Assignment 5
E3225
Art of Compact Modeling

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1 Problem 1

Solve Poisson's Equation(F.5 in Tsividis) using appropriate boundary conditions with varying Doping Concentration and Oxide Thickness.

Solution: Poisson's Equation for the MOS structure:

$$\frac{d^2\psi}{dy^2} = -\frac{qN_A}{\epsilon_s}[e^{-\psi(y)/\phi_t} - 1 - e^{-2\phi_F/\phi_t}(e^{\psi(y)/\phi_t} - 1)]\,. \tag{1}$$

Parameters used:

$$\epsilon_{Si} = 3.9\epsilon_0$$

$$\epsilon_{SiO_2} = 11.4\epsilon_0$$

$$\Delta\Phi_{MS} = 0.21\ eV$$

$$\phi_t = 26\ meV$$

$$n_i = 10^{10}\ cm^{-3}$$

$$\phi_f = \phi_t ln\frac{N_A}{n_i}$$

$$t_{Si} = 100\ nm$$

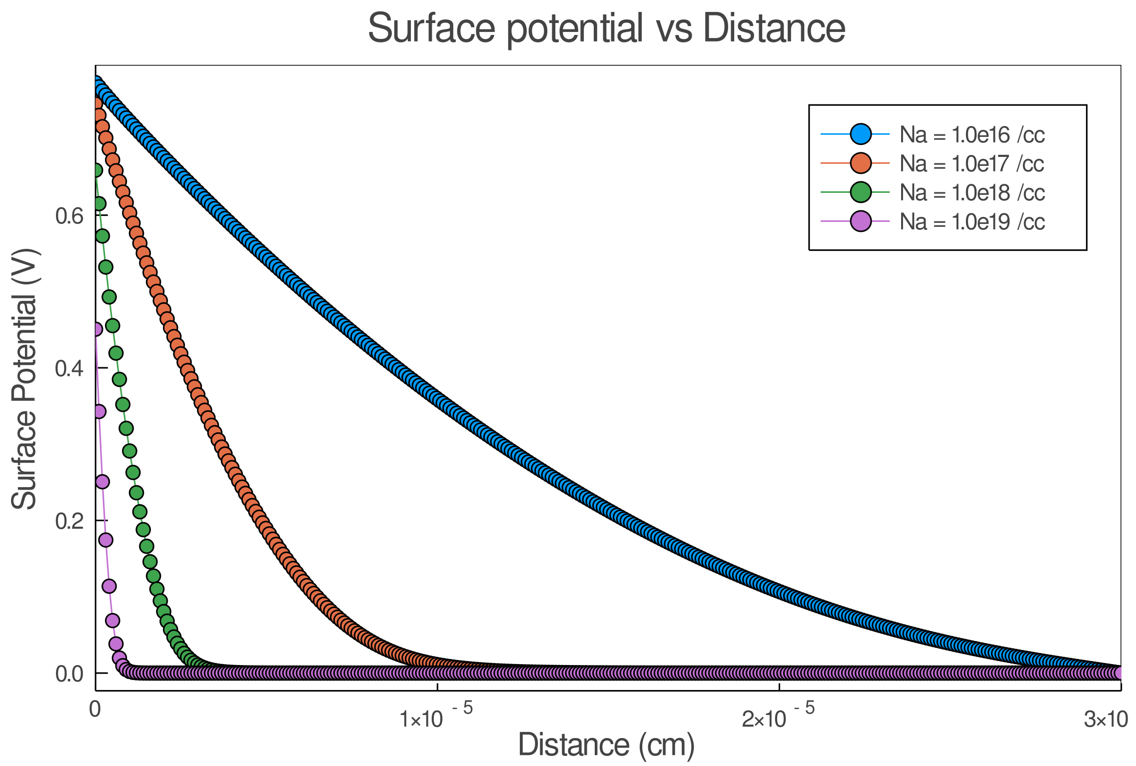
- $$N_A \in (10^{16}, 10^{19})\ cm^{-3}$$

  $t_{ox} = 1\,nm$

Boundary Conditions

$\psi(t_{Si}) = 0\ \ (Dritchle's)$

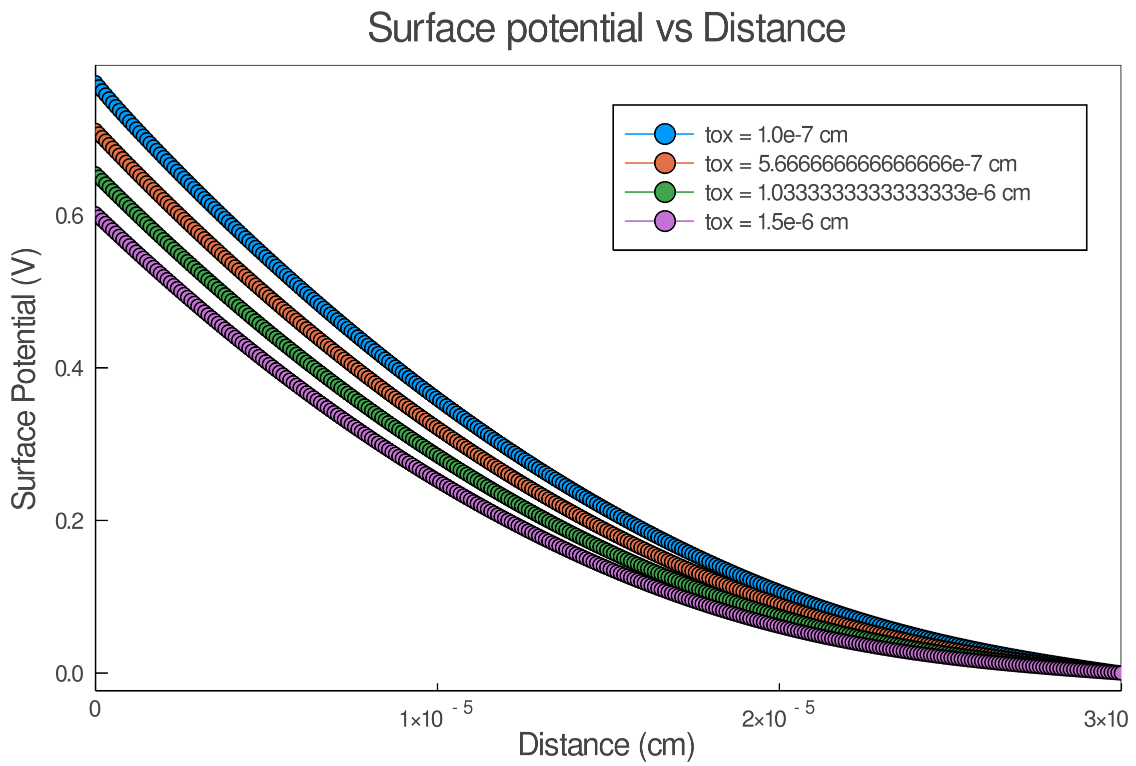
$-\frac{d\psi}{dy}|_{y=0} = \frac{C_{ox}}{\epsilon_{Si}}[V_{gs} - \psi(0)]\ \ (Mixed)$



increaed doping leads to decrease in depletion width and surface potetial.

- $$t_{ox} \in (1, 15)\, nm$$

  $\mathrm{N}_A = 10^{16} cm^{-3}$



with increased oxide thickness surface potential decreases.

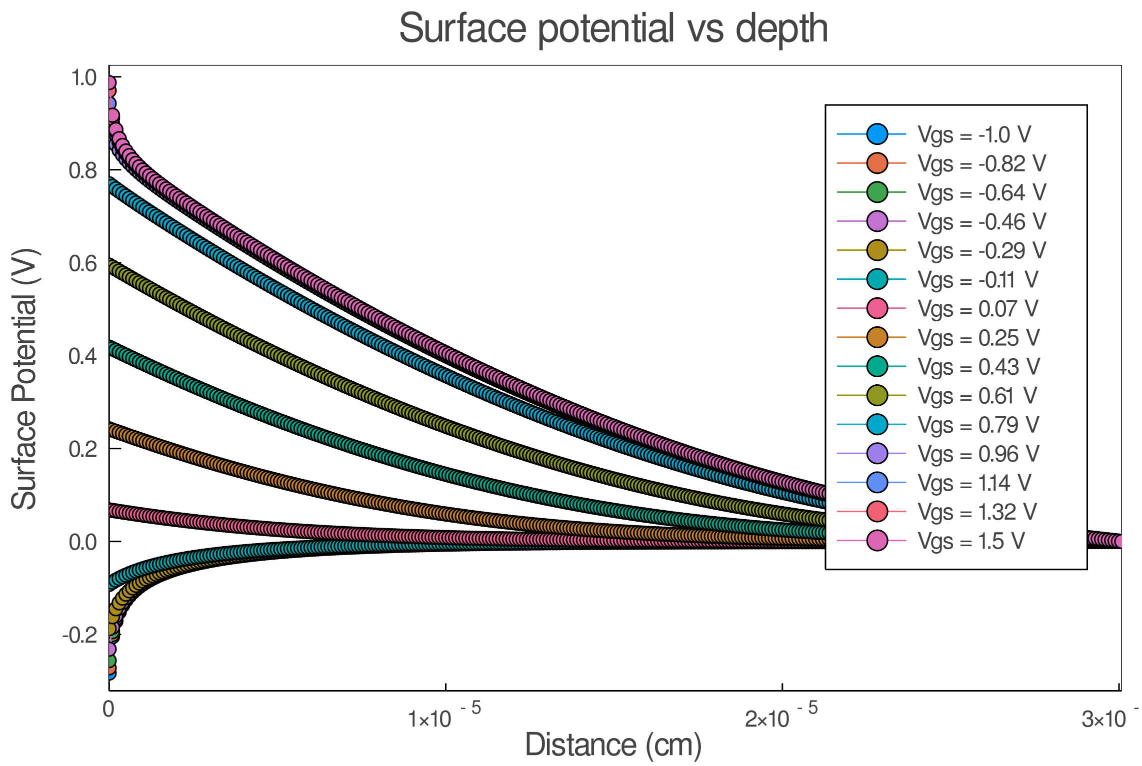
2 Problem 2

Plot Potential Profile ($\phi(y)$ vs y) with varying Gate Voltage.

Solution: Solved with same boundary conditions, here gate voltage was varied from -1 V to 1.5 V.

$N_A = 10^{16}\, cm^{-3}$
$t_{ox} = 1\, nm$

Rest all other parameters were the same.

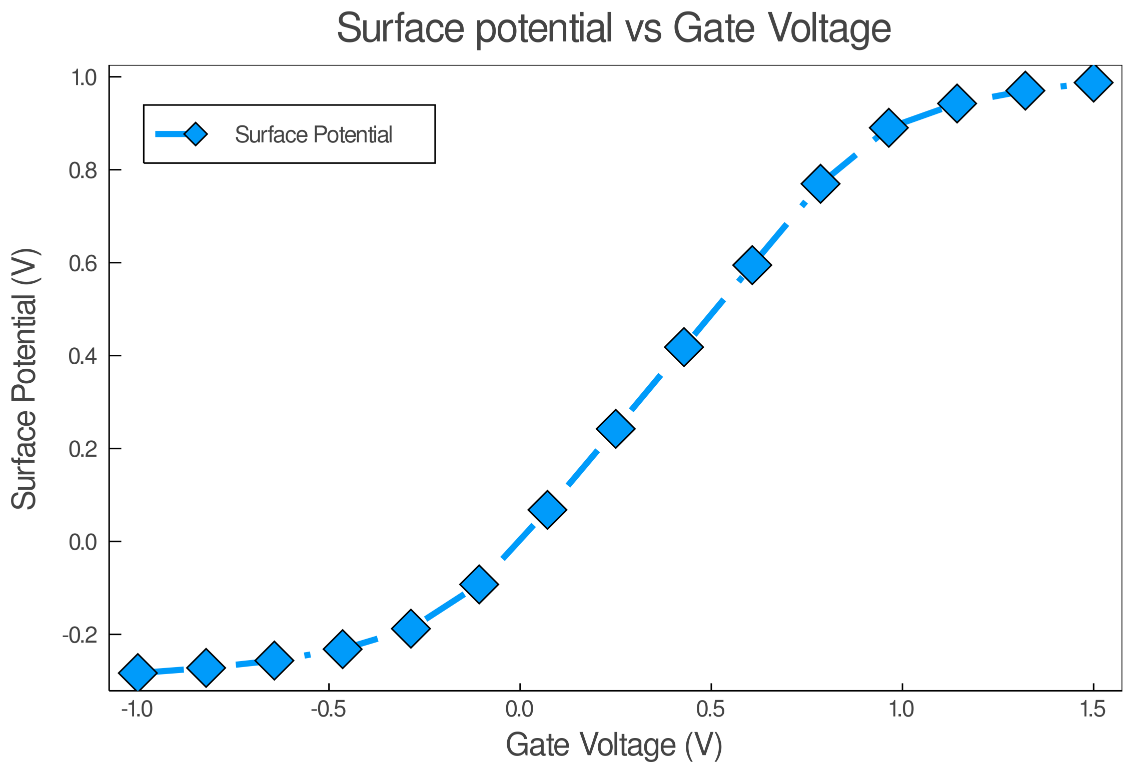


In negative V_g it saturates fast as accumulation regime reached. In positive V_{gs} the difference between successive ϕ_s decreases as it reaches from depletion to weak inversion. When it reaches strong inversion the potential curve saturates.

3 Problem 3

Plot Surface Potential as a function of Gate Voltage. Calculate the value of Surface Potential when curve saturates.

Solution: Extracted from the previous graph:



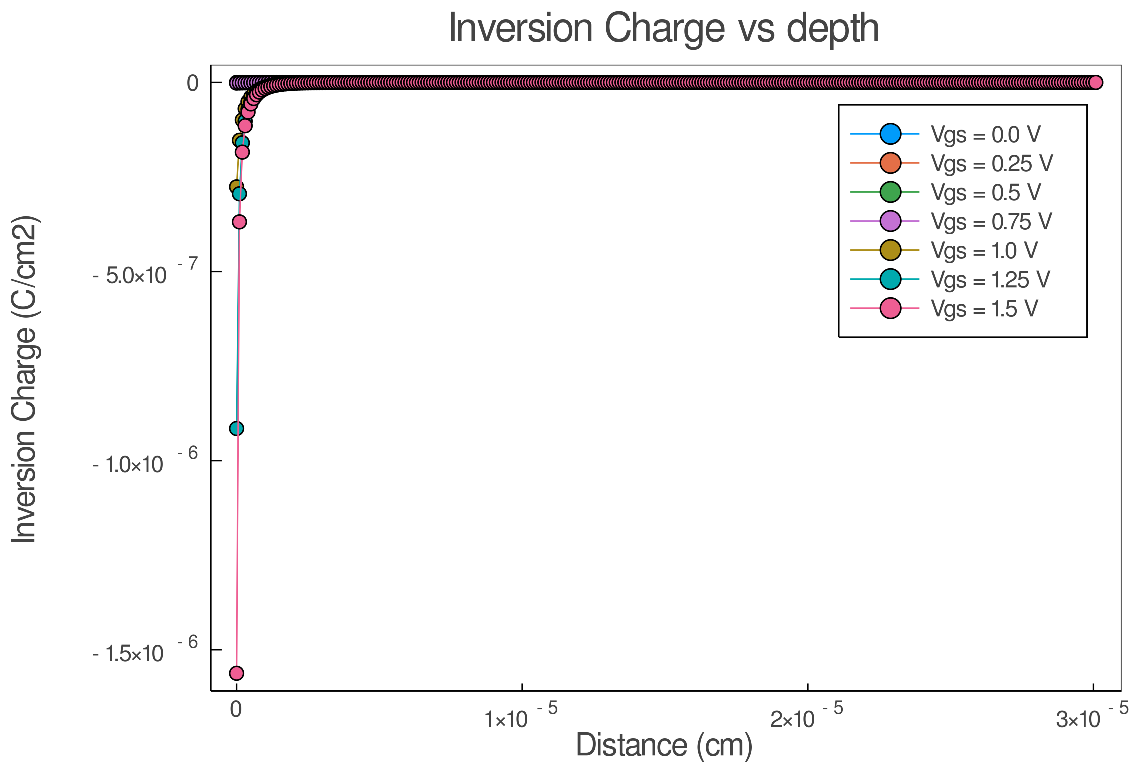
The surface potential extracted from the saturation regime was 0.987 eV which is slightly greater than $2\phi_f$.

4 Problem 4

Plot Inversion Charge Density ($n_i(y)$ vs y)with varying Gate Voltage.

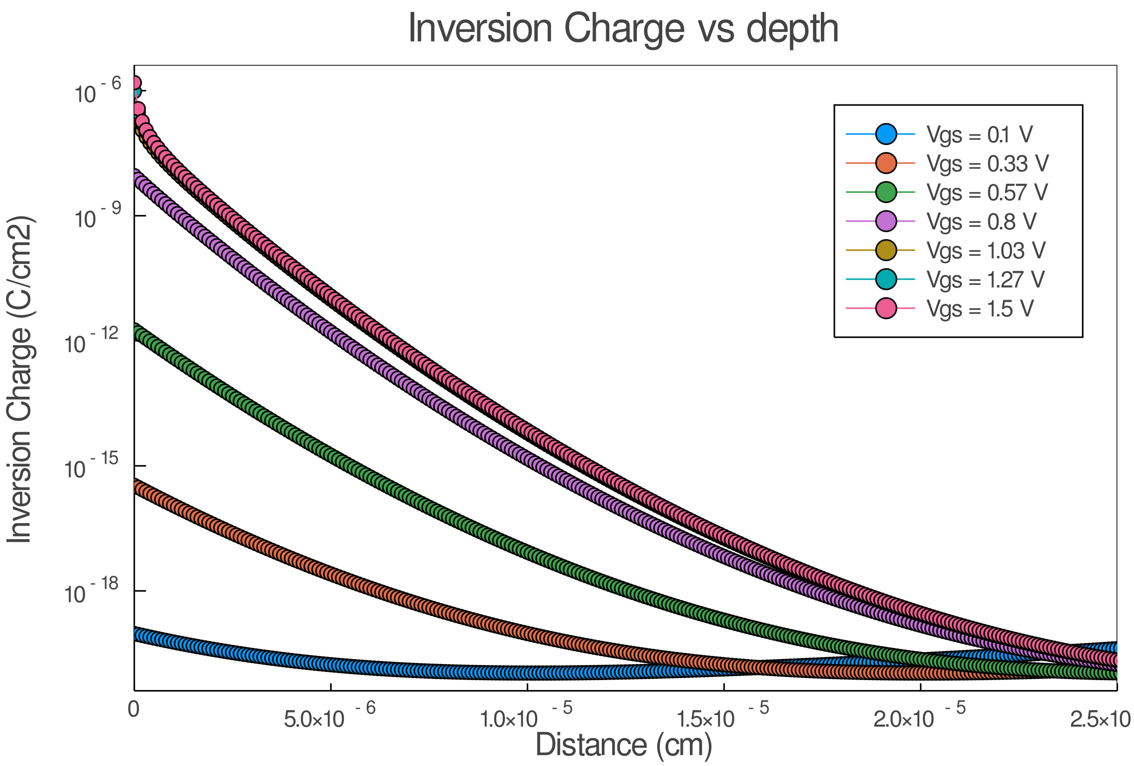
Solution: With the continuation of the problem 2. The eqation of n_i used was obtained from difference between total charge and the depletion charge at any particular gate voltage.

Inversion Charge density:
$Q_i = n_i q = -\sqrt{2qN_a\epsilon_s}[\sqrt{\psi(y) + \phi_t e^{\frac{\psi(y)-2\phi_f}{\phi_t}}} - \sqrt{\psi(y)}]$



It comes out to be negative as charge of electron is negative.

For better clarity absolute value of same is plotted in semilog axis.



It can be seen from this plot that the inversion charge is negligible when V_{gs} is below $2\phi_f$ V, as it approaches value of surface potential i.e at around 0.98 V the inversion charge becomes significant, and when it crosses threshold it saturates.