ECE 3030 Spring 2025 HOMEWORK ASSIGNMENT NO. 7

Due: Friday, March 28th 11:59 pm upload to Carmen 3030 SpeedGrader

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1. (15 pts) Calculate the capacitance for the following Si n^+-p junction. $N_a = 10^{15}$ cm^{-3}; Area = 0.001 cm^2; Reverse bias V_R = 1, 5, and 10 V. $\varepsilon = 11.8\ \varepsilon_0$. Plot $1/C^2$ vs. V_R; Demonstrate that the slope yields N_a. Repeat calculations for $N_a = 10^{17}$ cm^{-3}. Since n^+ doping is not specified, approximate with $E_F^n \sim ½\ E_G$.
2. (15 pts) A p^+-n Si junction is doped with $N_d = 3x10^{16}$ cm^{-3} on the n side, where D_p = 10 cm^2/s and τ_p = 0.1 μs. The junction area is 10^{-4} cm^2. Find (a) the junction capacitance C_j with a reverse bias of 10 V, and (b) the charge storage capacitance C_s with a forward bias of 0.6 V, where $C_s = qI\ \tau_p / kT$
3. (15 pts) Modify the x_{po} and x_{no} expressions for the case of reverse bias $V_r >> V_0$ and show that the peak electric field $\mathcal{E}_0$ is dominated by the doping on the lightly doped side of the junction. Solve for V_r for a p^+-n junction. If avalanche occurs at a peak field of about 400 kV/ cm in a Si p^+-n junction doped with 10^{16} cm^{-3} donors on the n side, what is the breakdown voltage?
4. (15 pts) If the critical field for Zener breakdown is 10^6 V/cm, calculate the reverse bias required for this type of breakdown in the following abrupt Si junction: N_a on the p side = N_d on the n side = 4 x 10^{18} cm^{-3}. Assume that breakdown can occur if the peak electric field in the junction reaches 10^6 V/cm.
5. (10 pts) A p^+n Si diode (V_0=0.956 V) has a donor doping of 10^{17} cm^{-3} and an n-region width = 1 μm. Does it break down by avalanche or punch through (W > 1 μm)? From Lecture 23, slide 6 (S&B Fig. 5-22), avalanche V_{br} = 13 V.
6. (15 pts) An ideal Schottky barrier is formed on n-type Si with $N_d = 10^{17}$ cm^{-3}. The metal work function is 4.8 eV, and electron affinity is 4 eV. Draw equilibrium diagrams such as in S&B Fig. 5-40 to scale. Draw the forward- and reverse-bias diagrams, as in Fig. 5-42 to scale, for V_f = 0.3 V and V_r = 3 V.
7. (15 pts) A Schottky barrier is formed between a metal having a work function of 4.3 eV and p-type Si. The acceptor doping in the Si is 10^{17} cm^{-3}. (a) Calculate V_0 and draw the equilibrium band diagram, illustrating V_0, (b) Draw the band diagram with 0.3 V forward bias. Repeat for 2 V reverse bias.
8. **(10 pt Bonus)** <u>Design</u> an abrupt Si p^+-n junction that has a reverse breakdown voltage of 150 V and provides a forward current of 1 mA when V = 0.6 V. Solve for square or circle area A. Assume that n-side τ_p = 0.1 μs and that $\mu_p \sim$ 450 cm^2/V-s from S&B fig. 3-23.