EE566 Solid State Devices

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Dept of Electrical Engineering
University of Notre Dame
Instructor: Debdeep Jena (djena@nd.edu, x8835)

Assignment 9
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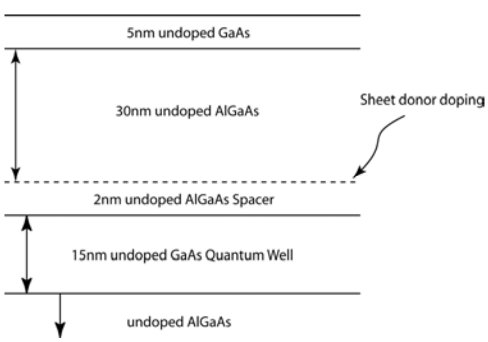
Due: 04/28/2006

Reading
Chapters 8 and 10 of Textbook.

Problem 1: (MESFETs – Practice problem)
Problem 8.13, textbook (page 427). Sketch the band diagrams a) along the channel from source to drain, and b) perpendicular to the channel at the source- and drain-ends of the gate when i) $V_G<V_T$, $V_{DS}>V_{DS}(sat)$, and ii) when $V_G>V_T$, $V_{DS}>V_{DS}(sat)$. You should have *four* band diagrams (a-i, b-i, a-ii, b-ii).

Problem 2: (MESFETs – 2-dimensional problem)
Derive and plot the two-dimensional potential profile in the depletion region under the gate of a MESFET with zero gate voltage, and drain-source bias high enough that the current I_{ds} is saturated. Plot the electric field, potential, and band diagrams along the channel from source to drain, and perpendicular to the channel at the source- and drain-ends of the gate. Assume the MESFET channel to be long, such that gradual channel approximation holds near the source end. Explain everything you assume in the derivation. (Read the Grebene and Ghandhi paper!).

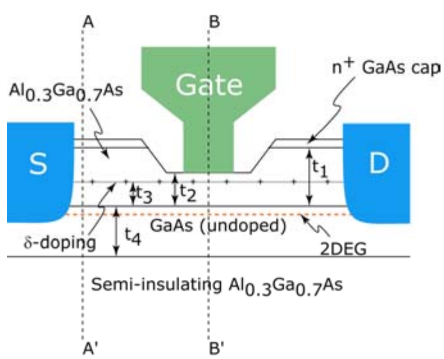
Problem 3: (HEMTs – Design your own structure)



Consider the AlGaAs/GaAs (ΔE_C=0.25eV) HEMT layer structure shown. Assume that surface states pin the GaAs surface Fermi level 1eV below the conduction band. I require the sheet –density of the channel to be $n_s=10^{12}/cm^2$.

a) *Calculate* the sheet doping in the donor layer required to achieve that. Clearly draw the charge, field, and band diagrams. Verify with 1D Poisson. Note that the quantum well is triangular in shape.
b) Calculate the g_m vs V_{gs} curve for the HEMT, assuming v_{sat}(GaAs)=10^7cm/s, v_{sat}(AlGaAs)=2×10^6cm/s, gate length to be short, and V_{ds} is high, such that the saturated velocity model holds. Make any simplifying assumptions you think reasonable. Calculate the threshold voltage V_{th} required to deplete the channel.
c) Now, I want the quantum well to be flat instead of triangular. Design that for me.
d) Why would anyone need a flat quantum well? Are there any disadvantages?

Problem 4: (AlGaAs/GaAs HEMT charge control and transconductance)



Consider the AlGaAs/GaAs HEMT structure shown. The structure is grown by MBE, and the thickness and doping of the layers are - cap layer: $N_D=7*10^{17}/cm^3$, t_{cap}=5nm, $Al_{0.3}Ga_{0.7}As$ layer thickness t_1=25nm, after gate-recess etch, AlGaAs thickness t_2=17nm, delta-doped layer thickness=1nm & effective 3D-doping=$3.5*10^{19}/cm^3$, t_3=5nm, and GaAs quantum well thickness t_4=10nm. Assume the surface barrier is pinned at $q\Phi_s$=0.6eV below the conduction band edge for both GaAs and AlGaAs.

a) Calculate the 2DEG sheet density in the GaAs QW below the gate. Draw the charge-field-band diagram along line B-B' for finding the sheet density. Verify your calculated value with 1D Poisson simulation of the charge-field-band diagram. Is there any quantum-confinement[1]? How many quantum-confined states are formed in the GaAs QW? What are the eigenvalues?

b) Calculate the 2DEG sheet density in the GaAs QW below the source-and drain-access regions. Draw the charge-field-band diagram along line A-A' for finding the sheet density. Verify your calculated value with 1D Poisson simulation of the charge-field-band diagram. Comment on quantum confinement and eigenvalues.

c) What is the gate-capacitance C_g? Assuming the HEMT to be a short-channel FET, calculate the transconductance g_m using GaAs material parameters. Calculate the threshold voltage V_{th} for the HEMT.

d) Explain, using 2DEG-sheet density results of parts a) and b) and the transconductance of part c), what is gained by the gate-recess process. What would the transconductance be if the gate was not recessed?

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[1] Run the "schrodingerstart", and "schrodingerstop" functions, and use the "*.status" file in 1-D Poisson.