EE 362 Electronic, Magnetic, & Optical Properties of Materials
Quiz 8 (Spring 2026)

Name **KEY A**

Instructions: Open book & notes. Place answers in indicated spaces. Show **all** work. Use 4-5 significant figures.

At 300 K, a MOS capacitor has a silicon substrate uniformly doped with acceptor atoms (8×10^{15} #/cm^3). It has a 28 nm thick silicon dioxide layer with an equivalent trapped charge density of 1×10^{11} #/cm^2. The gate is made with p$^+$ polysilicon. Find the oxide capacitance C_{ox} (F/m^2), maximum depletion layer thickness (m), maximum space charge density magnitude (C/m^2), ϕ_{fp} (V), metal-semiconductor work function (V), and threshold voltage V_T (V).

From Table B.4, $n_i = 1.5 \times 10^{10}\ \mathrm{cm}^{-3}$ & $\varepsilon_r = 11.7$ for silicon at 300 K.

From Table B.6, $\varepsilon_r = 3.9$ for SiO$_2$ at 300 K.

From Figure 10.16, $\underline{\boldsymbol{\phi_{ms}} \mathbf{= 0.3\ V}}$.

Per (10.35), $C_{\mathrm{ox}} = \dfrac{\varepsilon_{\mathrm{ox}}}{t_{\mathrm{ox}}} = \dfrac{3.9(8.8541878\times10^{-12}\ \mathrm{F/m})}{28\times10^{-9}\ \mathrm{m}}$ $\Rightarrow$ $\underline{\mathbf{C_{ox} = 1.23326\times10^{-3}\ F/m^2}}$.

Per (7.10), $V_t = \dfrac{k_B T}{e} = \dfrac{8.617333\text{•}10^{-5}\ \mathrm{eV/K}(300\ \mathrm{K})}{e}$ $\Rightarrow$ $V_t = 0.025852$ V.

Per (10.4), $\phi_{fp} = V_t \ln\left(\dfrac{N_a}{n_i}\right) = 0.025852 \ln\left(\dfrac{8\times10^{15}}{1.5\times10^{10}}\right)$ $\Rightarrow$ $\underline{\boldsymbol{\phi_{fp}} \mathbf{= 0.34090779\ V}}$.

Per (10.6),

$$x_{dT} = \left(\frac{4\varepsilon_s \phi_{fp}}{eN_a}\right)^{0.5} = \left(\frac{4\,(11.7)\,8.8541878\times10^{-12}\,(0.340908)}{1.602176634\times10^{-19}\,(8\times10^{21})}\right)^{0.5} \Rightarrow \underline{\mathbf{x_{dT} = 3.3198278\times10^{-7}\ m}}.$$

Per (10.27), $\left|Q'_{SD}(\max)\right| = eN_a x_{dT} = 1.602176634\text{•}10^{-19}(8\times10^{21})(3.31983\text{•}10^{-7})$

$\Rightarrow$ $\underline{\mathbf{|Q'_{SD}(max)| = 4.25516\times10^{-4}\ C/m^2}}$.

$$V_{TN} = \frac{\left|Q'_{SD}(\max)\right|}{C_{\mathrm{ox}}} - \frac{Q'_{SS}}{C_{\mathrm{ox}}} + \phi_{ms} + 2\phi_{fp}$$

Per (10.31a),

$$= \frac{4.25516\times10^{-4}}{1.23326\times10^{-3}} - \frac{1.602176634\text{•}10^{-19}(10^{15})}{1.23326\times10^{-3}} + 0.3 + 2(0.3409078)$$

$$= 0.3450335 - 0.129904 + 0.3 + 0.6818156$$

$\Rightarrow$ $\underline{\mathbf{V_{TN} = 1.197\ V}}$.

C_{ox} = **1.23326×10^{-3} F/m^2** max. depl. layer thickness = **x_{dT} = 3.31983×10^{-7} m = 331.98 nm**

max. space charge density mag. = **$|Q'_{SD}(\max)|$ = 4.25516×10^{-4} C/m^2** ϕ_{fp} = **0.340908 V**

metal-semiconductor work function = **ϕ_{ms} = 0.3 V** V_T = **V_{TN} = 1.197 V**

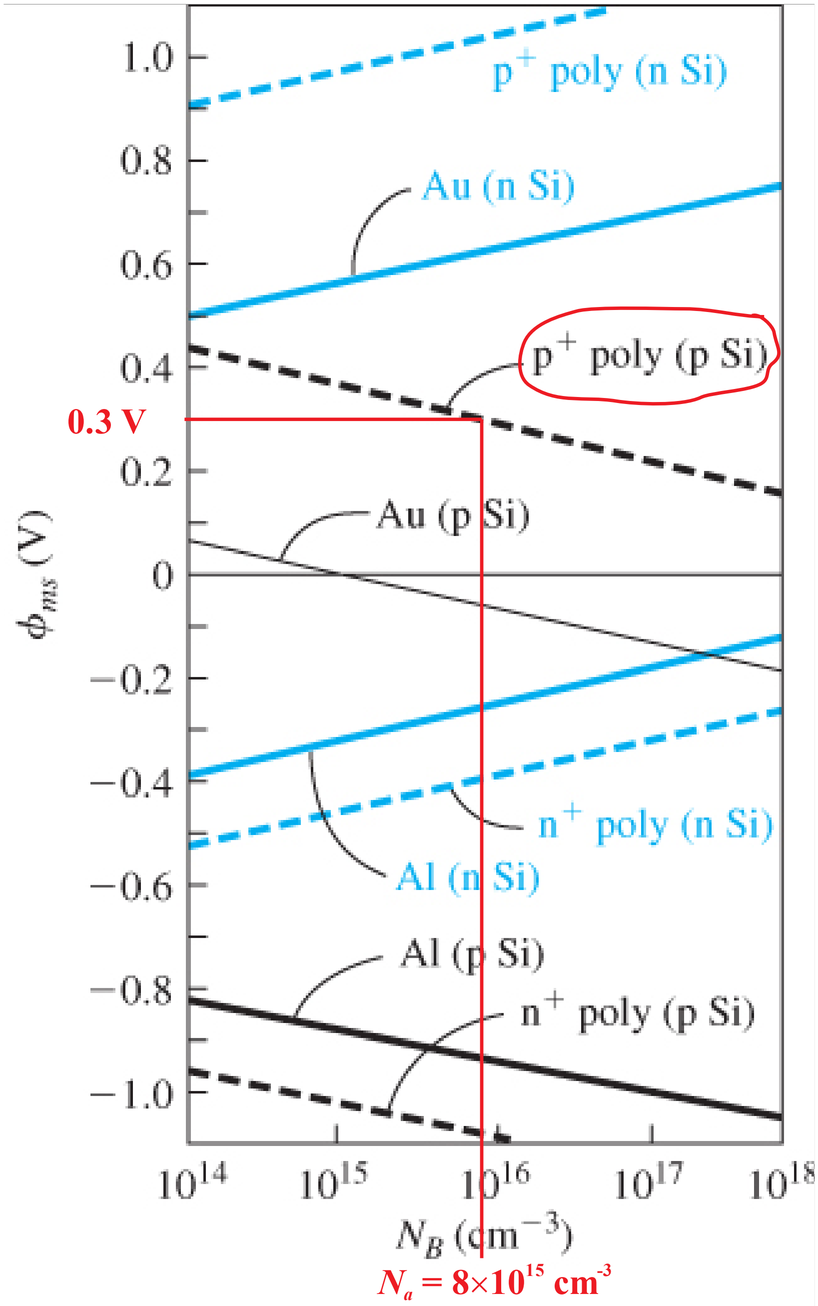

Figure 10.16 | Metal–semiconductor work function difference versus doping for aluminum, gold, and n^- and p^- polysilicon gates.

(*From Sze [17] and Werner [20].*)

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Name **KEY B**

Instructions: Open book & notes. Place answers in indicated spaces. Show **all** work. Use 4-5 significant figures.

At 300 K, a MOS capacitor has a silicon substrate uniformly doped with acceptor atoms (2×10^{17} #/cm^3). It has a 20 nm thick silicon dioxide layer with an equivalent trapped charge density of 3×10^{11} #/cm^2. The gate is made with p$^+$ polysilicon. Find the oxide capacitance C_{ox} (F/m^2), maximum depletion layer thickness (m), maximum space charge density magnitude (C/m^2), ϕ_{fp} (V), metal-semiconductor work function (V), and threshold voltage V_T (V).

From Table B.4, $n_i = 1.5 \times 10^{10}$ cm^{-3} & $\varepsilon_r = 11.7$ for silicon at 300 K.

From Table B.6, $\varepsilon_r = 3.9$ for SiO$_2$ at 300 K.

From Figure 10.16, **ϕ_{ms} = 0.2 V**.

Per (10.35), $C_{\text{ox}} = \dfrac{\varepsilon_{\text{ox}}}{t_{\text{ox}}} = \dfrac{3.9(8.8541878\times10^{-12}\,\text{F/m})}{20\times10^{-9}\,\text{m}}$ $\Rightarrow$ **C_{ox} = 1.7265666×10^{-3} F/m^2**.

Per (7.10), $V_t = \dfrac{k_BT}{e} = \dfrac{8.617333\bullet10^{-5}\,\text{eV/K}(300\text{ K})}{e}$ $\Rightarrow$ $V_t = 0.025852$ V.

Per (10.4), $\phi_{fp} = V_t \ln\left(\dfrac{N_a}{n_i}\right) = 0.025852 \ln\left(\dfrac{2\times10^{17}}{1.5\times10^{10}}\right)$ $\Rightarrow$ **ϕ_{fp} = 0.424122166 V**.

Per (10.6),

$$x_{dT} = \left(\frac{4\varepsilon_s\phi_{fp}}{eN_a}\right)^{0.5} = \left(\frac{4\,(11.7)\,8.8541878\times10^{-12}\,(0.424122)}{1.602176634\times10^{-19}\,(2\times10^{23})}\right)^{0.5}$$

$\Rightarrow$ **x_{dT} = 7.4058103×10^{-8} m**.

Per (10.27), $\left|Q'_{SD}(\max)\right| = eN_a x_{dT} = 1.602176634\bullet10^{-19}(2\times10^{23})(7.40581\times10^{-8})$

$\Rightarrow$ **|Q'_{SD}(max)| = 2.3730832×10^{-3} C/m^2**.

$$V_{TN} = \frac{\left|Q'_{SD}(\max)\right|}{C_{\text{ox}}} - \frac{Q'_{SS}}{C_{\text{ox}}} + \phi_{ms} + 2\phi_{fp}$$

Per (10.31a),

$$= \frac{2.37308\times10^{-3}}{1.726567\times10^{-3}} - \frac{1.602176634\bullet10^{-19}(3\times10^{15})}{1.726567\times10^{-3}} + 0.2 + 2(0.424122)$$

$$= 1.374452 - 0.2783866 + 0.2 + 0.848244$$

$\Rightarrow$ **V_{TN} = 2.1443 V**.

C_{ox} = **1.72657×10^{-3} F/m^2** max. depl. layer thickness = **x_{dT} = 7.40581×10^{-8} m**

max. space charge density mag. = **$|Q'_{SD}(\max)|$ = 2.37308×10^{-3} C/m^2** ϕ_{fp} = **0.424122 V**

metal-semiconductor work function = **ϕ_{ms} = 0.2 V** V_T = **V_{TN} = 2.144 V**

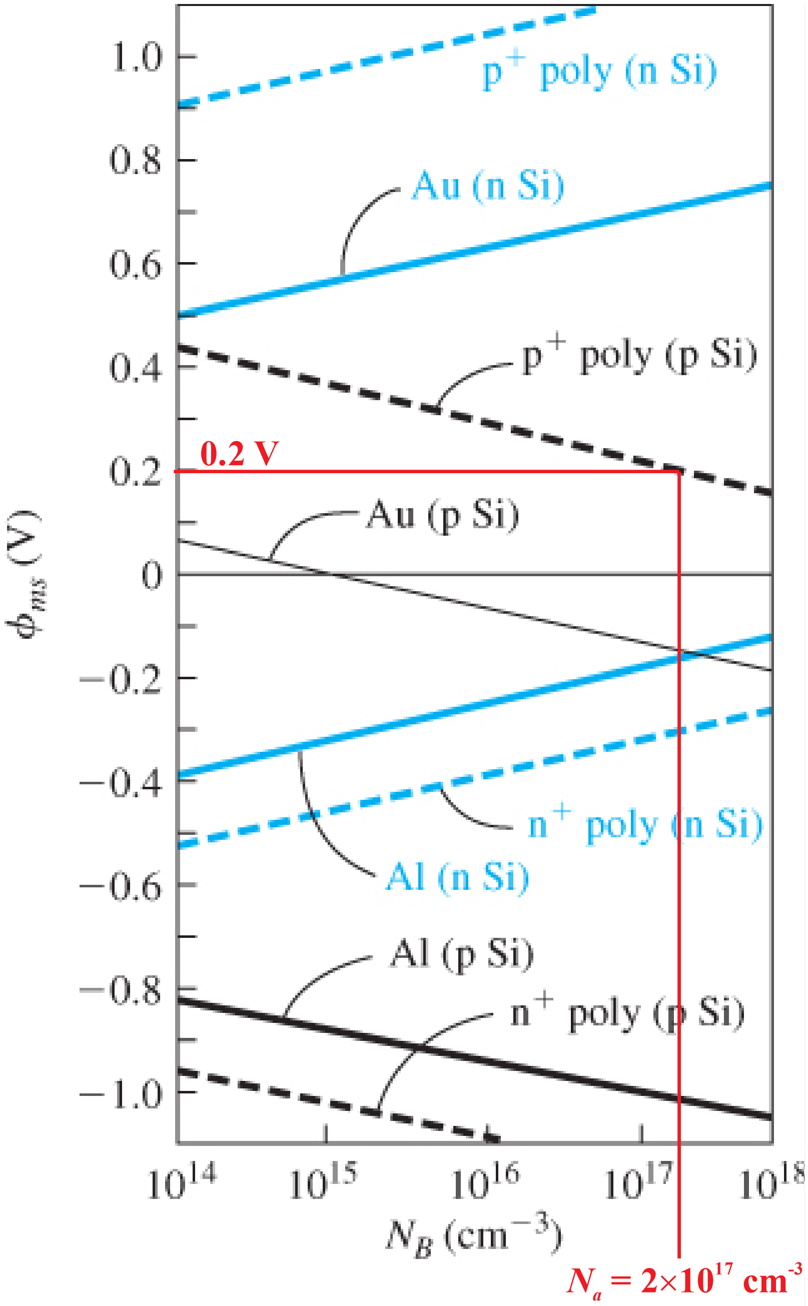

Figure 10.16 | Metal–semiconductor work function difference versus doping for aluminum, gold, and n^- and p^- polysilicon gates.
(From Sze [17] and Werner [20].)