
EE566 Solid State Devices

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Dept of Electrical Engineering

University of Notre Dame

Instructor: Debdeep Jena (djena@nd.edu, x8835)

Assignment 4

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Due: 02/21/2005

Reading

Chapter 4 of Muller/Kamins/Chan (**MKC**).

Read the sections on Heterojunctions (4.2), Capacitance (4.3), and Breakdown (4.4) critically.

Problem 1¹ (Exact solution for a homojunction)

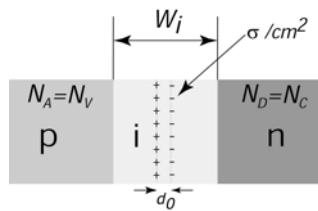
Consider a $n^- - n^+$ homojunction made of GaAs. Let the doping densities on the two sides of the junction be $N_{D1}=10^{15}/\text{cm}^3$ and $N_{D2}=10^{17}/\text{cm}^3$, and the two sides to be long ($>2000\text{nm}$).

- Find the potential barrier to electron flow across the junction. Is the junction ohmic or rectifying?
- 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.
- Calculate the maximum electric field at the junction *exactly*. (Do not neglect Gummel corrections!).
- 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 (Practice problem)

Problem 4.5, **MKC**.

Problem 3 (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 $d_0=5\text{nm}$) is embedded in the form of very thin donor and acceptor layers in the center of the intrinsic region (thickness $W_i=100\text{nm}$) 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!

- Sketch the charge-field-band diagram in the *absence* of the embedded dipole. Find the field in the diode.
- 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.
- 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.
- Find the capacitance of the diode as a function of the applied bias - both forward and reverse.

Problem 4 (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.