

Example 7.3

Calculate the threshold voltage of a silicon nMOSFET when applying a substrate voltage, $V_{BS} = 0, -2.5, -5, -7.5$ and -10 V. The capacitor has a substrate doping $N_a = 10^{17} \text{ cm}^{-3}$, a 20 nm thick oxide ($\epsilon_{ox} = 3.9 \epsilon_0$) and an aluminum gate ($\Phi_M = 4.1$ V). Assume there is no fixed charge in the oxide or at the oxide-silicon interface.

Solution

The threshold voltage at $V_{BS} = -2.5$ V equals:

$$V_T = V_{T0} + \frac{g}{\sqrt{2f_F}} \left(\sqrt{1 + \frac{V_{SB}}{2f_F}} - 1 \right)$$

$$= -0.09 + \frac{0.75}{\sqrt{2 \times 0.42}} \left(\sqrt{1 + \frac{2.5}{2 \times 0.42}} - 1 \right) = 0.73 \text{ V}$$

Where the flatband voltage without substrate bias, V_{T0} , was already calculated in example 6.2. The body effect parameter was obtained from:

$$g = \frac{\sqrt{2\epsilon_s q N_a}}{C_{ox}} = \frac{\sqrt{2 \times 11.9 \times 8.85 \times 10^{-14} \times 1.6 \times 10^{-19} \times 10^{17}}}{3.9 \times 8.85 \times 10^{-14} / 20 \times 10^{-7}}$$

$$= 0.75 \text{ V}^{-1/2}$$

The threshold voltages for the different substrate voltages are listed in the table below.

	$V_{BS} = -2.5 \text{ V}$	-5 V	-7.5 V	-10 V
V_T	0.73 V	1.26 V	1.68 V	2.04 V