Exam #1 — EE 531

Spring 2009

This is a take-home exam. You are welcome to use any notes and/or books. However, you are not permitted to have the assistance of any other person on the exam. If you have any questions regarding interpretation of the questions, you should submit your question to class GoPost web site.

Your exam papers are due back in my office (EE 218) by 10:00am on Monday, May 11. Please do not spend more than 10 hours actively working on the exam. In completing these questions, you are encouraged to make reasonable assumptions, but be sure to state them clearly and check them when possible. Assume $T = 300$K unless otherwise specified.

1. A 100nm thick silicon film is uniformly doped with $N_a = 10^{18}\text{cm}^{-3}$. At the top surface ($x = 0$), electrons are injected giving current of -1 mA/cm^2. There is no hole current at top surface and no light generation. The back surface has a recombination velocity of $s = 10^4$cm/s. Assume $\tau_n = 50$ns and $\tau_p = 100$ns and midgap traps.

   (a) Determine the excess electron concentration as a function of position.

   (b) Calculate the drift current density for holes near $x = 100$nm.

2. To help reduce thickness of the inversion layer, a pMOSFET uses a 2nm thick SiGe layer on top of Si. Assume that this material has a valence band maxima 0.3eV higher than that of Si and that this offset is sufficient to strongly confine holes in inversion layer to the SiGe. Assume that for quantum calculations this region can be approximated by infinite potential well with constant energy equal to the average over the width of this layer. For electrostatics calculations, assume that the inversion charge for each subband can be approximated by a sheet of charge at the mean distance from oxide interface. $N_a = 5 \times 10^{18}\text{cm}^{-3}$, $x_{ox} = 1.0$nm, $\phi_m = \chi_{Si} + E_g^{Si}$.

   (a) What would be the relative energies (above conduction band without confinement) of the three lowest energy sub-bands? Assume that SiGe has same valence band structure as Si and consider both heavy and light hole bands.

   (b) Considering just these three sub-bands, what would be the effective mass tensor for holes in the inversion layer?

   (c) If the threshold voltage is defined as the voltage for which the inversion capacitance and the depletion capacitance are equal, find an expression for V_T as a function of device parameters and calculate value.

   (d) Calculate value for the subthreshold slope.

3. Consider a long-channel nMOSFET transistor with uniform channel doping N_a. The gate is split laterally in half, with the half near the source having ϕ_m^S, while the half near the drain has ϕ_m^D.

   (a) Derive an expression for the linear region drain current. You can use linearized model for depletion charge versus channel voltage.

   (b) Determine expression for the saturation voltage.