EE566 Solid State Devices

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Final Exam (2 Hours, 4 Problems, 25 Points)
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Problem 1 (6 Points): Short Questions (give brief answers)

a) As a rectifier, what are the advantages/disadvantages of a p-n junction vs a Schottky diode?
b) MOS capacitors can be used for DRAM memory cells. What is the effect of the bandgap on the working of the memory? How will Germanium perform as compared to Silicon?
c) What is "quantum capacitance", and how does it affect HEMT/MOSFET performance?

Problem 2 (4 Points): p-n Junctions and HBTs

The operation of bipolar transistors is dependent on the high degree of asymmetry of the electron and hole components of the current flowing across a forward biased (Emitter-Base) n-p junction diode. Consider the hypothetical situation the diffusion constants of electrons and holes are equal, and that the diode has a short base (doping N_{AB}, width W_B) and a short emitter (doping N_{DE}, width W_E).

a) Assuming that the base transport factor is unity, show that the Emitter-Base bandgap difference in a heterojunction diode necessary to obtain a gain of β is given by the relation $\Delta E_G \geq kT \ln[\beta \frac{W_B N_{AB}}{W_E N_{DE}})]$.
b) Explain why in determining the gain in BJTs, the emitter injection efficiency is more important whereas in HBTs, the base transport factor is more important.

Problem 3 (5 Points): HEMTs

Show that the intrinsic channel transit time for electrons in a HEMT is

a) $\tau_{LC} = \frac{4L^2}{3\mu(V_G - V_T)}$ for a long-channel HEMT. All symbols have their usual meanings.

b) $\frac{4L}{3v_{sat}} \leq \tau \leq \tau_{LC}$ for a short-channel HEMT.

c) What do you think would be the "channel transit-time" in a ballistic HEMT?

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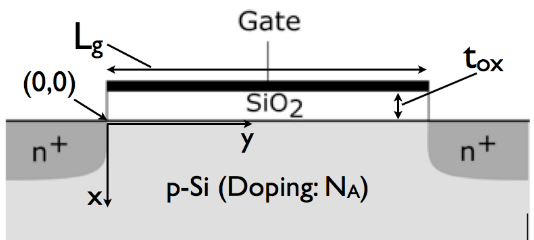
Problem 4 (10 Points): MOSFETs



Consider the MOSFET shown above (width = W). Assume that the n+ regions are degenerately doped (N_D=N_c), and that there are no charges in the oxide layer. Remember to draw relevant sketches. Give all answers *algebraically*. Use the following material properties for your answers.

Si: Intrinsic carrier concentration: n_i, Electron Affinity: $q\chi_{Si}$, Bandgap: E_{gSi}

SiO_2: Electron Affinity: $q\chi_{ox}$, Bandgap: E_{gox}

a) Find the work-function of the gate metal for a zero flat-band voltage.
b) Calculate the threshold voltage V_T for that gate metal.
c) Show that in the saturation region, the small-signal capacitance between the gate and the source is given by $C_{GS} = \frac{2}{3} C_{ox} W L_g$.
d) Find an expression for the depletion depth at $V_G = V_T$, and call it the junction depth x_j.
e) In class, we derived a characteristic length $l = \sqrt{\frac{\varepsilon_S}{\varepsilon_{ox}} t_{ox} x_j}$ that controls the electrostatics of short-channel FETs. Assuming that the electric field for reaching velocity saturation F_{sat} is much smaller than the breakdown electric field of the channel F_{BD}, derive an expression for the drain voltage at which the MOSFET channel will suffer breakdown.