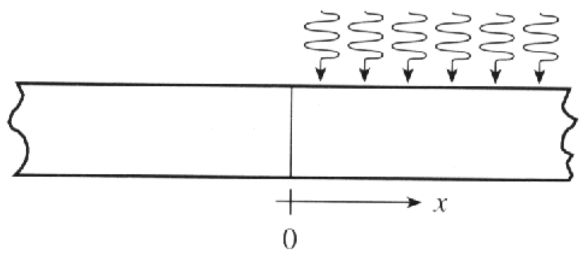
UNIVERSITY OF CALIFORNIA
College of Engineering
Department of Electrical Engineering and Computer Sciences

EE 130 / EE 230A Prof. Liu
Fall 2013

Homework Assignment #4
Due at the beginning of class on Thursday 9/26/13

Problem 1: Continuity Equation and Quasi-Fermi Levels
Consider a bar of p-type silicon that is uniformly doped ($N_A = 10^{17}/\text{cm}^3$) with minority carrier lifetime $\tau_n = 10^{-7}$ sec, maintained at T = 300K. As shown in the figure below, the bar is partially illuminated with light, which generates 10^{16} electron-hole pairs/cm^3-sec uniformly throughout the $x > 0$ region of the bar. The electron-hole generation rate (G_L) is zero for $x < 0$. Steady state conditions prevail.



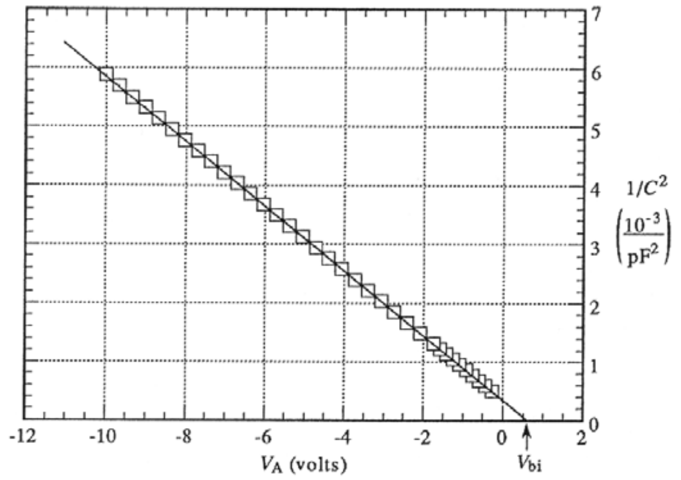
(a) What are the electron and hole concentrations at $x = -\infty$? Draw the corresponding energy band diagram.
(b) What are the electron and hole concentrations at $x = +\infty$? Draw the corresponding energy band diagram. Do low-level injection conditions prevail?
(c) Derive separate expressions for the excess electron concentration $\Delta n(x)$ for $x > 0$ and $x < 0$.
Note that $\Delta n(x)$ and its derivative $d\Delta n(x)/dx$ must be continuous at $x = 0$.

Problem 2: MS contact – p-type Si
Consider an ideal contact between Al (Φ_M = 4.1eV) and p-type silicon with $N_A = 10^{17}$ cm^{-3}, maintained at T = 300K.
(a) Draw the equilibrium (V_A = 0 V) energy-band diagram, indicating numerical values for the Schottky barrier height Φ_{Bp}, depletion-layer width W, $E_F - E_v$ in the neutral region, and built-in potential V_{bi}.
(b) Draw the energy-band diagram for an applied bias V_A = -0.5 V.
(c) Qualitatively sketch the equilibrium (V_A = 0 V) charge density distribution $\rho(x)$, the electric field distribution $\mathcal{E}(x)$, and potential distribution $V(x)$ for this contact. Show how these distributions change with an applied bias V_A = -0.5 V.

Problem 3: MS contact – n-type Si
Consider a contact between NiSi and n-type silicon with $N_D = 10^{17}$ cm^{-3}, maintained at T = 300K.
(a) Draw the equilibrium (V_A = 0 V) energy-band diagram, indicating numerical values for the Schottky barrier height Φ_{Bn}, depletion-layer width W, $E_c - E_F$ in the neutral region, and built-in potential V_{bi}. (**Note:** Use the Schottky barrier value given in Lecture #7.)
(b) Draw the energy-band diagram for an applied bias V_A = -0.5 V.
(c) Qualitatively sketch the equilibrium (V_A = 0 V) charge density distribution $\rho(x)$, the electric field distribution $\mathcal{E}(x)$, and potential distribution $V(x)$ for this contact. Show how these distributions change with an applied bias V_A = -0.5 V.

<u>Problem 4</u>: Schottky Diode – Small-Signal Capacitance

Consider the following reverse-bias capacitance data for a Schottky diode (n-type silicon):



Illustrate with simple <u>quantitative</u> sketches how the measured curve would change if

a) the Schottky barrier Φ_B decreases to 0.4 eV while the Si doping concentration remains the same (N_D = 10^{16} cm^{-3}).

b) the semiconductor doping concentration N_D decreases to10^{15} cm^{-3} while the Schottky barrier remains the same (Φ_B = 0.8 eV).