Analog Electronics Notes

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1 Some basic concepts

To manipulate currents externally, we generally need to create a gradient, which generates an electric field which can be controlled externally

Band gap in Si $= 1.12eV$
$\Rightarrow$ For Silicon to function as a semiconductor, $\frac{1}{2}k_BT \geq 1.12eV$

where k_B is the Boltzmann constant.

In a simple p-n junction, the p-n junction is a metallurgical junction, and at thermal equilibrium, it forms a depletion layer, which results in a built-in potential V_{bi}, due to a distribution of charge.

If the p-side is doped with N_a acceptor atoms(cm^{-3}) and the n-side is doped with N_d donor atoms(cm^{-3}), then:

$$V_{bi} = \frac{k_BT}{q}\ln(\frac{N_aN_d}{n_i^2}) \tag{1}$$

which at $T \approx 300K$:

- V_T called the thermal voltage $q = e = 1.6 * 10^{-19}$,

$$V_T = \frac{k_B T}{q} \approx 26mV$$

.

- $n_i = 1.35 * 10^{10} \approx 10^{10} cm^{-3}$

Note that this voltage difference can not be used to extract energy if there's no temperature difference. (The Second Law of Thermodynamics)

1.1 Law of Mass Action

In equilibrium:

$$n_i^2 = n * p \tag{2}$$

where n and p are the electron and hole concentration of a doped semiconductor

Generally, you dope it with either:

- donor atoms, which causes it to become an n-type semiconductor

  If it's doped with donor atoms, with concentration $N_d >> n_i$, then $n \approx N_d$ and $p \approx \frac{n_i^2}{N_d}$

- acceptor atoms, which causes it to become a p-type semiconductor

  If it's doped with donor atoms, with concentration $N_a >> n_i$, then $p \approx N_a$ and $n \approx \frac{n_i^2}{N_a}$

1.2 Capacitance across the depletion layer

Due to the build-up of charge across the depletion layer in reverse or zero bias (immobile as it may be), we can model this behaviour as a capactiance:

$$C_t = \frac{\epsilon A}{W_{dep}} \tag{3}$$

$$W_{dep} = \sqrt{\frac{2\epsilon}{q}(V_{bi} + V_R)(\frac{1}{N_a} + \frac{1}{N_d})} \tag{4}$$

2 BJT and Biasing