Exam #2 — 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 3pm on Thursday, June 11. Please do not spend more than 10 hours actively working on the exam. In completing these questions, feel free to make reasonable assumptions, but be sure to state them clearly and check them when possible. Assume $T = 300$K unless otherwise specified.

1. The doping in a PMOS transistor with a p^+ poly gate ($E_f = E_v$) and $t_{ox} = 1.2$nm varies linearly with depth from a very small surface concentration to $5 \times 10^{19}\text{cm}^{-3}$ at depth a and then is constant.

   (a) What should be the depth a such that it has a long-channel threshold voltage of $-0.5\,\text{V}$ and a subthreshold slope of $75\,\text{mV/decade}$.

   (b) What is the minimum channel length such that $dV_T/dL < 0.002\text{V/nm}$. Use the expression for short channel effects on threshold voltage given in Taur and Ning (assuming $x_j \cong W_d^{max}$). What is the associated threshold voltage?

   (c) What is the minimum channel length such that $I_{\text{off}}/W < 10^{-4} A/\mu\text{m}$ with $V_{GS} = 0\text{V}$ and $V_{DS} = -1.5\text{V}$.

   (d) Would the minimum channel lengths calculated in (b) and (c) be larger or smaller for uniformly doped channel with same long channel threshold voltage? Explain.

2. Consider a symmetric dual gate Si nMOSFET with undoped 4 nm silicon body thickness, a midgap gate work function, and 0.8nm equivalent oxide thickness.

   (a) Calculate the inversion charge as function of gate voltage in weak inversion (neglect inversion charge in electrostatics). Include effects of quantum confinement.

   (b) Calculate the inversion charge as function of gate voltage in strong inversion. Assume that the electron potential in the silicon can be considered uniform with value equal to average over body thickness.

3. In a Si nMOSFET, uniaxial stress and quantum confinement stress raise the the k_z and k_y minima relative to k_x minima by 30 and 60 meV, respectively.

   (a) Calculate the resulting effective mass in y-direction.

   (b) Estimate the change in τ_m assuming elastic isotropic (independent of initial and final k) scattering both within and between minima. Assume nondegenerate statistics.

   (c) Combine your results to calculate resulting change in the channel electron mobility.