Solid State Devices I - Purdue ECE-606

Homework No. 7

Student name: _____

Student ID: _____

I solved the homework assignment myself without copying a solution from someone else or from the web. Student Initials here: _____

Problem 1. (24 Points total, 2 points each)

Answer the following questions as concisely as possible.

a) What is the physical origin of the junction capacitance?

b) Sketch the m = -1 hyperabrupt profile of an n^+-p junction.

c) Define quasistatically.

d) Define varactor.

e) Define profiling.

f) Make a sketch of the low-frequency conductance of an ideal diode showing both forward and reverse bias. Comment as necessary to forestall a misinterpretation of your sketch.

g) What is the physical origin of the diffusion admittance?

h) Why does the diffusion conductance increase with increasing $\omega\tau_p$ when $\omega\tau_p \geq 1$?

i) Name the dominant current component in MS diodes.

j) Somehow the $I_{M\rightarrow S}$ component of the current in an MS (n-type) diode was determined without a detailed mathematical analysis of electron injection from the metal into the semiconductor. How was this accomplished?

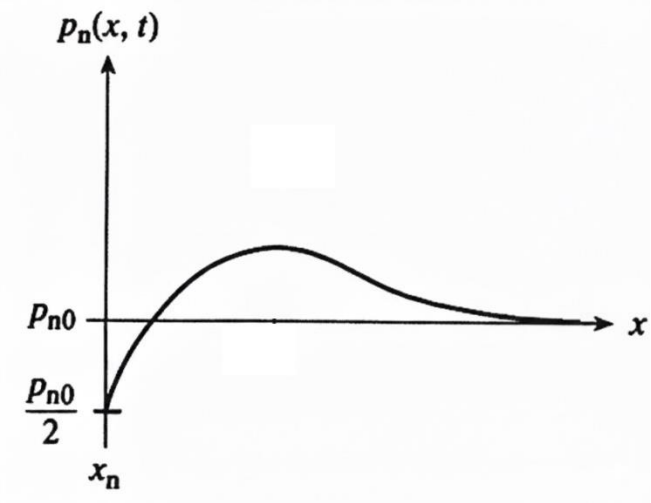
k) Explain why MS diodes do not exhibit a diffusion capacitance or diffusion conductance.

l) Explain why MS diodes switch very rapidly from the forward-bias on state to the reverse-bias off state.

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Problem 2 (6 points total)

The hole concentration on the n side of a pn step junction diode at a given instant of time is as pictured below.



a) Is the junction forward or reversed biased? Explain how you arrived at your answer.

b) If $p_{no} = 10^4/cm^3$ and $\tau = 300K$, determine v_A.

c) Is there a forward or reverse current flowing through the diode? Explain how you arrived at your answer.

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Problem 3 (10 points total)

An ideal p^+-n step junction diode initially forward biased at I_{F1} is pulsed to a constant current of $I_{F2} > I_{F1}$ at t=0.

a) Sketch the expected variation of $p_n(x,t)$ versus x at progressively increasing times after t=0.

b) Assuming a quasistatic build-up of the stored charge, derive an expression for $v_A(t)$.

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Problem 4 (10 points total)

At t = 0 the current through a p^+-n diode is switched from I_F = 1mA to i= -I_R = -1 mA. After 1μs a current pulse is applied to switch the diode back to I_F = 1mA. Assume the diode to be ideal with $\tau_p = 1\ \mu s$.

a) Sketch the i(t) through the diode as a function of time.

b) Establish an expression for v_A(t) at times $\tau > 1\ \mu s$.

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Problem 5 (8 points total)

An ideal rectifying contact is formed by depositing gold ($\Phi_M = 5.10eV$) on an $N_D = 10^{15}/cm^3$ doped silicon substrate maintained at room temperature. Calculate

a) Φ_B

b) V_{bi}

c) W under equilibrium conditions

d) $|\mathcal{E}|_{max}$ in the semiconductor under equilibrium conditions.

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Problem 6 (8 points total)

The minority-carrier injection ratio is often cited as a quantity of interest in characterizing MS diodes. By definition, it is the number of minority carriers injected into the semiconductor per majority carrier injected from the semiconductor into the metal when the device is forward biased. Mathematically, the ratio is just I_{IDFF}/I_{TE}. I_{DIFF} and I_{TE} are respectively the diffusion and thermionic emission currents flowing in the MS diode. Estimate the minority carrier injection ratio in a silicon MS diode where $A^* = 140 A/cm^2 - K^2$, $\Phi_B = 0.72 eV$, $N_D = 10^{16}/cm^3$, $\tau_p = 10^{-6} s$, and $T = 300 K$. I_{DIFF} in the given diode may be equated to the I_{DIFF} flowing in a p^+-n step junction diode with equivalent device parameters.