EE566 Solid State Devices

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

Assignment 2
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Reading
Chapter 3 of Muller/Kamins/Chan **(MKC)**
For material constants & parameters go to - http://www.ioffe.rssi.ru/SVA/NSM/

Problem 1[1]
We learnt that the electron density in a bulk (3D) semiconductor in the most general case is given by $n_{3d} = N_C^{3d} F_{1/2}(\eta)$, where N_C^{3d} is the conduction band effective density of states, $F_{1/2}(...)$ is the Fermi-Dirac integral of order $1/2$, and $\eta = (E_F - E_C)/kT$. A similar result exists for a two-dimensional electron gas (2DEG)[2]. Show that if electrons are confined to move in *two dimensions*, the sheet density is given by

$$n_{2d} = N_C^{2d} \ln(1 + e^{\eta}),$$

where $N_C^{2d} = m^* kT / \pi\hbar^2$. Plot $E_F - E_C$ as a function of the 2DEG density (typical values are $10^{11}/cm^2 < n_{2d} < 10^{12}/cm^2$) for $T = 0, 77, \; \& \; 300\; K$ for a 2DEG located in a GaAs quantum well. Show that at low temperatures, n_{2d} becomes *independent* of temperature. Is the 2DEG carrier distribution degenerate or non-degenerate at low temperatures?

Problem 2
You are given a piece of semiconductor that has an *arbitrary* planar shallow doping profile $N_D(x)$ along the *x*-axis.

a) Find the *internal* electric field profile $E(x)$ that develops inside the semiconductor at a temperature *T*. Explain all your steps at arriving at this result.
b) What happens to the electric field as temperature changes?
c) Verify from your result that $E(x) = 0$ for a constant doping profile.
d) Plot the field for a silicon sample at room temperature and mobility $\mu = 400 cm^2/V.s$ where the doping profile from the surface ($x = 0$) is given by $N_D(x) = N_0 e^{-(x/\lambda)^2}$ ($N_0 = 10^{18}/cm^3$, λ=100nm).

Problem 3
MKC Problem 3.7.

Problem 4
MKC Problem 3.17.

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[1] Remember to use proper units and label every figure/plot. Turn in your answers worked out neatly. Please attach this question sheet to your solution when you turn it in.

[2] This statistics will be useful when we study field-effect transistors (specifically the MODFET) later in this class.