
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 Muller/Kamins/Chan (**MKC**)

For material constants & parameters go to - <http://www.ioffe.rssi.ru/SVA/NSM/>

Problem 1¹

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, $F_{1/2}(\dots)$ 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

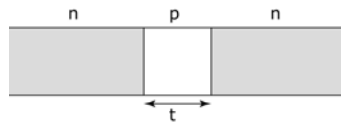
$$n_{2d} = N_C^{2d} \ln(1 + e^\eta),$$

where $N_C^{2d} = m^* kT / \pi \hbar^2$. Plot $E_F - E_C$ as a function of the 2DEG density (typical values are $10^{11} / \text{cm}^2 < n_{2d} < 10^{12} / \text{cm}^2$) for $T = 0, 77, \& 300 \text{ K}$ 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.

- 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.
- What happens to the electric field as temperature changes?
- Verify from your result that $E(x) = 0$ for a constant doping profile.
- Plot the field for a silicon sample at room temperature and mobility $\mu = 400 \text{ cm}^2 / \text{V}\cdot\text{s}$ where the doping profile from the surface ($x = 0$) is given by $N_D(x) = N_0 e^{-(x/\lambda)^2}$ ($N_0 = 10^{18} / \text{cm}^3$, $\lambda = 100 \text{ nm}$).



Problem 3

As a device engineer in a reputed company, you are asked to design the silicon capacitor shown in the figure on the left. The n-regions are doped with donor density N_D . The requirement is that the capacitance (per unit area) at no external bias should be $C_0 = \epsilon_s / d$. *Design* the doping N_A and the thickness t to achieve this. Use $N_D = 10^{17} / \text{cm}^3$ and $d = 300 \text{ nm}$. ϵ_s is the dielectric constant of silicon. Remember, a real life design problem can have many possible solutions! (In fact, sometimes, the allowed ranges have to be changed!).

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.