EE566 Solid State Devices

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Dept of Electrical Engineering
University of Notre Dame
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Assignment 2

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Reading: Chapter 3 of the Textbook (Muller/Kamins/Chan: MKC). For material constants & parameters, Table 1.3 page 52 of MKC should work. For materials not listed in this table, go to - http://www.ioffe.rssi.ru/SVA/NSM/.

Problem 1[*] (2-Dimensional Electron Gases, 2DEGs)

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, $F_{1/2}(\ldots)$ 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)[†]. 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

We derived the expression for the electron current density in a semiconductor in terms of the quasi-Fermi level as $J_n = n\mu_n \nabla E_{Fn}$, where E_{Fn} is the electron quasi-Fermi level, and all other symbols have their usual meanings. Show that in an *inhomogeneously* n-type doped semiconductor with doping density $N_D(x)$, this relation can be used to find the *internal* electric field $F(x)$ inside the semiconductor. For the specific case when the doping profile changes as $N_D(x) = N_0[1 + \cos^2(2\pi x / L)]$, find the variation of $F(x)$. With the aid of a schematic sketch of the charge and the field, explain how your result intuitively makes sense.

Problem 3

Solve Problem 3.3 from MKC (practice problem for Schottky Junctions).

Problem 4

Solve Problem 3.7 from MKC (tunneling in Schottky Junctions).

Problem 5

Solve Problem 3.8 from MKC (practice with drift-diffusion currents in Schottky Junctions).

In general, make sure you are comfortable with the chapter-end problems of MKC Chapter 3.

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[*] 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.

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