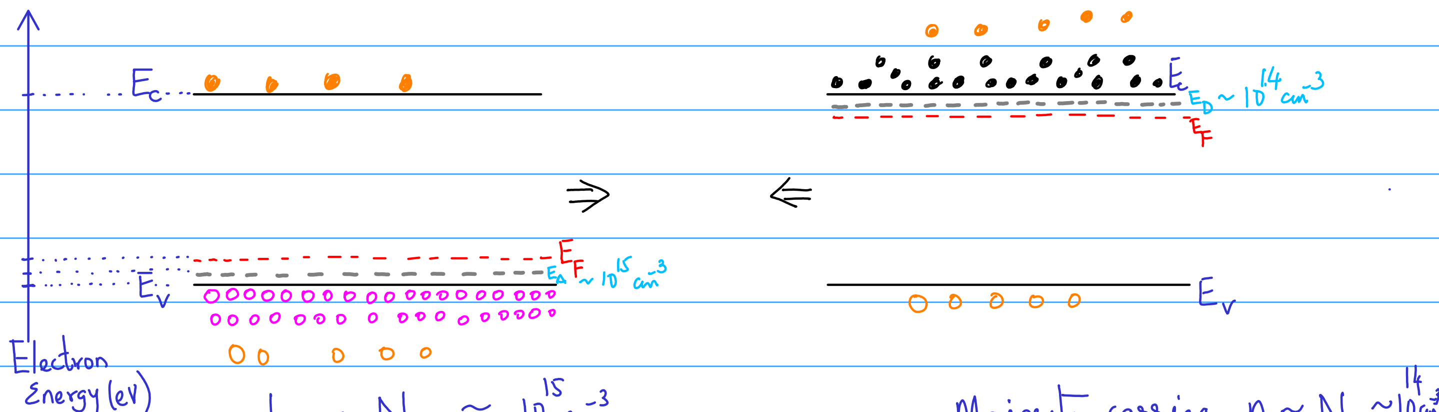
17.01.2022

p-n Junction Diode

T = 300K

p-type Silicon n-type Silicon



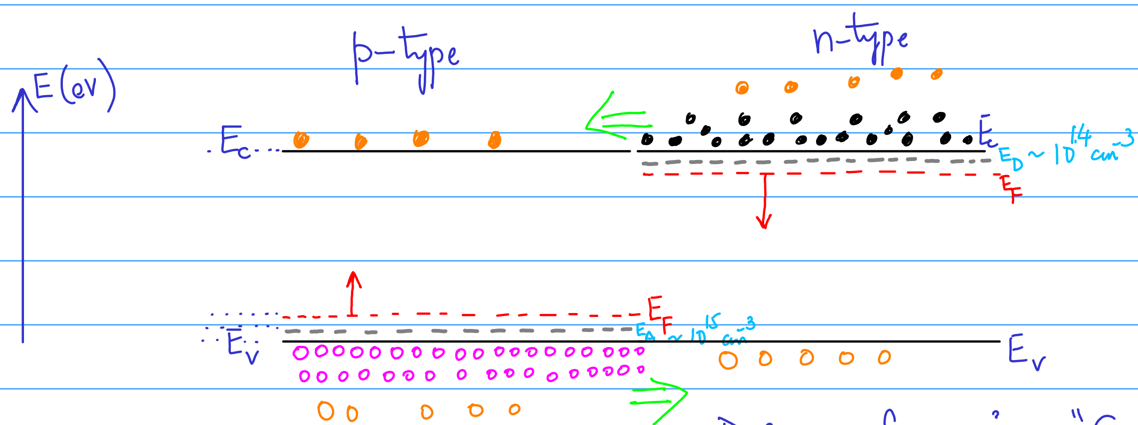
majority carriers $p \simeq N_A \approx 10^{15}\,cm^{-3}$

minority carriers $n = \dfrac{n_i^2}{p} \approx 10^{5}\,cm^{-3}$

Majority carriers $n \simeq N_D \approx 10^{14}\,cm^{-3}$

minority carriers $p = \dfrac{n_i^2}{n} = 10^{6}\,cm^{-3}$

Ques: What happens when you join p-type and n-type semiconductors (here Silicon) together?

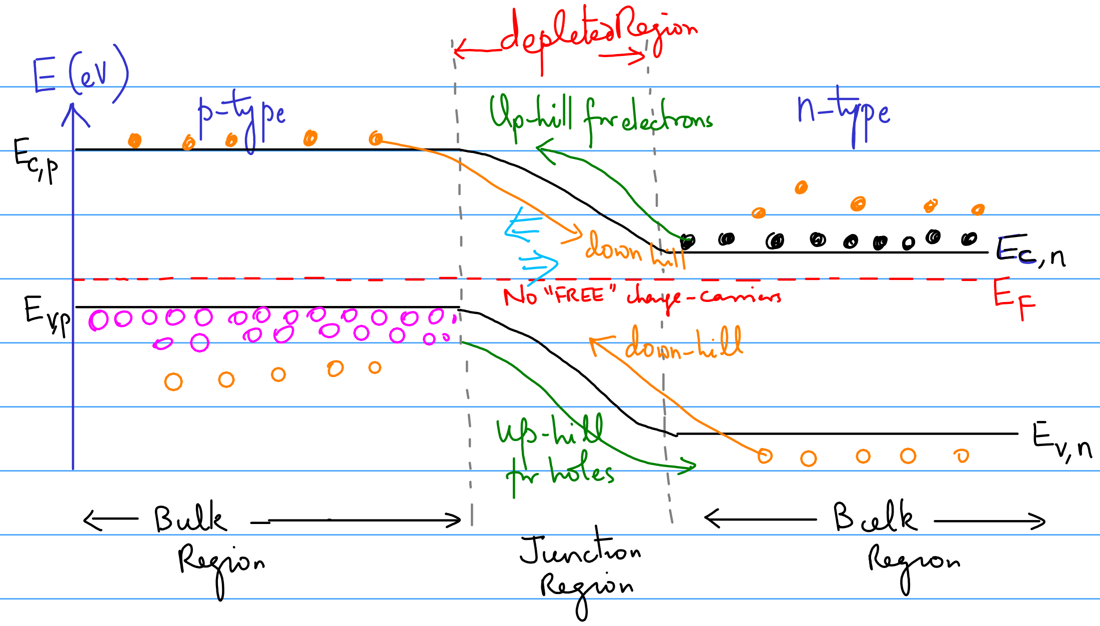


Driving force is "Concentration Gradient"

$\Rightarrow$ "Diffusion".

As a result, the majority charge-carriers flow under the driving force of diffusion until the position of the Fermi-level becomes same in both p- and n-side.

This results in band-bending in the junction region.



In steady-state, the diffusive flux of majority charge-carriers is equal to drift flux of the minority charge-carriers.

Diffusion current (majority carriers) = Drift current (minority carriers).

This band-bending in the junction region is referred as built-in-potential. (V_{bi})

The depletion width is dependent on the extent of doping level, ie, depends upon the density of dopant atoms.

The depletion width $W = \sqrt{\frac{2\epsilon_r \epsilon_0}{q} V_{bi} \left(\frac{N_A + N_D}{N_A \cdot N_D} \right)}$

The built-in potential also depends upon the extent of doping level.

$$V_{bi} = \frac{k_B T}{q} \left[\ln \left(\frac{N_A \cdot N_D}{n_i^2} \right) \right]$$

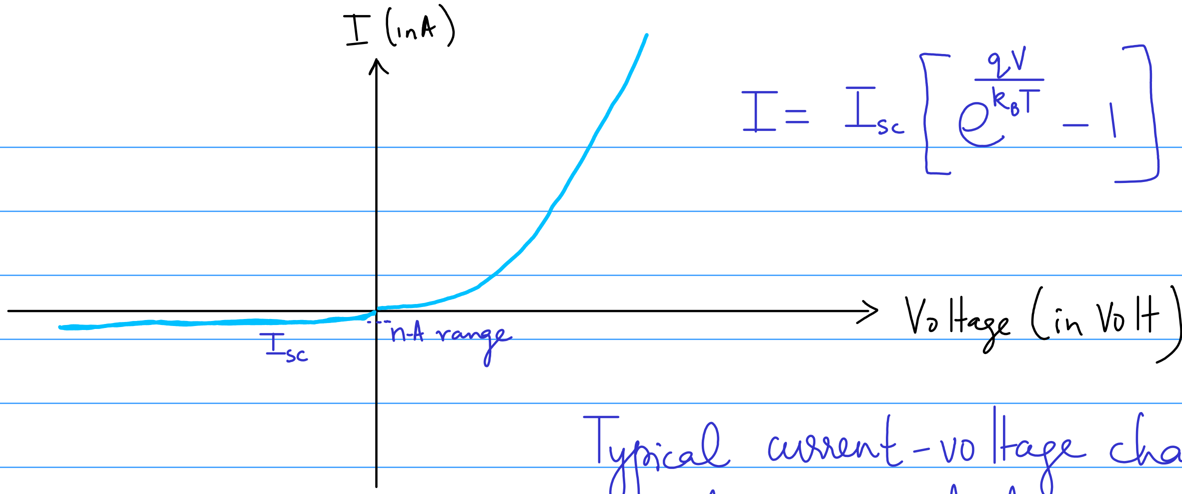
Ques: What will be the effect of Applied external voltage bias?

⇒ If p-side is connected with higher bias voltage w.r.t. n-side, we term it as "Forward-bias".

Under this condn: depletion width decreases & diffusion current increases exponentially.

⇒ If p-side is connected with lower bias voltage w.r.t. n-side, we term it as "Reverse-bias".

Under this condn: depletion width increases & diffusion current decreases to almost zero, whereas, the drift current flows. This leads to some saturation current.



$$I = I_{sc}\left[e^{\frac{qV}{k_B T}} - 1\right]$$

Typical current-voltage charac. of a p-n diode.