Fall 2008

EE 612: Nanoscale Transistors

HW11: DUE THURSDAY, DECEMBER 11

1D SOI Electrostatics

In class, we will derive the following expressions to relate the front and back gate voltages to the front and back surface potentials,

$$V_{gf}' = \psi_{sf} - \frac{\left(0.5Q_B + Q_{nf}\right)}{C_{of}} + \frac{C_{Si}}{C_{of}}\left(\psi_{sf} - \psi_{sb}\right) \tag{1}$$

$$V_{gb}' = \psi_{sb} - \frac{\left(0.5Q_B + Q_{nb}\right)}{C_{ob}} + \frac{C_{Si}}{C_{ob}}\left(\psi_{ssb} - \psi_{sf}\right) \tag{2}$$

where

$V_{gf}' = V_{gf} - \phi_{ms}$ is the front gate voltage

ψ_{sf} is the front surface potential

$Q_B = -qN_A t_{Si}$ is the depleted charge in the SOI body

Q_{bf} is the front channel inversion layer charge.

$C_{of} = \frac{\varepsilon_{ox}}{t_{of}}$ is the front oxide capacitance per unit area

$C_{Si} = \frac{\varepsilon_{Si}}{t_{Si}}$ is the capacitance associate with the depleted silicon film.

Similar quantities are defined for the back of the device.

1) Derive these equations.

2) Show that the subthreshold swing for an ideal double gate SOI MOSFET ($V_{gf} = V_{gb}$ and $C_{of} = C_{ob}$) is **ideal**. The subthreshold swing of the front channel current is $S = 2.3\left(\frac{\partial V_{gf}}{\partial \psi_{sf}}\right)\frac{k_B T}{q}$.

3) Consider a double gate device ($V_{gf} = V_{gb}$) for which $C_{of} \neq C_{ob}$. Derive an expression for the subthreshold swing.

4) Assume single gate operation with the back gate held at a **constant potential**. Derive an expression for the subthreshold swing.

5) Show that the total inversion layer charge in an ideal, double gate MOSFET is $Q_n = Q_{nf} + Q_{nb} = -2C_{ox}\left(V_g - V_T\right)$.

6) It is possible to make an asymmetric double gate device ($V_{gf} = V_{gb}$ and $C_{of} = C_{ob}$) by using a different workfunction for the back gate. For example, we might use n^+ poly silicon for the front gate and p^+ for the back gate. It is possible, therefore, to have a channel at the front but not at the back. Show that the total inversion layer charge is still $Q_n = Q_{nf} = -2C_{of}\left(V_g - V_T\right)$. Assume that the workfunctions are such that when the front surface inverts, $\psi_{sb} \approx 0$.