EE566 Solid State Devices

Spring 2004
Dept of Electrical Engineering
University of Notre Dame
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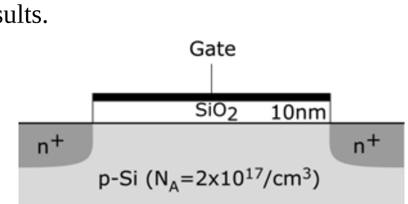
Final Exam
05/04/2004

Problems (Total 30 Points)

1) **8** Points (Short questions – Make generous use of figures)
   a) Schottky Barrier clamping (**3** Points):
   Explain how Schottky Barrier clamping of the base-collector junction of bipolar transistors improves their speed.

   b) C-V of MOS structures(**5** Points):
   Explain the difference in the high-frequency capacitance-voltage characteristics of a MOS capacitor and a MOSFET. For a MOS capacitor, suggest *at least two* ways to *reduce* the time required to form the inversion layer. What effect do you expect these changes to have on a DRAM performance?

2) **14** Points – MOSFET device physics
   a) (7 Points) Find the flatband voltage V_{FB}, and then the threshold voltage V_{TH} of the MOSFET structure shown in the figure at 300K. Assume that there are no charges in the oxide layer. Use all material parameters you need from book/notes. Assume the gate metal is Aluminum, with a work function $q\Phi_M = 4.1$eV. Sketch the charge-field-band diagrams at $V_{Gate}=V_{TH}$ to solve the problem.
   b) (7 Points) Due to sloppy oxidation, I incorporated a *positive* sheet charge distribution $\sigma_0=10^{10}/cm^2$ in the oxide layer at a depth of t_0 from the gate-SiO_2 interface. What is the *new* flatband voltage at 300K as a function of t_0? Sketch the charge-field-band diagrams at $V_{Gate}=0$ and $V_{Gate}=V_{FB}$ for solving this problem. What is the resultant shift in the threshold voltage? Give numerical values of V_{FB}, and V_{TH} for t_0=4nm and t_0=0nm. Explain your results.



3) **8** Points – (Real Life Problem)
   When the epitaxial growth of n-GaAs (doping density N_D/cm^3) by MBE is interrupted and the crystal surface exposed to the air before regrowth, a sheet of *acceptors* of density σ_A ($/cm^2$) incorporates at the regrowth interface. Assume T=300K, and dielectric constant of GaAs=13.
   a) By drawing a charge-field-band diagram, show that this results in a "hump" in the conduction band, which acts as a barrier to the flow of electrons in the growth direction in the n-type GaAs. (Do NOT neglect Gummel correction!).
   b) Find a relation between σ_A and N_D such that the height of this hump is less than the thermal energy ($E=k_BT$) of the conduction electrons, which will ensure the easy flow of electrons in the growth direction. Do NOT neglect Gummel correction (Why?). For $N_D=10^{16}/cm^3$, find the maximum acceptor sheet density I can allow.

NOTE: Sketches, sketches with proper LABELS!! (wherever the situation demands). State and justify your approximations clearly, and use your intuition to cut down on the math.