Problems

1. Consider an aluminum-SiO_2-silicon MOS capacitor (F_M = 4.1 V, e_{ox}/e_0 = 3.9, χ = 4.05 V and $N_a = 10^{17}$ cm^{-3}) MOS capacitor with t_{ox} = 5 nm.

   a) Calculate the flatband voltage and threshold voltage.

   b) Repeat for an n-type silicon substrate with $N_d = 10^{16}$ cm^{-3}.

   c) Repeat with a surface charge of 10^{-7} C/cm^2

   d) Repeat with a charge density in the oxide of 10^{-1} C/cm^3

2. A high-frequency capacitance voltage measurement of a silicon MOS structure was fitted by the following expression:

   $$C(V_G) = 6 \text{ pF} + 12 \text{ pF}/(1 + \exp(V_G))$$

   a) Calculate the oxide capacitance per unit area and the oxide thickness. The area of the capacitor is 100 x 100 micron and the relative dielectric constant equals 3.9.

   b) From the minimum capacitance, calculate the maximum depletion layer width and the substrate doping density.

   c) Calculate the bulk potential.

   d) Calculate the flatband capacitance and the flatband voltage.

   e) Calculate the threshold voltage.

3. An MOS capacitor with an oxide thickness of 20 nm has an oxide capacitance, which is three times larger than the minimum high-frequency capacitance in inversion. Find the substrate doping density.

4. A CMOS gate requires n-type and p-type MOS capacitors with a threshold voltage of 2 and -2 Volt respectively. If the gate oxide is 50 nm what are the required substrate doping densities? Assume the gate electrode is aluminum. Repeat for a p^+ poly-silicon gate.

5. Consider a p-MOS capacitor (with an n-type substrate) and with an aluminum gate. Find the doping density for which the threshold voltage is 3 times larger than the flat band voltage. t_{ox} = 25 nm. Repeat for a capacitor with 10^{11} cm^{-2} electronic charges at the oxide-semiconductor interface.

6. A silicon p-MOS capacitor . ($N_d = 4 \times 10^{16}$ cm^{-3}, t_{ox} = 40 nm) is biased halfway between the flatband and threshold voltage. Calculate the applied voltage and the corresponding capacitance