Homework #4 - September 30, 2005

Due: October 7, 2005 at recitation (2 PM latest)
(late homework will not be accepted)

Please write your recitation session time on your problem set solution.

1. [30 points] In a paper on Si p-n junction varactors, you see the following graph with the capacitance-voltage characteristics of the diode at room temperature:

   ![Graph](image_url)

   Assuming that the diode is highly asymmetrically doped, reverse engineer the diode.

   a) [10 points] Estimate the built-in potential of the junction.
   b) [10 points] Estimate the depletion region thickness at \( V = -5 \) V.
   c) [5 points] Estimate the doping level of the lowly-doped side, \( N_L \).
   d) [5 points] Estimate the doping level of the highly-doped side, \( N_H \).
2. [40 points] Consider the following MOS structure:

\[
\begin{array}{c}
\text{n+ polySi} \\
\text{oxide} \\
\text{p-Si (N_A = 10^{17} \text{ cm}^{-3}) contact} \\
\end{array}
\]

a) [10 points] Calculate the flatband voltage.

b) [10 points] Calculate the extent of the depletion region in the semiconductor at threshold.

c) [10 points] Calculate the electric field in the oxide at threshold.

d) [10 points] Calculate the inversion layer sheet charge when the electric field in the oxide is \( \mathcal{E}_{ox} = 10^6 \text{ V/cm} \).

3. [30 points] You are given an MOS capacitor fabricated with a n+ polysilicon gate and a p-type substrate with a doping concentration of \( N_a = 5 \times 10^{16} \text{ cm}^{-3} \), as sketched below on the left. The capacitance-voltage curve for this device is shown below on the right.

\[
\begin{array}{c}
\text{metal} \\
n^+\text{polysilicon} \\
silicon dioxide \\
\end{array}
\]

\[
\begin{array}{c}
p\text{-type Si} \quad N_a = 5 \times 10^{16} \text{ cm}^{-3} \\
\end{array}
\]

a) [5 points] Calculate \( V_{GB} = V_1 \).
b) [5 points] Calculate the oxide thickness.

c) [5 points] Calculate $V_{GB} = V_2$.

d) [5 points] Calculate $C_{min}$.

e) [5 points] Calculate the electric field in the oxide when $V_{GB} = V_2 + 1 \text{ V}$.

f) [5 points] Calculate the electric field in the oxide when $V_{GB} = V_1 - 1 \text{ V}$. 