10.16 An n^+ polysilicon gate–silicon dioxide–silicon MOS capacitor has an oxide thickness of $t_{ox} = 18$ nm $= 180$ Å and a doping of $N_a = 10^{15}$ cm^{-3}. The oxide charge density is $Q'_{ss} = 6 \times 10^{10}$ cm^{-2}. Calculate the (a) flat-band voltage and (b) threshold voltage.

From Semiconductor Physics and Devices: Basic Principles (4th Edition), Donald A. Neamen, McGraw Hill, 2012, ISBN 978-0-07-352958-5.

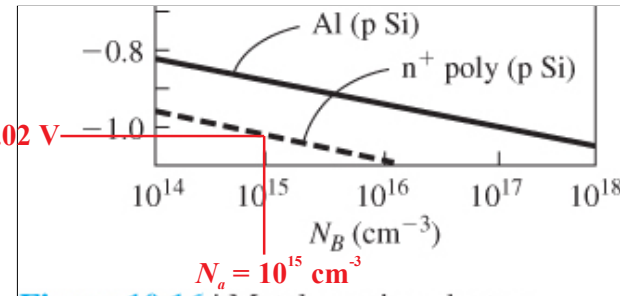

Figure 10.16 | Metal–semiconductor work function difference versus doping for aluminum, gold, and n^- and p^- polysilicon gates. (*From Sze [17] and Werner [20].*)

Table B.4, $n_i = 1.5 \times 10^{10}$ cm^{-3}, $\epsilon_r = 11.7$ for Si @ 300K

Table B.6, $\epsilon_r = 3.9$ for SiO_2 @ 300K

$$Q_{ss}' = 6 \times 10^{10}\ \text{cm}^{-2}\left(1.602176634 \times 10^{-19}\right) = 9.61306 \times 10^{-9}\ \text{C/cm}^2$$

(10.1) $$C' = \frac{\epsilon}{d} \Rightarrow C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{3.9(8.8541878 \times 10^{-12})}{18 \times 10^{-9}}$$

$$C_{ox} = 1.918407 \times 10^{-3}\ \text{F/m}^2 = 1.9184 \times 10^{-7}\ \text{F/cm}^2$$

$$V_t = \frac{k_B T}{e} = \frac{8.617333 \times 10^{-5}\ \text{eV/K}\,(300\text{K})}{e} = 0.025852\ \text{V}$$

Per (10.4), $$\phi_{fp} = V_t \ln\left(\frac{N_a}{n_i}\right) = 0.025852 \ln\left(\frac{10^{15}}{1.5 \times 10^{10}}\right)$$

$$= 0.28715\ \text{V}$$

a) From Fig 10.16, $\phi_{ms} = -1.02$ V

Per (10.25), $$V_{FB} = \phi_{ms} - \frac{Q_{ss}'}{C_{ox}}$$

$$= -1.02 - \frac{9.613 \times 10^{-9}}{1.9184 \times 10^{-7}} \Rightarrow \underline{\underline{V_{FB} = -1.07\ \text{V}}}$$

b) Per (10.8), $X_{dT} = \left\{ \frac{4 \epsilon_s \phi_{sB}}{e N_a} \right\}^{1/2}$

$$= \left\{ \frac{4(11.7)\,8.8541878 \times 10^{-12}\,(0.28715)}{1.6021766 \times 10^{-19}\,(10^{21})} \right\}^{1/2}$$

$$= 8.617803 \times 10^{-7}\ m$$

Per (10.27), $|Q_{SD}'(max)| = e N_a X_{dT}$

$$|Q_{SD}'(max)| = 1.6021766 \times 10^{-19}\,(10^{21})\,8.6178 \times 10^{-7}$$

$$= 1.380724 \times 10^{-4}\ C/m^2 = 1.3807 \times 10^{-8}\ C/cm^2$$

Per (10.31c), $V_{TN} = \frac{|Q_{SD}'(max)|}{C_{ox}} + V_{FB} + 2\phi_{sB}$

$$V_{TN} = \frac{1.3807 \times 10^{-4}}{1.9184 \times 10^{-3}} - 1.07011 + 2(0.28715)$$

$$= -0.42384\ V$$

$$\underline{V_{TN} = -0.424\ V}$$