P1.

a) Schottky barrier diode: exponential relationship 5'

ohmic contact diode: linear relatonship

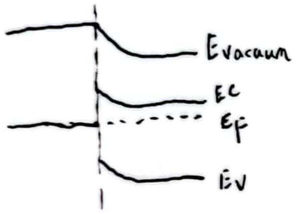
(b) Metal-semiconductor: $I \neq$ constant 0 5'

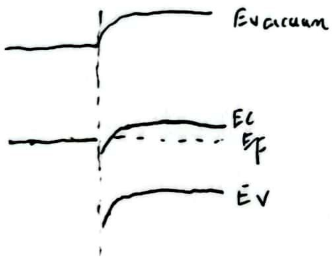
MOS structure: capacitor, ideally $I=0$ in steady state

(c) when $\phi_s \geq 2\phi_f$. the main contribution of the electric potential becomes the originally minority carriers (instead of the ionized dopants), so x_d changes slightly and reaches the maximum width 5'

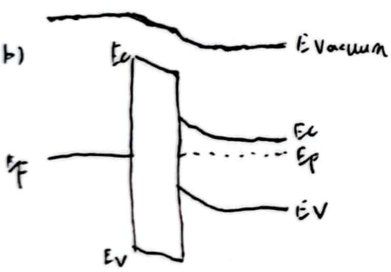
P2

(a) Schottky barrier diode 5' Ohmic contact diode 5'





(b) 5'



P3 complete ionization, T=300K

(a) $\phi_n = \frac{kT}{q} \ln\left(\frac{N_c}{N_d}\right) = 0.0259 \cdot \ln \frac{2.8\times10^{19}}{5\times10^{15}} = 0.2235\,V$ 2'

(b) $V_{bi} = \phi_{Bn} - \phi_n = 0.6665\,V$ 2'

(c) $J_{ST} = A^* T^2 \cdot \exp\left(-\frac{e\phi_{Bn}}{kT}\right) = 120 \cdot 300^2 \cdot \exp\left(-\frac{1.6\times10^{-19} \cdot 0.89V}{0.0259\,eV}\right) = 1.288\times10^{8}\ A/cm^2$ 3'

(d) $J_n = J_{ST}\left(\exp\left(\frac{eV_a}{kT}\right)-1\right) = 5\,A/cm^2$ 3'

$V_a = 0.5122V$

P4 complete ionization

(a) $V_{bi} = 0.75V$ 3' 0.9v is wrong!

(b) $\frac{2}{e\varepsilon_s N_d} = \frac{3}{2+0.75}\ 10^{-15} \cdot 10^{30}\ cm^4 F^{-2} V^{-1}$

$N_d = 9.8\times10^{-15}\,cm^{-3}$ 4'

(c) $\phi_n = \frac{kT}{q} \ln\left(\frac{N_c}{N_d}\right) = 0.1V$ 4'

(d) $\phi_{B0} = \phi_n + V_{bi} = 0.85V$ 4'

P5

(a) n type 2'

(b) $C_{ox} = \frac{200\,pF}{2\times10^{-3}} = 10^{-7}\ F/cm^2$

$t_{ox} = \frac{\varepsilon_{ox}}{C_{ox}} = \frac{3.9\cdot 8.85\cdot10^{-14}}{10^{-7}} = 3.45\times10^{-6}\ cm$ 4'

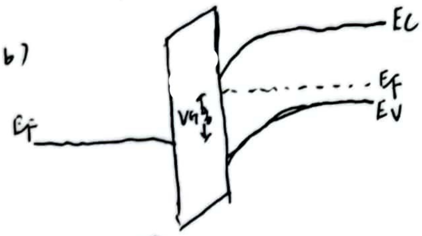
(c) $V_{FB} = \phi_{MS} - \frac{Q_{ss}'}{C_{ox}}$

$Q_{ss}' = 3\times10^{-8}\ C/cm^2$ or $6\times10^{-11}\ C$ / $\cancel{2.75\times10^{11}}$ $1.875\times10^{11}/cm^2$ 4'

P6

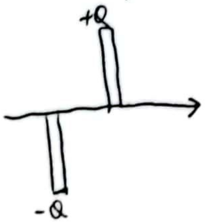
(a) p type 2'

(b)



5'

(c)



5'

(d) $C_{ox} = \frac{100\,pF}{3\times10^{-3}} = 3.33\times10^{-8}\ F/cm^2$

$t_{ox} = \frac{\varepsilon_{ox}}{C_{ox}} = \frac{3.9\times8.85\times10^{-14}}{3.33\times10^{-8}} = 1.04\times10^{-5}\ cm$ 3'

(e) $C_{min} = \frac{\varepsilon_{ox}}{t_{ox} + \left(\frac{\varepsilon_{ox}}{\varepsilon_s}\right) x_{dT}} = \frac{20\,pF}{3\times10^{-3}\ cm^2}$

$x_{dT} = 1.24\times10^{-4}\ cm$

$x_{dT} = \left(\frac{4\varepsilon_s\phi_{fp}}{eN_a}\right)^{\frac{1}{2}}$, $\phi_{fp} = V_t \ln\frac{N_a}{n_i}$. 300k, complete ionization

$N_a = 4.5\times10^{14}\ cm^{-3}$ 8'

7 300k, complete ionization

(a) $\phi_{fn} = V_t \ln\frac{N_d}{n_i} = 0.288\ V$ 4'

$x_{dT} = \left(\frac{4\varepsilon_s\phi_{fn}}{eN_d}\right)^{\frac{1}{2}} = \sqrt{\frac{4\times11.7\times8.85\times10^{-14}\cdot0.288}{1.6\times10^{-19}\cdot10^{15}}} = 8.63\times10^{-5}\ cm$

(b) $V_{TP} = \left(-eN_d x_{dT} - Q_{ss}'q\right)\frac{t_{ox}}{\varepsilon_{ox}} + \phi_{ms} - 2\phi_{fn}$

$= -1.07\ V$

8'

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