10.10 Consider a MOS device with a p-type silicon substrate with $N_a = 2 \times 10^{16}$ cm^{-3}. The oxide thickness is $t_{ox} = 15$ nm $= 150$ Å and the equivalent oxide charge is $Q'_{ss} = 7 \times 10^{10}$ cm^{-2}. Calculate the threshold voltage for (*a*) an n$^+$ polysilicon gate, (*b*) a p$^+$ polysilicon gate, and (*c*) an aluminum gate.

➢ Also, find $|Q_{SD}'(\text{max})|$ and C_{ox}.

From Table B.4, $n_i = 1.5 \times 10^{10}\ cm^{-3}$, & $\epsilon_r = 11.7$ Silicon

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

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

Per (10.4), $\phi_{fp} = V_t \ln\left(\frac{N_a}{n_i}\right) = 0.025852 \ln\left(\frac{2 \times 10^{16}}{1.5 \times 10^{10}}\right)$

$$= 0.364596\ V$$

Per (10.6), $x_{dT} = \left\{\frac{4 \epsilon_s \phi_{fp}}{e N_a}\right\}^{1/2}$

$$= \left(\frac{4(11.7)\,8.8541878 \times 10^{-12}\,(0.364596)}{1.602176634 \times 10^{-19}\,(2 \times 10^{22})}\right)^{1/2}$$

$$= 2.171365 \times 10^{-7}\ m$$

Per (10.27), $|Q_{sp}'(\text{max})| = e N_a x_{dT}$

$$= 1.6022 \times 10^{-19}(2 \times 10^{22})(2.1714 \times 10^{-7})$$

$$|Q_{sp}'(\text{max})| = 6.95782 \times 10^{-4}\ \frac{C}{m^2} = 6.958 \times 10^{-8}\ \frac{C}{cm^2}$$

Per (10.1), $C' = \epsilon/d \Rightarrow C_{ox} = \frac{\epsilon_{ox}}{t_{ox}} = \frac{3.9(8.8541878 \times 10^{-12})}{15 \times 10^{-9}}$

$$C_{ox} = 2.30209 \times 10^{-3}\ F/m^2 = 2.3021 \times 10^{-7}\ F/cm^2$$

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

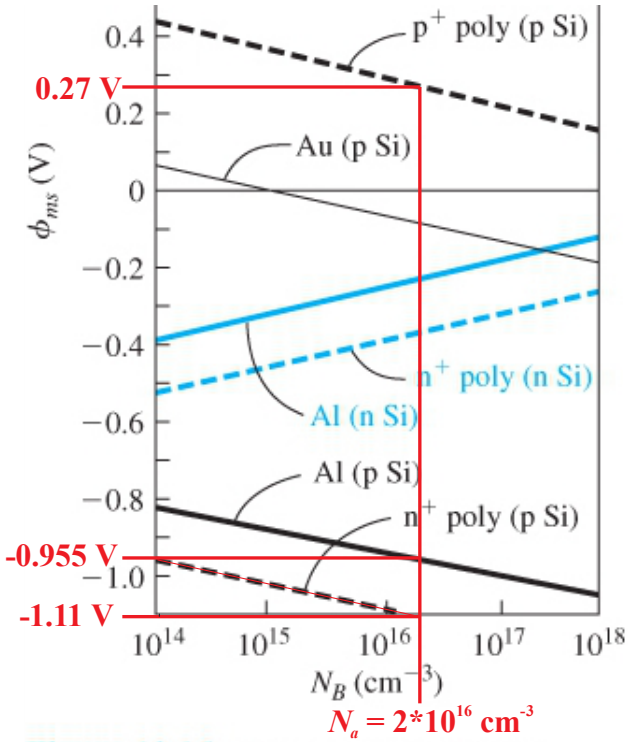

Figure 10.16 | Metal–semiconductor work function difference versus doping

Per (10.31a), $V_{TN} = \frac{|Q_{SO}'(max)|}{C_{ox}} - \frac{Q_{ss}'}{C_{ox}} + \phi_{ms} + 2\phi_{sp}$

a) Per Fig 10.16, $\phi_{ms} = -1.11$ V for n+ poly

$$V_{TN} = \frac{6.95782\times10^{-8}}{2.30209\times10^{-7}} - \frac{1.6021766\times10^{-19}(7\times10^{10})}{2.30209\times10^{-5}} - 1.11 + 2(0.3646)$$

$$= 0.30224 - 0.04872 - 1.11 + 0.72919$$

$$V_{TN} = -0.127 \text{ V}$$

b) Per Fig 10.16, $\phi_{ms} = 0.27$ V for p+ poly

$$V_{TN} = 0.30224 - 0.04872 + 0.27 + 0.72919 \Rightarrow V_{TN} = 1.25 \text{ V}$$

c) Per Fig 10.16, $\phi_{ms} = -0.955$ V for Al

$$V_{TN} = 0.30224 - 0.04872 - 0.955 + 0.72919 \Rightarrow V_{TN} = 0.028 \text{ V}$$