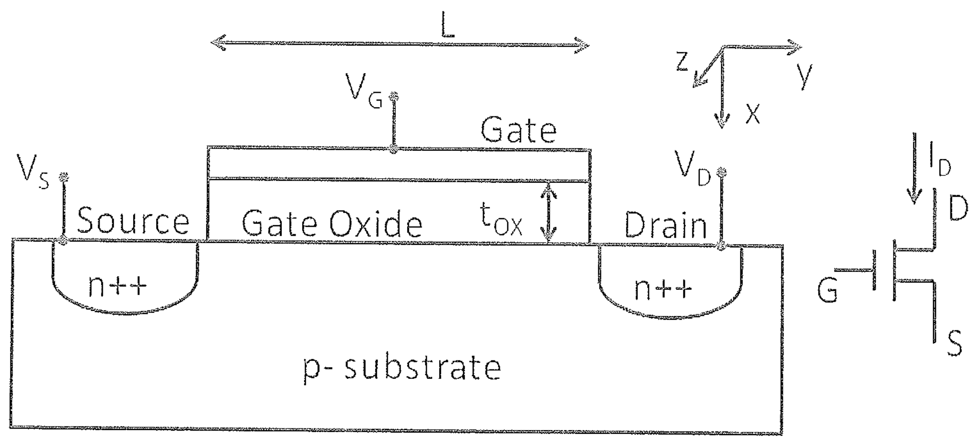
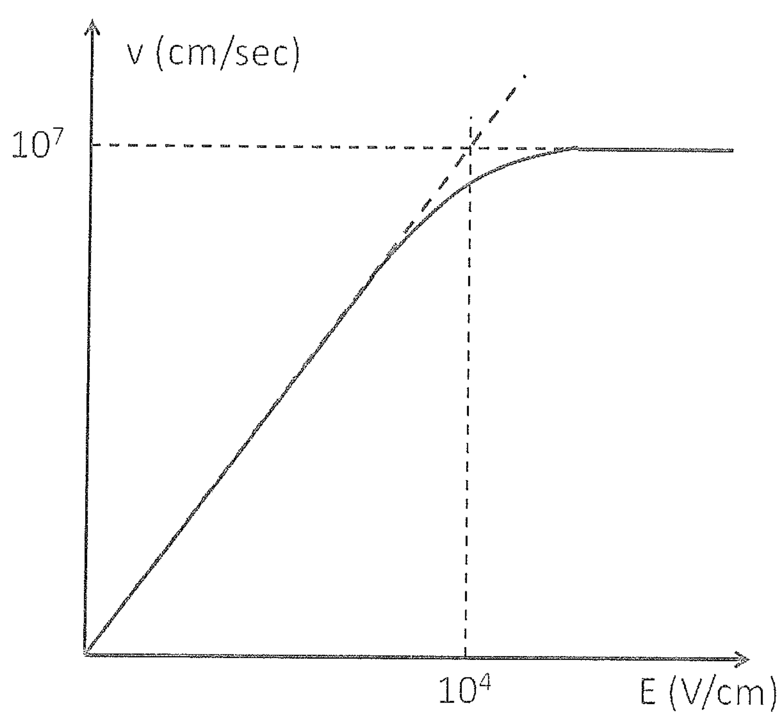
MN-3
August 2012 QE

Consider the MOSFET structure shown below.



The width of the channel is Z. Note that a high K dielectric (K_{Sox} = 20) is used. The p-doped semiconductor (doping density =N_A) has a K_S =10. Within a region of the semiconductor near the surface, the velocity-field relationship for electrons is shown below.



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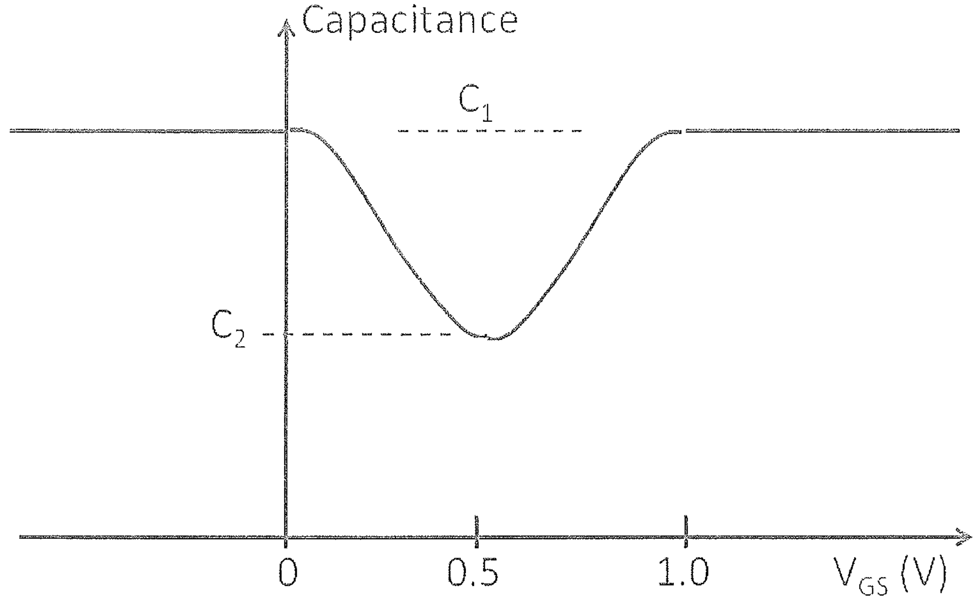
Before operating the device as a FET, we i) ground the source and drain and ii) measure the capacitance between the gate and the S/D regions as a function of V_{GS}. The result is shown below.



a) (10 pts) What is the thickness of the gate oxide (t_{ox})?

b) (21 pts) Assuming that $V_S = V_D = 0$, sketch the volume charge density ($\rho_v(x)$), electric field ($E_x(x)$) and potential ($V(x)$) at the center of the gate region ($y = L/2$) for

i) $V_{GS} = 0$
ii) $V_{GS} = 0.5V$
iii) $V_{GS} = 1.0V$

For full credit, your sketches should accurately represent the signs of ρ_v, E and V, as well as the relative amplitudes of E and V in various regions.

c) (12 pts) What is the numerical value of threshold voltage (V_T) of the MOSFET? Clearly explain your logic.

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d) (21 pts) Assuming that "long channel" conditions apply, derive an expression for I_D as a function of V_{GS} and V_{DS}. For this part, restrict your analysis to small values of V_{DS}.

e) (12 pts) Assume that the conditions associated with part d) still apply, except that we wish to consider a bias point near the transition between triode and saturation regions (and with $V_{GS} > V_T$). Sketch the sheet charge density ($\rho_{SH}(y)$), electric field (($E_y(y)$) and potential ($V(y)$) versus position (y). Note that this problem asks for variations along the length of the channel.

f) (12 pts) What is the minimum gate length for which the "long channel" assumption is valid? Assume that the effective oxide thickness is sufficiently small that the gate controls the electrostatic potential of the channel. You can also assume that the maximum supply voltage is 3V.

g) (12 pts) Suppose that we make the channel length one-half of the value you found in part f). In contrast to the expected values for the long-channel case, how would you expect the values of V_T, I_{Dsat} and V_{DSsat} to change? Note that I_{Dsat} and V_{DSsat} are the current in saturation and the drain-source bias at which saturation is reached, respectively. Your answer for V_{DSsat} should be quantitative, but I_{DSsat} can be qualitative.

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