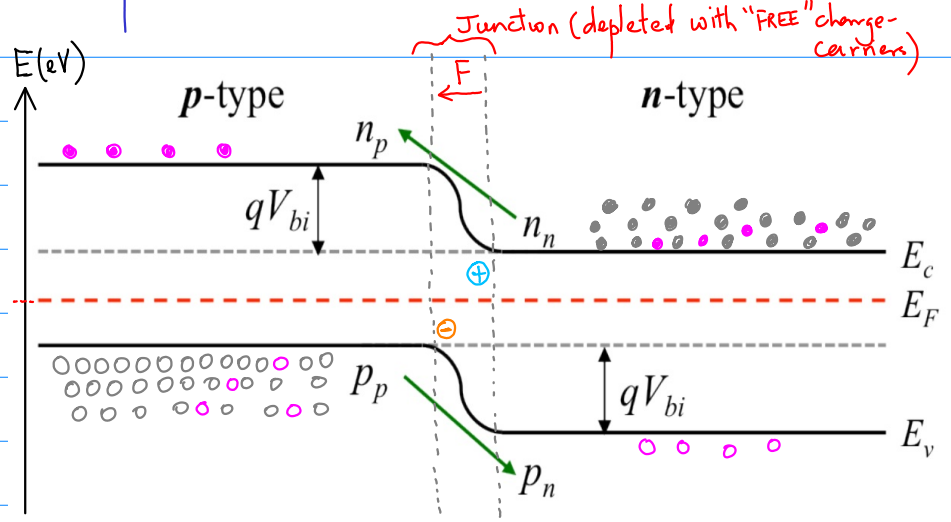
18.01.2022

p-n Junction Diode

1. Unbaised p-n Junction at T = 300K.



Dopants:
⊕ : Donor atoms
⊖ : Acceptor atoms

Free charge-carriers:

- ● ≡ Electrons from the donor atoms } Majority carriers "Extrinsic" source
- ○ ≡ Holes from the acceptor atoms
- ● ≡ Electrons due to excitation } Minority carriers "Intrinsic" carriers
- ○ ≡ Holes due to excitation of electrons

V_{bi} ≡ Built-in voltage is simply the difference of the Fermi-levels in p- and n-type semiconductors before they are joined.

$$\Rightarrow \quad eV_{bi} = E_{F,n} - E_{F,p}$$

at any temperature T;

$$E_{F,n} = E_{F_i} + k_B T \ln\left(\frac{N_D}{n_i}\right) \quad \uparrow \text{ towards } E_c$$

$$E_{F,p} = E_{F_i} - k_B T \ln\left(\frac{N_A}{n_i}\right) \quad \downarrow \text{ towards } E_v$$

Subtract the two, we get

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

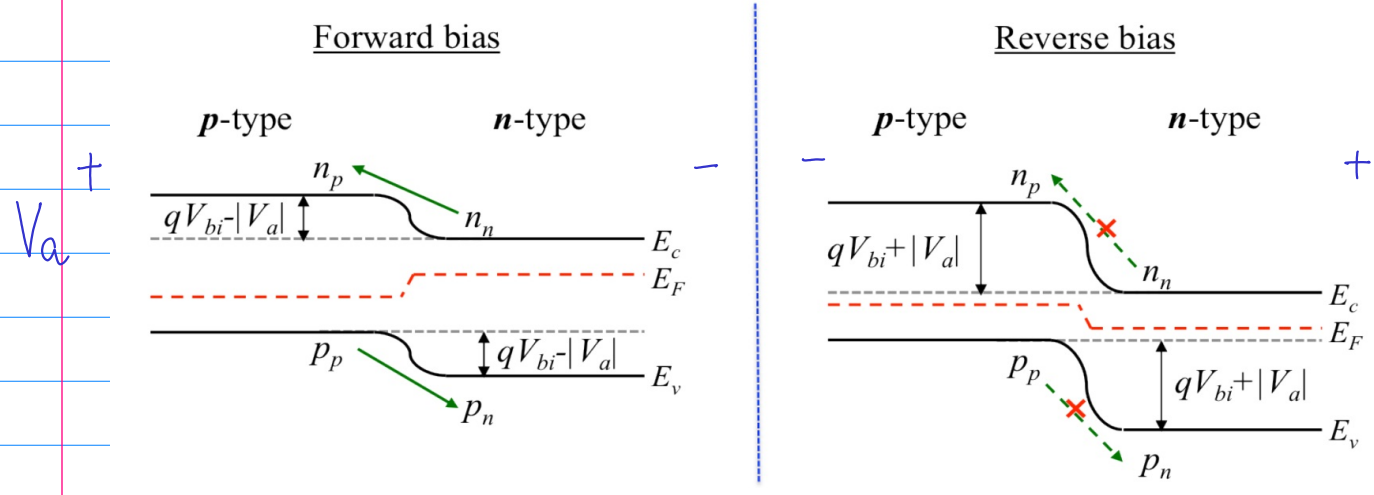
In steady-state,

Diffusion current = Drift current

2. Effect of Biasing the p-n junction : (Biased p-n junction)

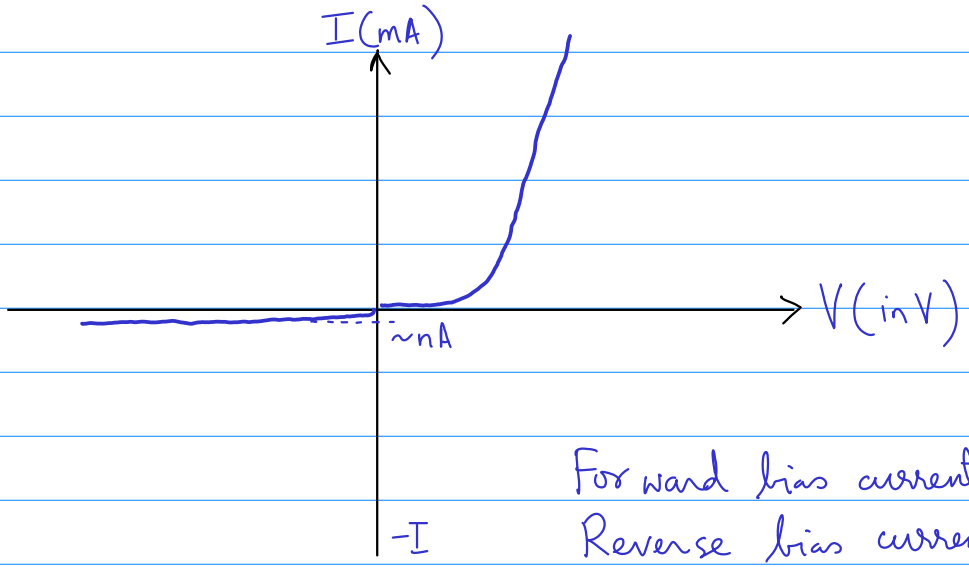
p-type = +ve terminal of the source
→ forward bias p-n junction

= -ve terminal of the source
→ Reverse bias p-n junction.



- Applying a +ve potential V_a to p-side increases the diffusion of majority charge-carriers due to lowering of potential barrier.

- Reverse effect will take place when -ve potential is applied to p-side.



Forward bias current ~ mA
Reverse bias current ~ nA

The difference of forward current to the reverse current through the p-n junction device is roughly of six order of magnitude.

This behaviour is termed as "Unipolar" (Rectifying) characteristics.

What kind of devices can be built using p-n junction?

- p-n junction under applied bias: Diode, transistor, LEDs, LASER diode.

- p-n junction under illumination: Solar Cells, photo-detector.

p-n junction is useful in fabricating "opto-electronic devices"