SEDRA/SMITH

Microelectronic Circuits

SEVENTH EDITION

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2 ways charge can be stored in *pn* junction.

1. charge in depletion region (more visible when reverse bias)
2. minority charge in n and p material (more visible when forward bias)
   - concentration profile by injecting to n-dope
   - " " to p-dope

3.5.1 Depletion or Junction Capacitance

Assumption: *pn* junction reversed bias with V_R, charge on either side of junction:

$$Q_J = A\sqrt{2\epsilon_s q \frac{N_A N_D}{N_A + N_D}(V_0 + V_R)} = \alpha\sqrt{(V_0 + V_R)} \tag{3.1}$$

We denote α as $A\sqrt{2\epsilon_s q \frac{N_A N_D}{N_A+N_D}}$ and observe that $Q_J \not\propto V_R$ (also not linearly related)

- Hard to define capacitance that accounts for changing Q_J when V_R changes

  Assumption: junction operates as a point Q and define

$$C_j = \left.\frac{dQ_J}{dV_r}\right|_{V_R=V_Q} \tag{3.2}$$

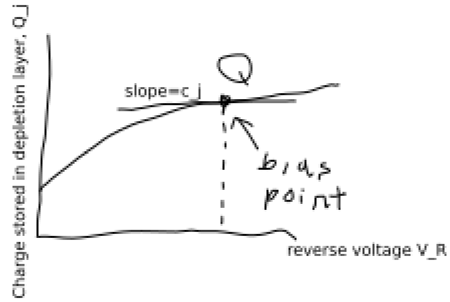

Figure 3.1: The charge stored on either side of the depletion layer as a function of the reverse voltage V_R

Note:-

The definition of capacitance

$$q = CV \implies C = q/V = \frac{\Delta q}{\Delta V}$$

- Equation 3.2 useful in electronic cct design
- This equation used in this book frequently
- Called the **"incremental-capacitance approach"**

Combining equations 3.2 with 3.1 we obtain:

$$C_j = \frac{\alpha}{2\sqrt{V_0 + V_R}} \tag{3.3}$$

We observe that C_j at reverse bias ($V_R = 0$) is $C_{j0} = \frac{\alpha}{2\sqrt{V_0}}$, so we can write C_j as

$$C_j = \frac{C_{j0}}{\sqrt{1 + \frac{V_R}{V_0}}} \tag{3.4}$$

Substituting for α, we obtain:

$$C_j = A\sqrt{\left(\frac{\epsilon_s q}{2}\right)\left(\frac{N_A N_D}{N_A + N_D}\right)\left(\frac{1}{V_0}\right)} \tag{3.5}$$

Before leaving concept of junction capacitance, we introduce

Definition 3.5.1: Terms

Abrupt junction *pn* junction, doping concentration changes abruptly at junction boundary (this is deliberately done)

Graded junction: *pn* junction, carrier concentration changes gradually from one side to another. Then C_j becomes:

$$C_j = \frac{C_{j0}}{\left(1 + \frac{V_R}{V_0}\right)^m}$$

where m is the **Grading coefficient**

Note:-

- m ranges from 1/3 to 1/2
- m depends on manner in which concentration changes from p to n side

Question 1: Exercise 3.14

For the pn $\ldots \mathrm{cm}^2$.

Solution: Solution

3.5.2 Diffusion Capacitance