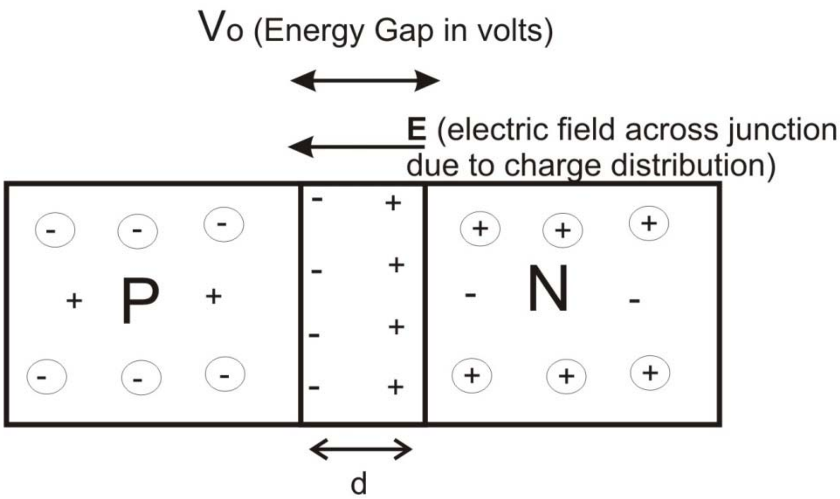
4061- Lecture Eleven

The band structures of semiconductors at p-n junctions have led to several applications



In p type materials, negative acceptor ions are fixed and holes are mobile.
In these materials holes can be pictured as being in the valence band
Example: Silicon doped with aluminum

In n type materials, positive doner ions are fixed and electrons are mobile.
The electrons can be pictured as being in the conductance band
Example: Silicon doped with Phosphorous

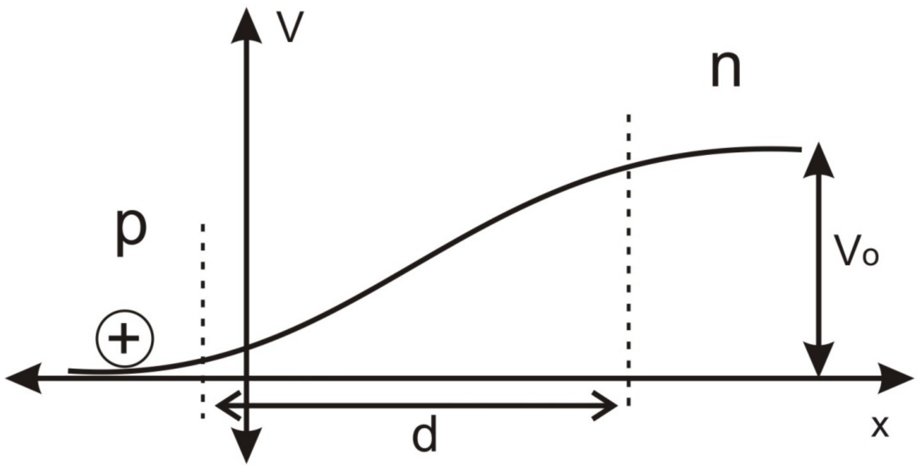
At a Junction holes drift to n-side and electrons drift to p-side

- Attraction between mobile holes and electrons leads to annihilation of charge carriers and a depletion zone
- Positive and negative ion cores remain creating an electric field across the junction
- Diffusion of charge carriers is limited because of electrical conductivity and the induced E field present across the juntion
- Charge density at interface because of – and + cores

In Thermal Equilibrium

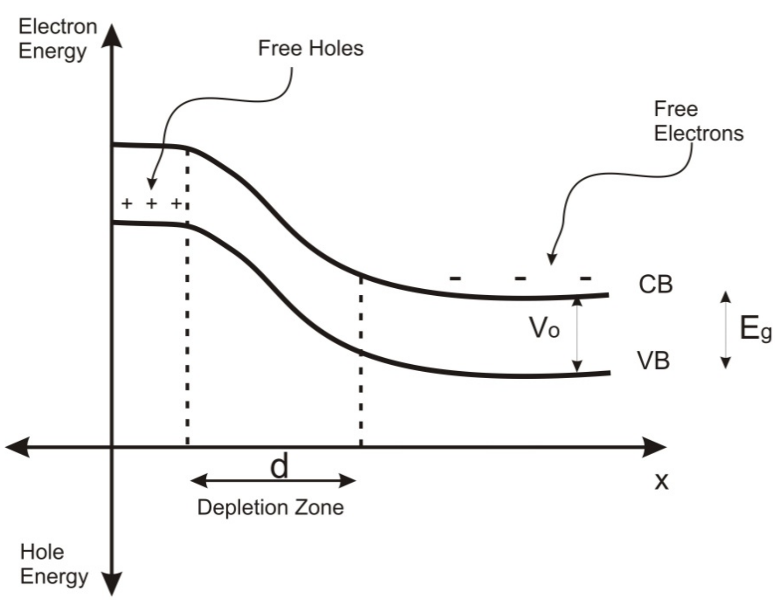
- Holes can easily migrate from n to p but not from p to n
- Fraction of holes crossing barrier is proportional to $\exp[-qV_o/k_BT]$

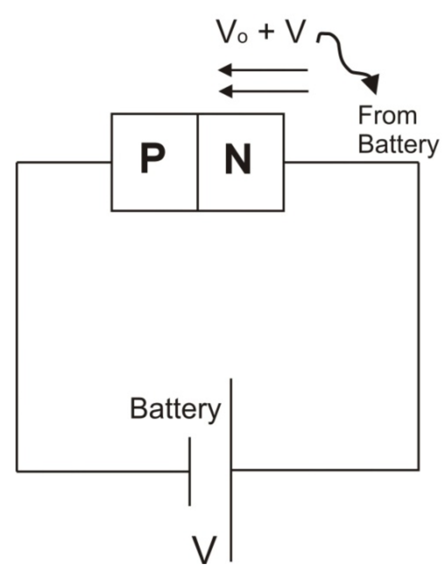
Energy Gap across Junction



- V_o changes relative energies of VB and CB
- Holes have to climb barrier to get to n side, this requires energy

Reverse Bias





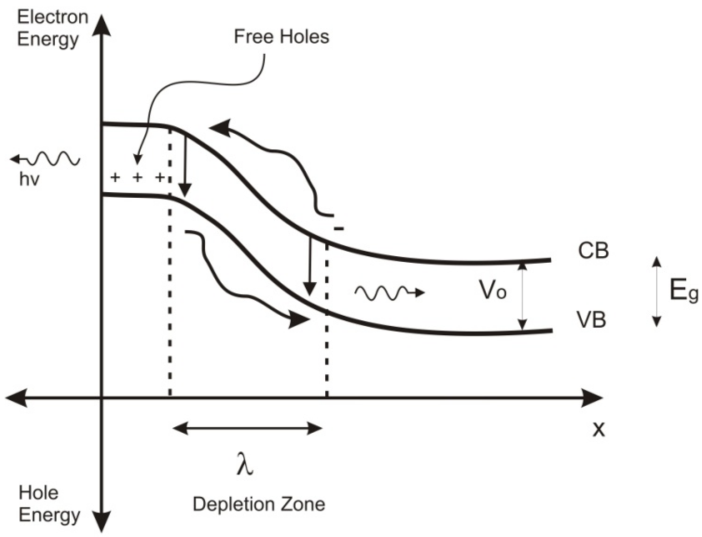
- electrons on n side need energy to get to p side and holes need energy to get to n side

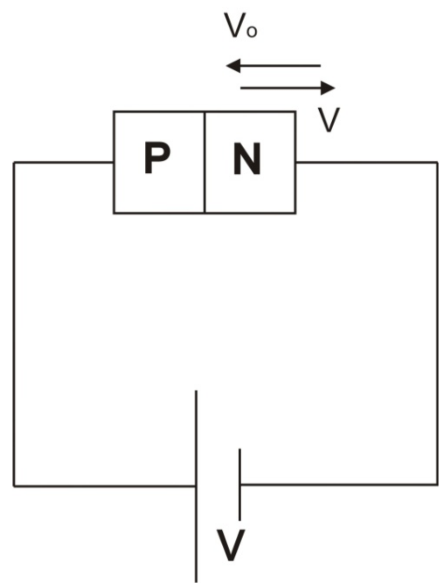
In the presence of a battery Vo → V_o + V and E_{gap} is larger

Here the applied voltage increases barrier to V_o + V

So in this arrangement, there is no conduction (open circuit)

Forward Bias





Gap V_o is reduced to Vo – V since applied voltage from battery lowers barrier
E_{gap} is smaller thereby permitting increased current and recombination
But hole current from p to n side increases when V is applied

Assume $V << V_o$

$I_{holes} \propto n_h(\text{p-side})\exp[-q(V_o - V)/k_BT] - n_h(\text{n-side})$

$I_h = I_{ho}[\exp(+qV/k_BT) -1]$

$I_e = I_{eo}[\exp(+qV/k_BT) -1]$

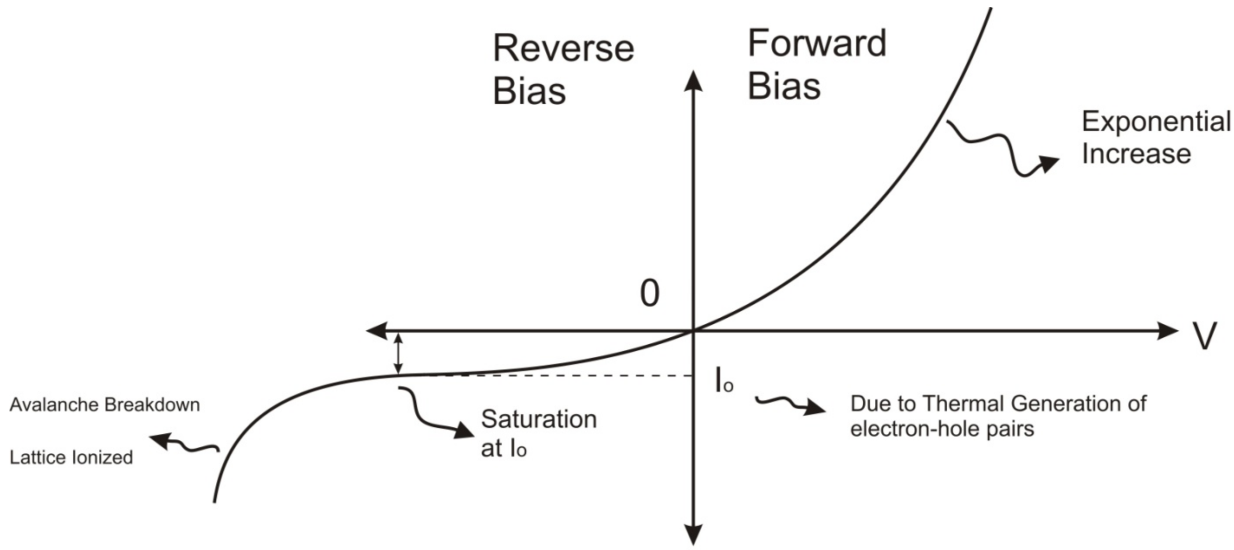
$I_{tot} = I_h + I_e = I_o[\exp[(+qV/k_BT) -1]$ (1)

Where $I_o = I_{ho} + I_{eo}$ is the saturation current

In contrast with Reverse Bias

$I_{tot} = I_h + I_e = I_o[\exp[(-qV/k_BT) -1]$ (2)

Diode Conduction Graph



– V_o about 0.5 volts in Si and Ge

Real Junctions have recombination within depletion zone. This is an effect that has been ignored.