EEE F477- Course Assignment

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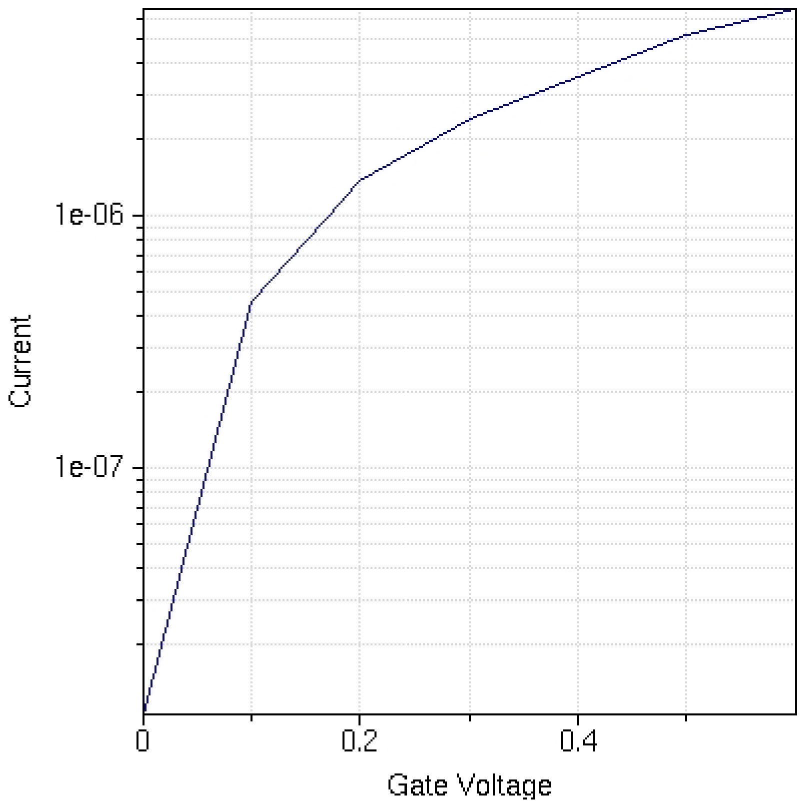
2019A3PS0415H

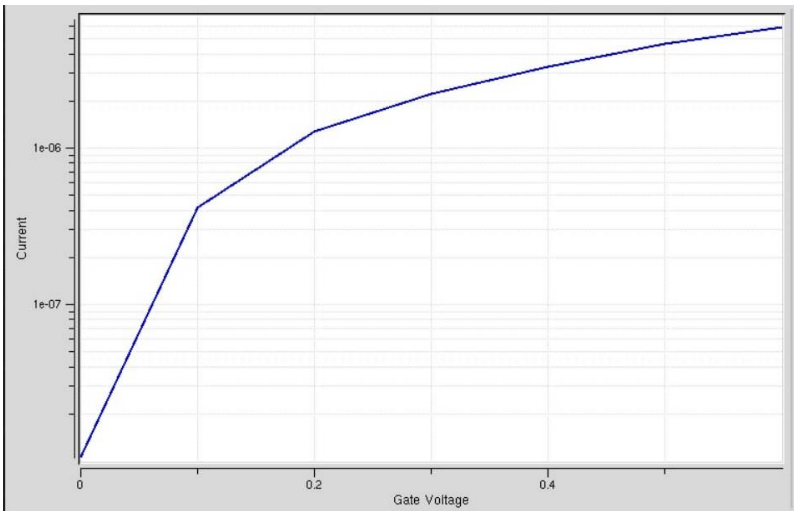
Assignment 1

(i) For effective oxide thickness 1.95 nm:
Ion = 6.65668e-06 A, Ioff = 1.06901e-08 A



For effective oxide thickness 0.975 nm:

Ion = 5.89245e-06 A, Ioff = 1.0525e-08 A



The geometric screening for the 1.95nm device is higher because of a larger oxide thickness, hence the effect of DIBL is more (electric field lines from drain will penetrate further into the channel). Because of a larger DIBL effect, the on-state current and the off-state current are higher. A large DIBL effect implies more lowering of the barrier because of drain voltage which in turn implies a larger current.

(ii)

Calculating DIBL

For device with effective oxide thickness 0.975nm:

Assuming current to be 1.28463e-06 A

Vgs at 0.3V : 0.2V

Vgs at 0.6V : 0.199943V

DIBL = (0.2 - 0.199943)/(0.3) = 0.19 mV/V

For device with effective oxide thickness 1.95nm:

Assuming current to be 1.36048e-06 A

Vgs at 0.3V : 0.2V

Vgs at 0.6V : 0.1999V

DIBL = (0.2 - 0.1999)/(0.3) = 0.33 mV/V

Therefore, DIBL effect in 1.95nm device is more, which is consistent with my analysis. The geometric screening for the 1.95nm device is higher because of a larger oxide thickness, hence the effect of DIBL is more.

(iii)

The worst DIBL effected device is the one with effective oxide thickness 1.95nm as explained earlier. A device engineering technique to reduce the effect of DIBL could be to increase the oxide Capacitance. This involves decreasing the oxide thickness and using a high-k dielectric as oxide. Another possible technique could be to carefully control the diameter of the nanowire to reduce the geometric screening length of the Nanowire Transistor.

Assignment 2

1.

(i) For longitudinal mass = 0.1, transverse mass = 0.1

Ion = 6.39055e-06 A, Ioff = 9.20773e-12 A

For longitudinal mass = 0.1, transverse mass = 1

Ion = 9.65369e-06 A, Ioff = 9.99338e-08 A

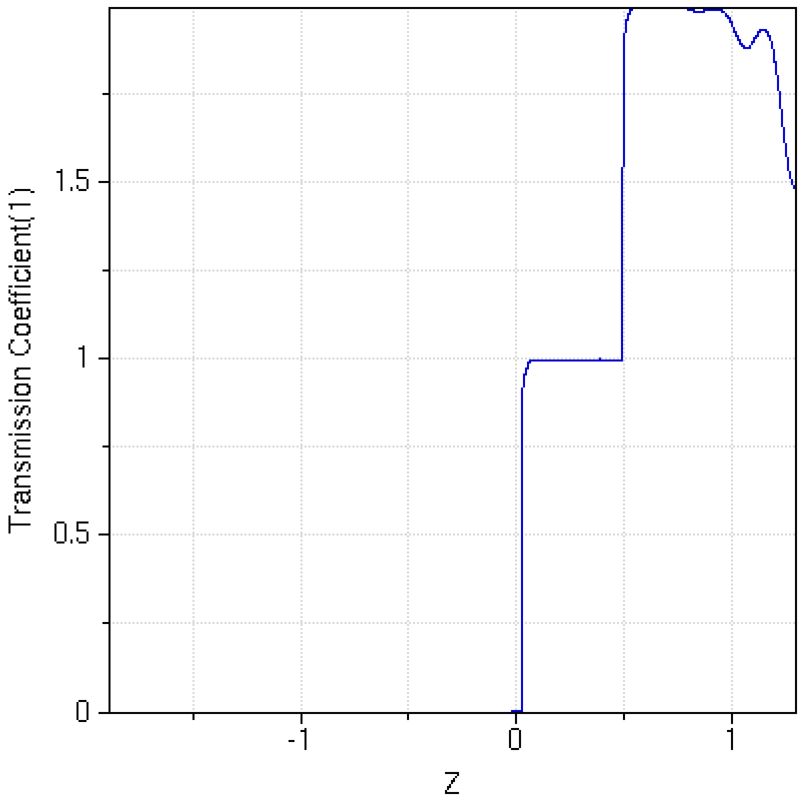
For longitudinal mass = 1, transverse mass = 0.1

Ion = 8.82744e-06 A, Ioff = 1.09915e-09 A

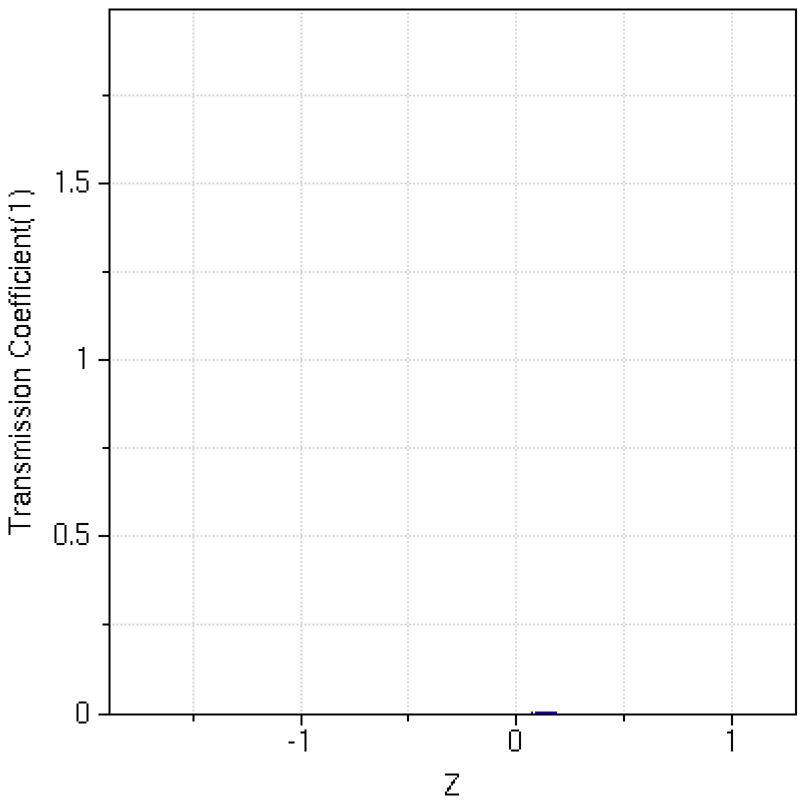
First, it is important to note that, a lower effective mass in a direction implies a higher mobility of carriers in that direction and hence a higher conduction in that direction.

As we can see, on-current is maximum in case (ii) (longitudinal mass = 0.1, transverse mass = 1). This can be reasoned as follows: The channel is in the longitudinal direction, hence a lower effective mass in this direction would result in a higher drain current. A higher effective mass in the transverse direction would result in a lower current in that direction, which means more electrons are available for the longitudinal current (which is the drain current). Therefore, the high currents in case(ii) can be justified by the high transverse mass and low longitudinal mass.

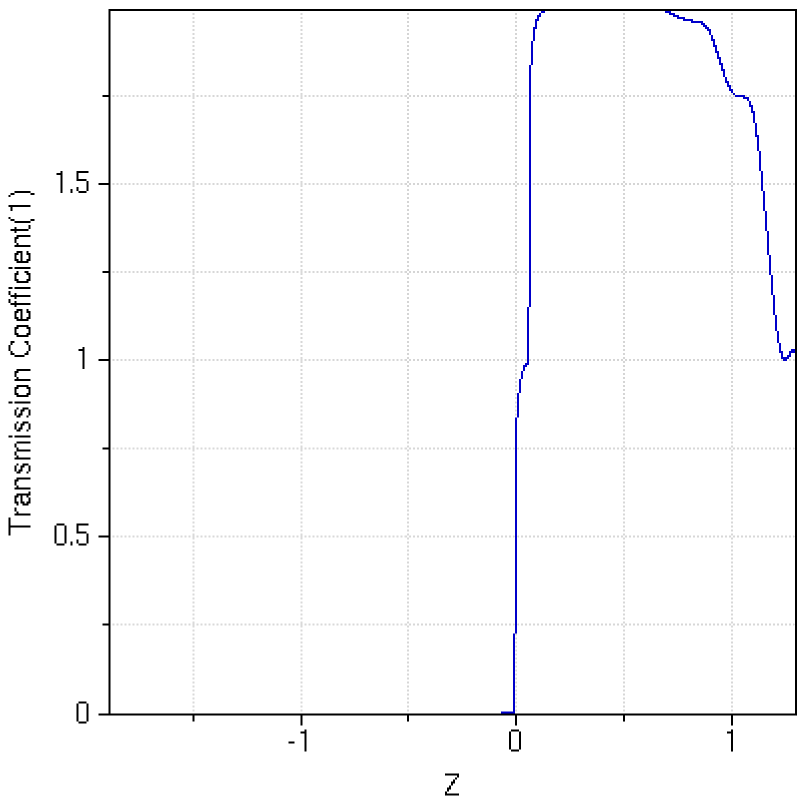
(ii) For longitudinal mass = 0.1, transverse mass = 0.1



For longitudinal mass = 0.1, transverse mass = 1



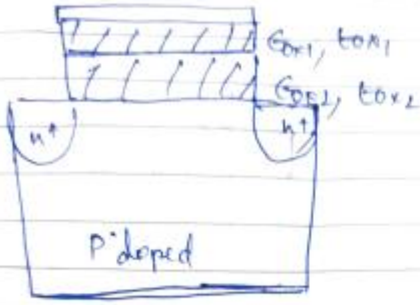
For longitudinal mass = 1, transverse mass = 0.1



Because of the high transverse mass, we can see a low transmission coefficient in the Z direction in case (ii). But there will be a very high transmission coefficient in the longitudinal direction (because of the low longitudinal mass). We can see a high transmission coefficient in the Z direction in case(i) and case(iii) because of a lower effective mass in transverse direction.

2.

Q2. Level 0 MOSFET model



1D Capacitance mode

$C_{ox1} = \frac{\epsilon_{ox1}}{t_{ox1}}$ in inversion

$C_{ox2} = \epsilon_{ox2}/t_{ox2}$ $\quad C_G \approx \frac{C_{ox1} \cdot C_{ox2}}{C_{ox1} + C_{ox2}}$

$C_{dep} = \epsilon_{si}/W_D$

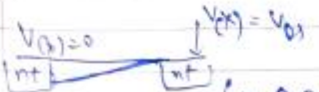
Inversion charge $Q_n(x)$: as $C_{dep} \gg C_{ox1}, C_{ox2}$

$Q_n(x) = 0 \quad V_{GS} \leq V_T$

$Q_n(x) = -C_G\left(V_{GS} - V_T - V(x)\right)$ for $V_{GS} > V_T$

$I_D(x) = -W\, Q_n(x) < V_n(x) >$

$I_D(0) = -W\, Q_n(0) < V_n(0) >$



(no DIBL)

$V(x)$ is negligible near source

it is safe to assume a constant electric field in channel $= \frac{V_{DS}}{L}$

below saturation $\langle v_x(x) \rangle = \mu_n E$

$$= \mu_n \frac{V_{DS}}{L}$$

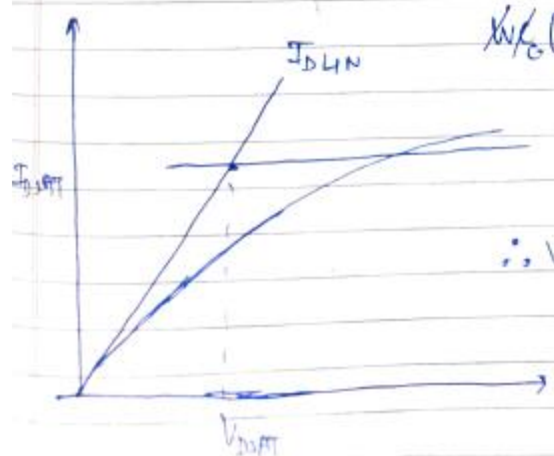
assuming 0 recombination/generation in channel, $I_D(0) = I_D(x)$

$\therefore I_D(x) = I_D(0) = I_{D,LIN} \Rightarrow Q_n(0) = -C_G(V_{gs} - V_T)$

$I_{D,LIN} = W C_G (V_{gs} - V_T) \mu_n \frac{V_{DS}}{L}$ for $V_{DS} < V_{DSAT}$

above saturation: $\langle V_n(x) \rangle = v_{sat}$

$I_{D,SAT} = W C_G v_{sat} (V_{gs} - V_T)$ for $V_{DS} > V_{DSAT}$



$\cancel{W}\cancel{C_G}(\cancel{V_{gs}} - \cancel{V_T}) \mu_n \frac{V_{DSAT}}{L} = \cancel{W}\cancel{C_G} v_{sat} (\cancel{V_{gs}} - \cancel{V_T})$

$\therefore V_{DSAT} = \frac{v_{sat} \cdot L}{\mu_n}$

using an emperical model for velocity

$$\langle v(V_{DS}) \rangle = F_{sat}(V_{DS}) \cdot v_{sat}$$

$$F_{sat}(V_{DS}) = \frac{V_{DS}/V_{DSAT}}{\left[1 + \left(\frac{V_{DS}}{V_{DSAT}}\right)^{\beta}\right]^{1/\beta}}$$

$$V_{DSAT} = \frac{v_{sat} \cdot L}{\mu_n}$$

We can finalize the level 0 model as

1) $I_{DS}/W = \cancel{|Q_n(0)|\, v(0)} = Q_n(V_{GS}) \langle v(V_{DS}) \rangle$

2) $Q_n(V_{GS}) = 0 \quad V_{GS} \leq V_T$

$= -C_G(V_{GS} - V_T) \quad V_{GS} > V_T$

$\cancel{C_G = \frac{C_{ox1}\, C_{dep1}\, C_{dep2}}{C_{ox1} C_{dep1} + C_{ox} C_{dep2} + C_{dep} C_{dep2}}}$

$$C_G = \frac{C_{ox1} \cdot C_{ox2}}{C_{ox1} + C_{ox2}}$$

3) $\langle v(V_{DS}) \rangle = F_{sat}(V_{DS}) \cdot v_{sat}$

4) $F_{sat}(V_{DS}) = \frac{V_{DS}/V_{DSAT}}{\left[1 + \left(\frac{V_{DS}}{V_{DSAT}}\right)^{\beta}\right]^{1/\beta}}$

5) $V_{DSAT} = \frac{v_{sat}\, L_{ch}}{\mu_{eff}}$

device specific parameters

$C_{ox1}, C_{ox2}, V_T, v_{sat}$

μ_{eff}, L_{ch}

1 emperical parameter

β

We can substitute Kox1 = 20 and tox1 = 1nm, Kox2 = 7.5 and tox2 = 2nm as per the specifications given in the question