19}\ x\ 1.83\ x\ 10^{19}}\, exp\ \left(\frac{-1.12}{2\ x\ 0.0258}\right) \\ &= 8.72\ x\ 10^{9} m^{-3} \end{aligned}$$

To get the value of T differ than room temperature (300 °K), and since Boltzmann constant is not given, so we can get the required value from the ratio between the value of KT at 300 °K (0.026 eV) and its value at 400 °K ,

- **At 300 °K = 0.026 eV, then KT at 400 °K is 400 x 0.026 / 300 = 0.0346 eV**

So,

$$\begin{aligned} n_i(400K) &= \sqrt{N_c N_v}\, exp\left(\frac{-E_g}{2\,KT}\right) \\ &= \sqrt{2.81\ x\ 10^{19}\ x\ 1.83\ x\ 10^{19}}\, exp\ \left(\frac{-1.12}{2\ x\ 0.0346}\right) \\ &= 4.52\ \text{x}\ 10^{12}\ \ electrons\ in\ m^{-3} \end{aligned}$$

- **At 300 °K = 0.026 eV, then KT at 500 °K is 500 x 0.026 / 300 = 0.0433 eV**
  - $n_i(500K) = \sqrt{N_c N_v}\, exp\left(\frac{-E_g}{2\,KT}\right) = \sqrt{2.81\ x\ 10^{19}\ x\ 1.83\ x\ 10^{19}}$

$$exp\ \left(\frac{-1.12}{2\ x\ \ 0.0433}\right) = 2.16\ \text{x}\ 10^{14}\ \ electrons\ in\ m^{-3}$$

- **At 300 °K = 0.026 eV , then KT at 600 °K is 600 x 0.026 / 300 = 0.052 eV**

$$n_i(600K) = \sqrt{N_c N_v}\, exp\left(\frac{-E_g}{2\,KT}\right) = \sqrt{2.81\ x\ 10^{19}\ x\ 1.83\ x\ 10^{19}}$$

$$exp\ \left(\frac{-1.12}{2\ x\ \ 0.052}\right) = 3.07\ \text{x}\ 10^{15}\ \ electrons\ in\ m^{-3}$$

Temperature °K	**300**	**400**	**500**	**600**
Intrinsic concentration	**8.72 x 10^{9}**	**4.52 x 10^{12}**	**2.16 x 10^{14}**	**3.07 x 10^{15}**
Change % above RT	**-----**	**5.183 %**	**247.7%**	**3520%**