ShanghaiTech University
School of Information Science and Technology

EE112 Analog Integrated Circuits I

Homework 3

Due: Oct. 27th before exam

Read the chapter 3.

1. A young designer, aiming to develop intuition concerning conducting paths within an integrated circuit, examines the end-to-end resistance of a connecting bar 10 µm long, 3 µm wide, and 1 µm thick, made of various materials. The designer considers:
   (a) intrinsic silicon
   (b) n-doped silicon with $N_D = 10^{16}/\text{cm}^3$
   (c) n-doped silicon with $N_D = 10^{18}/\text{cm}^3$
   (d) p-doped silicon with $N_A = 10^{16}/\text{cm}^3$
   (e) aluminum with resistivity of 2.8 µΩ.cm
   Find the resistance in each case. For intrinsic silicon, use the data in Table 3.1 of the textbook. For doped silicon, assume $\mu_n = 2.5\mu_p = 1200$ cm^2 /V.s. (Recall that $R = \rho L/A$)

2. Holes are being steadily injected into a region of n-type silicon (connected to other devices, the details of which are not important for this question). In the steady state, the excess-hole concentration profile shown in Fig. 1 is established in the n-type silicon region. Here "excess" means over and above the thermal-equilibrium concentration (in the absence of hole injection), denoted p_{n0}. If $N_D = 10^{16}/\text{cm}^3$, $n_i = 1.5*10^{10}/\text{cm}^3$, $D^n = 12$ cm^2/ s, and $W = 0.1$ µm, find the density of the current that will flow in the x direction.

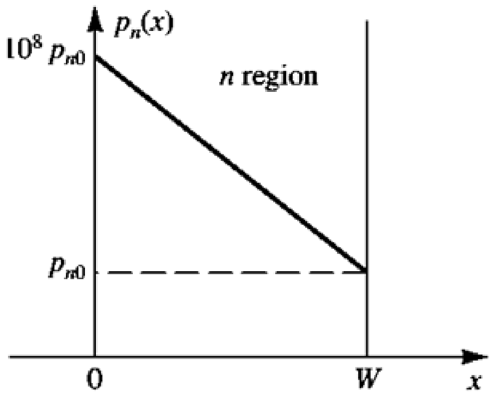

Figure 1

3. A p^+n junction is one in which the doping concentration in the p region is much greater than that in the n region. In such a junction, the forward current is mostly due to hole injection across the junction. Show that

$$I \approx I_p = Aqn_i^2 \frac{D_p}{L_p N_D}\left(e^{V/V_T} - 1\right)$$

For the specific case in which $N_D = 10^{16}/\text{cm}^3$, $D_p = 10\ \text{cm}^2/\text{s}$, $L_p = 10\ \mu\text{m}$, $A = 10^4\ \mu\text{m}^2$, find I_s and the voltage V obtained when $I = 0.5$ mA. Assume operation at 300 K where $n_i = 1.5*10^{10}/\text{cm}^3$.

4. The junction capacitance C_j can be thought of as that of a parallel-plate capacitor and thus given by

$$C_j = \frac{\varepsilon A}{W}$$

Show that this approach leads to a formula identical to that obtained by combining Eqs. (1) and (2) [or equivalently, by combining Eqs. (3) and (4)].

$$\alpha = A\sqrt{2\varepsilon_s q \frac{N_A N_D}{N_A + N_D}} \qquad (1)$$

$$C_j = \frac{\alpha}{2\sqrt{V_0 + V_R}} \qquad (2)$$

$$C_j = \frac{C_{j0}}{\sqrt{1 + \frac{V_R}{V_0}}} \qquad (3)$$

$$C_{j0} = A\sqrt{\frac{\varepsilon_s q}{2}\frac{N_A N_D}{N_A + N_D}\frac{1}{V_0}} \qquad (4)$$

5. A *pn* junction operating in the forward-bias region with a current I of 1 mA is found to have a diffusion capacitance of 10 pF. What diffusion capacitance do you expect this junction to have at $I = 0.1$ mA? What is the mean transit time for this junction?