EE566 Solid State Devices

Spring 2007
Dept of Electrical Engineering
University of Notre Dame
Instructor: Debdeep Jena (djena@nd.edu, x8835)

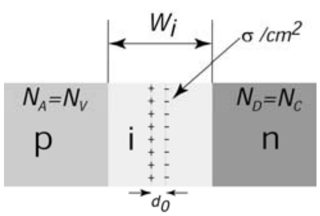
Assignment 4
Posted: 02/11/2007
Due: 02/19/2007

Reading
Chapter 4 of Muller/Kamins/Chan **(MKC).**
Read the sections on Heterojunctions (4.2), Capacitance (4.3), and Breakdown (4.4) critically.

Problem 1[1] (Exact solution for a homojunction)
Consider a n^- - n^+ homojunction made of GaAs. Let the doping densities on the two sides of the junction be N_{D1}=10^{15}/cm^3 and N_{D2}=10^{17}/cm^3, and the two sides to be long (>2000nm).

a) Find the potential barrier to electron flow across the junction. Is the junction ohmic or rectifying?
b) Sketch (qualitatively) the charge-field-band diagram for the junction. Denote the variation of the bands across the junction (parabolic, exponential, flat), and relate them to the Debye lengths on the two sides.
c) Calculate the maximum electric field at the junction *exactly*. (Do not neglect Gummel corrections!).
d) Simulate this band diagram using 1D Poisson. Compare the simulated maximum electric field with your calculated *exact* value in part c), and the smearing length of the free charge densities on the two sides with your calculation of Debye lengths in part b). Are they consistent?

Problem 2 (Effect of a dipole embedded in a p-i-n junction)



Consider the Silicon p-i-n junction shown in the figure (doping densities N_A=N_V, N_D=N_C). A sheet-dipole (magnitude σ, distance d_0=5nm) is embedded in the form of very thin donor and acceptor layers in the center of the intrinsic region (thickness W_i=100nm) of the diode. Neglect Gummel correction for this problem; solve analytically first, then substitute numerical values. Justify any approximations you make clearly - you will need to make some approximations!

a) Sketch the charge-field-band diagram in the *absence* of the embedded dipole. Find the field in the diode.
b) Find the dipole charge magnitude required such that there is *no* electric field inside the dipole layer. Call this dipole sheet density σ_c. Draw the charge-field-band diagram under this condition.
c) Fix the dipole charge density at $\sigma=\sigma_c/2$. How much bias voltage should I now apply across the diode to again achieve zero electric field inside the dipole? Is it forward or reverse bias? Draw the C-F-B diagram.
d) Find the capacitance of the diode as a function of the applied bias - both forward and reverse.

Problem 3 (Real problem related to fabrication).
Problem 4.10, **MKC**.

[1] Remember to use proper units and label every figure/plot. Use natural scales such as nm for length, KV/cm for electric fields, and eV for energies. Turn in your answers worked out neatly. Please attach this question sheet to your solution when you turn it in.