Example 6.3 Calculate the oxide capacitance, the flatband capacitance and the high frequency capacitance in inversion of a silicon nMOS capacitor with a substrate doping $N_a = 10^{17}$ cm$^{-3}$, a 20 nm thick oxide ($\varepsilon_{ox} = 3.9 \varepsilon_0$) and an aluminum gate ($\Phi_M = 4.1$ V).

Solution

The oxide capacitance equals:

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}} = \frac{3.9 \times 8.85 \times 10^{-14}}{2 \times 10^{-6}} = 173 \text{nF/cm}^2$$

The flatband capacitance equals:

$$C_{FB} = \frac{1}{\frac{L_D}{C_{ox}} + \varepsilon_s} = \frac{1}{\frac{173 \times 10^{-9}}{1 + \frac{1.3 \times 10^{-6}}{11.9 \times 8.85 \times 10^{-14}}} = 142 \text{nF/cm}^2$$

where the Debye length is obtained from:

$$L_D = \left(\frac{\varepsilon_s \varepsilon_F}{qN_a}\right) = \sqrt{\frac{11.9 \times 8.85 \times 10^{-14} \times 0.0259}{1.6 \times 10^{-19} \times 10^{17}}} = 13 \text{nm}$$

The high frequency capacitance in inversion equals:

$$C_{HF,inv} = \frac{1}{\frac{x_{d,T}}{C_{ox}} + \varepsilon_s} = \frac{1}{\frac{173 \times 10^{-9}}{1 + \frac{1.05 \times 10^{-5}}{11.9 \times 8.85 \times 10^{-14}}} = 63 \text{nF/cm}^2$$

and the depletion layer width at threshold equals:

$$x_{d,T} = \sqrt{\frac{2\varepsilon_s (2\Phi_F)}{qN_a}} = \sqrt{\frac{2 \times 11.9 \times 8.85 \times 10^{-14} \times 2 \times 0.419}{1.6 \times 10^{-19} \times 10^{17}}} = 105 \text{nm}$$

The bulk potential, $\Phi_F$, was already calculated in example 6.1