EE566 Solid State Devices

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Dept of Electrical Engineering
University of Notre Dame
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Assignment 10
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Reading: Chapters 9 &10 of the textbook (MS) and Natori's paper.

Problem 1 (MOSFETs – Subthreshold currents and future FETs)
Subthreshold leakage current flowing between the source and the drain is a major source of static power dissipation in MOSFET digital logic circuits.
a) By using the exact expression for charge in the MOSFET, show that the subthreshold leakage current varies with the gate voltage as

$$I_{DS} \approx I_0 e^{\frac{qV_{GS}}{\eta kT}}, \quad \text{where}$$

$$\eta = 1 + 3t_{ox}/x_{depl}, \quad I_0 = I_{D0}(1 - e^{-qV_{DS}/kT}), \text{ and } I_{D0} = \mu C_{ox}\frac{W}{L}\left(\frac{\varepsilon_S}{\varepsilon_{ox}}\cdot\frac{t_{ox}}{t_{depl}}\right)\left(\frac{kT}{q}\right)^2$$

b) Plot the inverse subthreshold slope $S = \ln 10 \cdot (\eta kT/q)$ for various ITRS technology nodes.

c) Explain why a low S is ideal for digital applications. What is the minimum S at room temperature? Explain why as gate lengths get scaled down further, S will increase unless proper care is taken in the design of the MOSFETs.
d) Recently, there have been some proposals of new device architectures to reduce S from the minimum values obtainable in traditional MOSFET design. Do some research and comment on these approaches. (Your best resource might be Dr. Seabaugh, but don't tell him I told you so!)

Problem 2 (The Ballistic FET)
In class, we discussed Natori's paper on the ballistic FET. The surprising result is that even under perfectly ballistic transport (no scattering), the MOSFET characteristics do not show a fundamental change from traditional long-channel behavior. However, some aspects of device behavior (such as the reason for current saturation) and current transport mechanism of left and right-going carriers needed re-thinking. Answer the following –

a) Go through the derivation of the ballistic FET I_{DS}-V_{DS} curves. For a ballistic Si-MOSFET described in the paper, plot the I-V curves and the injection velocity vs 2d carrier density (reproduce Fig 5a and Fig 8 from the paper).
b) Repeat part (b) for an AlN/GaN HEMT with t_{AlN}=3 nm. Comment how far are state-of-the-art nitride HEMTs from ballistic performance.

Problem 3 (FETs – Future generations)
Based on your knowledge, write a compact critique on the future generations of electronic switching devices.

"We call him the semi-conductor - he only works part time.

That's it – No more Assignments!!