Derivation of Diode Equation

No current is flowed from the junction at equilibrium condition.

The following equations of carrier concentration of electron and hole for non degenerate semiconductors

$$n_p = n_C e^{\frac{E_F - E_{CP}}{kT}} \qquad n_n = n_C e^{\frac{E_F - E_{CN}}{kT}}$$

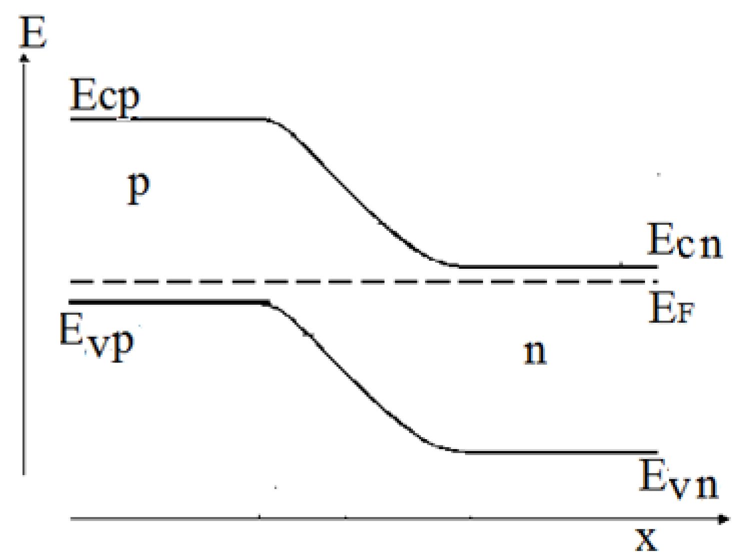
$$p_p = n_V e^{\frac{E_{VP} - E_F}{kT}} \qquad p_n = n_V e^{\frac{E_{VN} - E_F}{kT}}$$

$$\frac{p_p}{p_n} = e^{\frac{E_{VP} - E_F - E_{VN} - E_F}{kT}} = e^{\frac{e\Delta\Phi}{kT}}$$

$$p_n = p_p e^{\frac{-e\Delta\Phi}{kT}}$$

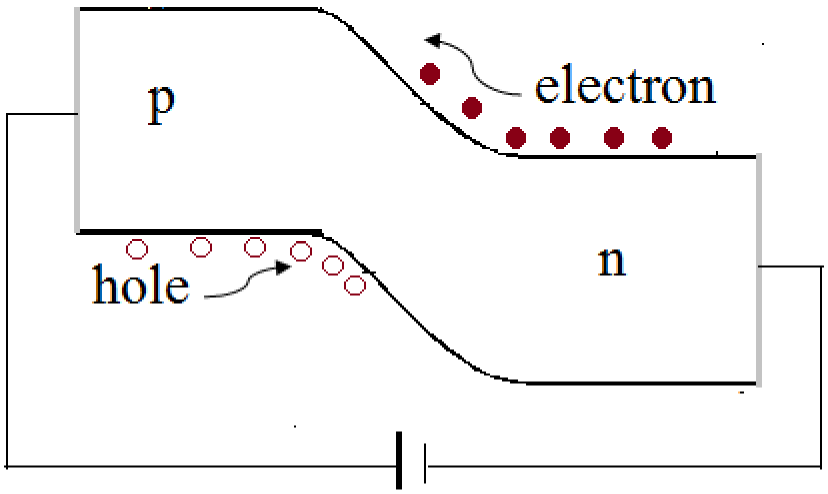
In Forward bias

$$p_n' = p_p e^{\frac{-(e\Delta\Phi - V)}{kT}}$$



pn junction in equilibrium condition (without bias)

When we forward bias , the Barrier height will be reduced. The hole will be injected towards the n region. The injected holes



$$\Delta p = p_n' - p_n$$

$$= p_p e^{\frac{-e(\Delta\Phi - V)}{kT}} - p_p e^{\frac{-e\Delta\Phi}{kT}}$$

$$= p_p e^{\frac{-e\Delta\Phi}{kT}} e^{\frac{-eV}{kT}} - p_p e^{\frac{-e\Delta\Phi}{kT}}$$

$$= p_p e^{\frac{-e\Delta\Phi}{kT}} \left[e^{\frac{-eV}{kT}} - 1 \right]$$

$$= p_n \left[e^{\frac{eV}{kT}} - 1 \right]$$

Current due to injected holes

$$J_h = -eD_p \frac{\partial(\Delta p)}{\partial x}$$

$$J_h = -eD_p \frac{\partial}{\partial x}\left\{\Delta p_0 e^{\frac{-x}{L_p}}\right\}$$

$$= \frac{eD_p \Delta p_0}{L_p} e^{\frac{-x}{L_p}}$$

$$= \frac{eD_p \Delta p}{L_p}$$

$$= \frac{eD_p}{L_p}\left[p_n(e^{\frac{eV}{kT}} - 1)\right]$$

$$= \frac{eD_p p_n}{L_p}\left[(e^{\frac{eV}{kT}} - 1)\right]$$

D_p is diffusion coefficient of minority carrier holes in n region

L_p is diffusion length for holes

Similarly current due to injected electron is given by

$$J_e = \frac{eD_n n_p}{L_n}\left\{e^{\frac{eV}{kT}} - 1\right\}$$

D_n is diffusion coefficient of minority carrier electrons in p region. L_n is diffusion length for electrons

$$J = J_e + J_h = \frac{eD_p P_n}{L_p}(e^{\frac{eV}{kT}} - 1) + \frac{eD_n P_p}{L_p}(e^{\frac{eV}{kT}} - 1)$$

$$J = \left(\frac{eD_p P_n}{L_p} + \frac{eD_n P_p}{L_p}\right)(e^{\frac{eV}{kT}} - 1)$$

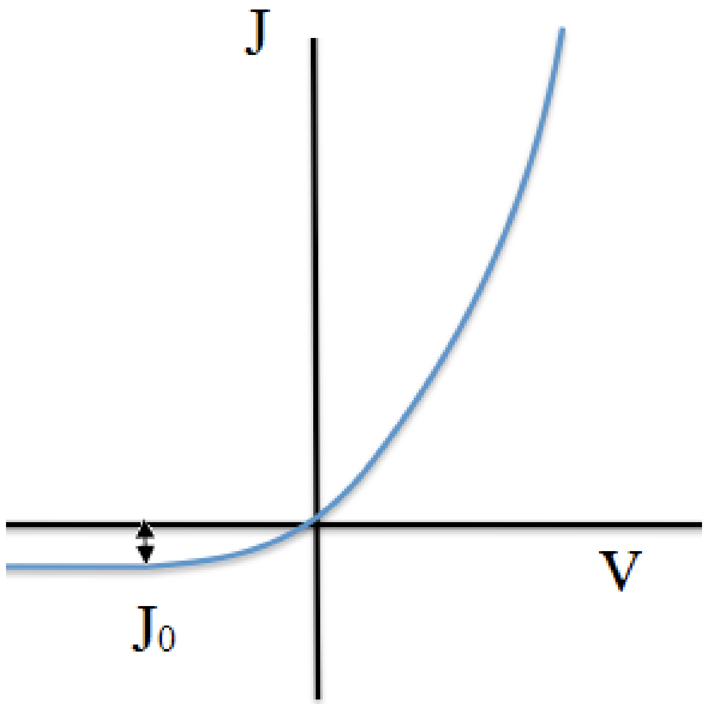
$$= J_o(e^{\frac{eV}{kT}} - 1)$$

$$J_o = \left(\frac{eD_p P_n}{L_p} + \frac{eD_n P_p}{L_p}\right)$$

For an ideal diode J_0 should be as small as possible

For V=+Ve $J=J_0(e^{eV/kT}-1)$

For V=-Ve $J=-J_0$



Recombination and Generation in transition region

Diode Ideality Factor

In analogy to the p-n junction we have assumed that the recombination and thermal generation of carriers occur primarily in the neutral p and n region, outside the transition region. In this model forward current in the diode is due to injection carriers into the neutral region. The reverse saturation current is due to thermal generation of EHP in the neutral region.

A more complete description of junction operation should include recombination and generation in the transition region.

When a junction is forward biased, the transition region contains Excess carriers of both type, which are in transit of one side of the junction to the other. Unless the width of the transition region is being small compared with carrier diffusion length L_n and L_p recombination can take place within the transition region(W).

The diode equation can be modified to include this effect by including the parameter n .

$$I=I_0(e^{eV/nkT}-1)$$

Where n varies between 1 and 2.

Since n determines the departure from the ideal diode characteristics ,it is often called the ideality factor