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 ($e_{ox} = 3.9\, e_0$) and an aluminum gate ($\Phi_M = 4.1$ V).

Solution The oxide capacitance equals:

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

The flatband capacitance equals:

$$C_{FB} = \frac{1}{\frac{1}{C_{ox}} + \frac{L_D}{e_s}}$$

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

where the Debye length is obtained from:

$$L_D = \sqrt{\frac{e_s V_t}{q N_a}} = \sqrt{\frac{11.9 \times 8.85 \times 10^{-14} \times 0.0259}{1.6 \times 10^{-19} \times 10^{17}}} = 13\,\text{nm}$$

The high frequency capacitance in inversion equals:

$$C_{HF,inv} = \frac{1}{\frac{1}{C_{ox}} + \frac{x_{d,T}}{e_s}}$$

$$= \frac{1}{\frac{1}{173 \times 10^{-9}} + \frac{1.05 \times 10^{-5}}{11.9 \times 8.85 \times 10^{-14}}} = 63\,\text{nF/cm}^2$$

and the depletion layer width at threshold equals:

$$x_{d,T} = \sqrt{\frac{2 e_s (2 f_F)}{q N_a}}$$

$$= \sqrt{\frac{2 \times 11.9 \times 8.85 \times 10^{-14} \times 2 \times 0.419}{1.6 \times 10^{-19} \times 10^{17}}} = 105\,\text{nm}$$

The bulk potential, f_F, was already calculated in example 6.1