金氧半電容元件 作業一 112,9,19 學號:1070729 姓名:蔡明軒

Si參數: electron affinity = 4.15 eV, E_g = 1.12 eV, $\epsilon_{Si} = 11.9\epsilon_0$, $\epsilon_0 = 8.85\times10^{-14}$ F/cm,
常溫下 $kT/q = 0.0259$ V, $n_i = 1.5\times10^{10}\,cm^{-3}$, 假設 $E_i = \frac{1}{2}(E_C + E_V)$ 成立
金屬Al: $q\phi_m = 4.1$ eV
SiO_2 參數: $\epsilon_{SiO_2} = 3.9\epsilon_0$, 厚度 d_{ox}, 假設 $Q_m = Q_{ot} = Q_f = Q_{it} = 0$
給予偏壓 V_G 時 $V_G = V_{FB} + V_{ox} + \psi_S = V_{FB} - \frac{Q_S}{C_{ox}} + \psi_S$

1. MOS(n)元件 $N_D = 1\times10^{14}\,cm^{-3}$, 其 V_{FB} = -0.382 (V); $N_D = 1\times10^{16}\,cm^{-3}$, 其 V_{FB} = -0.263 (V); MOS(p)元件, $N_A = 1\times10^{14}\,cm^{-3}$, 其 V_{FB} = -0.838 (V), 若 $N_A = 1\times10^{16}\,cm^{-3}$, 其 V_{FB} = -0.957 (V)。
2. MOS(p)元件, 對於 $N_A = 1\times10^{14}$ 及 $N_A = 1\times10^{16}\,cm^{-3}$ 兩種情形, 假設理論公式在 E_F 接近 E_V 及 E_C 時仍照常引用, 請在同一圖中繪出 ψ_S 由 $-(0.56-|\phi_B|)$ 至 $+(0.56+|\phi_B|)$ 範圍內之 $\log|Q_S|$ 對 ψ_S 分布曲線(六小題計)
3. MOS(p)元件, $N_A = 1\times10^{14}\,cm^{-3}$, 對於 d_{ox} = 500Å 及 800Å 兩種情形請在同一圖中繪出 ψ_S 由 $-(0.56-|\phi_B|)$ 至 $+(0.56+|\phi_B|)$ 範圍內之 V_G 對 ψ_S 分布曲線(六小題計)
4. MOS(p)元件, $N_A = 1\times10^{14}\,cm^{-3}$, d_{ox} = 800Å, 當偏壓使得 Si 表面達 intrinsic 時, ψ_S = 0.228, 此時之 V_G = -0.5496。
5. MOS(n)元件, $N_D = 1\times10^{14}\,cm^{-3}$, d_{ox} = 800Å, 當偏壓使得 Si 表面達 intrinsic 時, ψ_S = -0.228, 此時之 V_G = -0.6704。

(請於 112,9,26 前將 pdf 檔上傳 NTU COOL 繳交, 逾期不收! 演算過程請一併附上, 擱請填寫答案!)

1.

$Q_m = Q_{ot} = Q_f = Q_{it} = 0$

$\Rightarrow q\phi_{ms} = V_{FB}$

$q\phi_m = 4.1\ (eV)$

$q\phi_s = q\chi_{si} + \frac{1}{2}E_g - kT \ln \frac{N_D}{n_i}$

$\Rightarrow q\phi_s = 4.15 + 0.56 - 0.0259 \ln \frac{10^{14}}{1.5\times10^{10}}$

$\Rightarrow q\phi_s = 4.482\ (eV)$

$V_{FB} = q\phi_{ms} = q\phi_m - q\phi_s = -0.382\ (V)$ //

$N_D = 10^{16}\ (cm^{-3})$

$q\phi_s = 4.15 + 0.56 - 0.0259 \ln \frac{10^{16}}{1.5\times10^{10}}$

$\Rightarrow q\phi_s = 4.363\ (eV)$

$V_{FB} = 4.1 - 4.363 = -0.263\ (V)$ //

$N_A = 10^{14}\ (cm^{-3})$

$q\phi_s = 4.15 + 0.56 + 0.0259 \ln \frac{10^{14}}{1.5\times10^{10}}$

$\Rightarrow q\phi_s = 4.938\ (eV)$

$V_{FB} = 4.1 - 4.938 = -0.838\ (V)$ //

$N_A = 10^{16}\ (cm^{-3})$

$q\phi_s = 4.15 + 0.56 + 0.0259 \ln \frac{10^{16}}{1.5\times10^{10}}$

$\Rightarrow q\phi_s = 5.057\ (eV)$

$V_{FB} = 4.1 - 5.057 = -0.957\ (V)$ //

2.

$N_A = 10^{14}$

$q\phi_B = E_F - E_i = 0.0259 \ln \frac{N_A}{n_i}$

$\Rightarrow \phi_B = -0.228\,(V)$

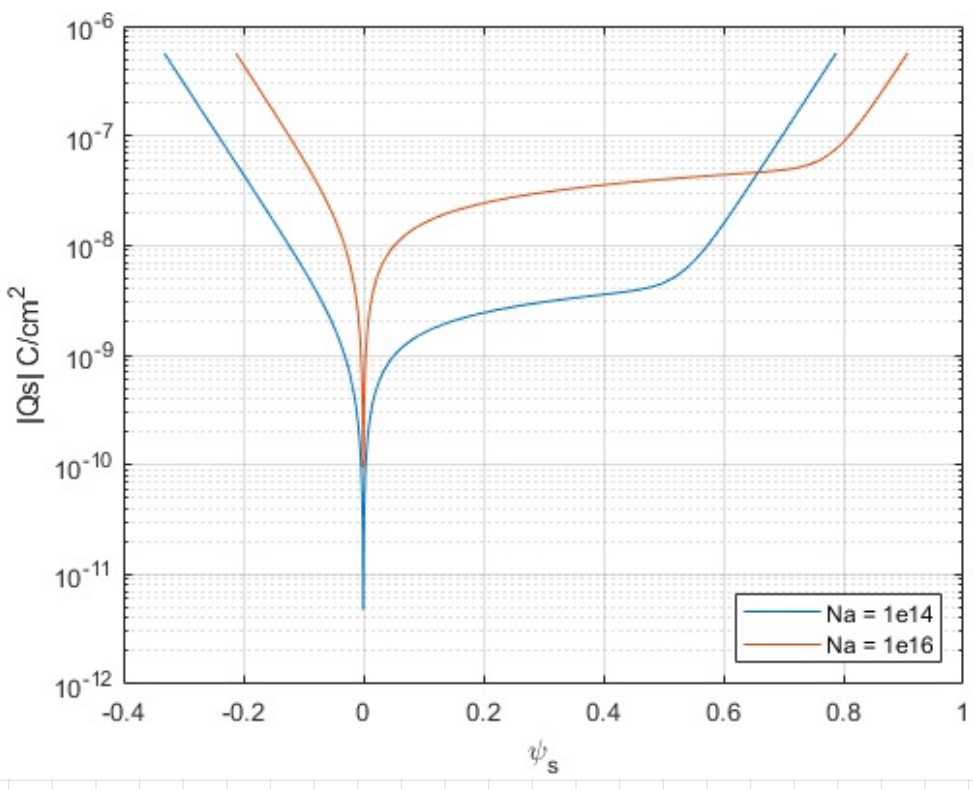
$N_A = 10^{16}$

$\phi_B = 0.0259 \ln \frac{N_A}{n_i} = -0.3474\,(V)$

$\lambda_i = \left[\frac{\epsilon_s kT}{2q^2 n_i}\right]^{0.5} = 0.0024\ (cm)$

$F_S = \mathrm{sign}(u_b - u_s) \frac{kT}{q\lambda_i} F(u_s, u_B)$

```
clear all
% Parameter
eps_si = 11.9 * 8.85 * 10^-14;
eps_sio2 = 3.9 * 8.85 * 10^-14;
ni = 1.5 * 10^10;
K = 1.38 * 10^-23;
T = 300;
KT = 0.0259;
q = 1.6 * 10^-19;
q_phi_m = 4.1;
q_x_si = 4.15;
eg_si = 1.12;
phi_B1 = -log(10^14 / (1.5*10^10)) * 0.0259;
phi_B2 = -log(10^16 / (1.5*10^10)) * 0.0259;
% Set x domain for na1 condition
x1_max = 0.56 + abs(phi_B1);
x1_min = -(0.56 - abs(phi_B1));
x1 = x1_min : x1_max / 1000 : x1_max;
% Formula reference for na2 condition
x2_max = 0.56 + abs(phi_B2);
x2_min = -(0.56 - abs(phi_B2));
x2 = x2_min : x2_max / 1000 : x2_max;
% Formula reference for na1 condition
phi_s1=x1+phi_B1;
us1=phi_s1/KT;
ub1=phi_B1/KT;
% Formula reference for na2 condition
phi_s2=x2+phi_B2;
us2=phi_s2/KT;
ub2=phi_B2/KT;
% Calculate na1 condition
na1 = 1e14;
lambda_p1 = (eps_si * KT / (2 * q * ni))^0.5;
Fs1= sign(ub1-us1) .* (2^0.5) * KT /  lambda_p1 .* ((ub1 - us1) * sinh(ub1) - (cosh(ub1) - cosh(us1))).^0.5;
Qs1 = eps_si * Fs1;
% Calculate na2 condition
na2 = 1e16;
lambda_p2 = (eps_si * KT / (2 * q * ni))^0.5;
Fs2 = sign(ub2-us2) .* (2^0.5) * KT / lambda_p2 .* ((ub2 - us2) * sinh(ub2) - (cosh(ub2) - cosh(us2))).^0.5;
Qs2 = eps_si * Fs2;
% Draw plot
semilogy(x1 , abs(Qs1) , x2 , abs(Qs2))
% Plot tag
legend({'Na = 1e14','Na = 1e16'},'Location','southeast')
xlabel('\psi_s');
ylabel('|Qs| C/cm^2');
```



3.

```
clear all
% Parameter
eps_si = 11.9 * 8.85 * 10^-14;
eps_sio2 = 3.9 * 8.85 * 10^-14;
ni = 1.5 * 10^10;
K = 1.38 * 10^-23;
T = 300;
KT = 0.0259;
q = 1.6 * 10^-19;
q_phi_m = 4.1;
q_x_si = 4.15;
eg_si = 1.12;
phi_B = -log(10^14 / ni) * 0.0259;
na = 1e14;
% Calculate Vfb
q_phi_s = q_x_si + eg_si/2 + KT * log(na / ni);
Vfb = q_phi_m - q_phi_s;
% Set x domain
x_max = 0.56 + abs(phi_B);
x_min = - (0.56 - abs(phi_B));
x = x_min : x_max / 1000 : x_max;
% Formula reference
phi_s=x+phi_B;
us=phi_s/KT;
ub=phi_B/KT;
% Calculate dox1 condition
dox1 = 5e-6;
Cox1 = eps_sio2 / dox1;
lambda_p1 = (eps_si * KT / (2 * q * ni))^0.5;
Fs1= sign(ub-us).* (2^0.5) * KT /  lambda_p1 .* ((ub - us) * sinh(ub) - (cosh(ub) - cosh(us))).^0.5;
Qs1 = eps_si * Fs1;
Vg1 = Vfb - Qs1 / Cox1 + x;
% Calculate dox2 condition
dox2 = 8e-6;
Cox2 = eps_sio2 / dox2;
lambda_p1 = (eps_si * KT / (2 * q * ni))^0.5;
Fs2 =sign(ub-us).* (2^0.5) * KT / lambda_p1 .* ((ub - us) * sinh(ub) - (cosh(ub) - cosh(us))).^0.5;
Qs2 = eps_si * Fs2;
Vg2 = Vfb - Qs2 / Cox2 + x;
% Draw plot
hold on
 plot(x , Vg1)
 plot(x , Vg2)
hold off
legend({'dox = 500 Å','dox = 800 Å'},'Location','southwest')
xlabel('\psi_s');
ylabel('Vg');
```

$\phi_m = 4.1$

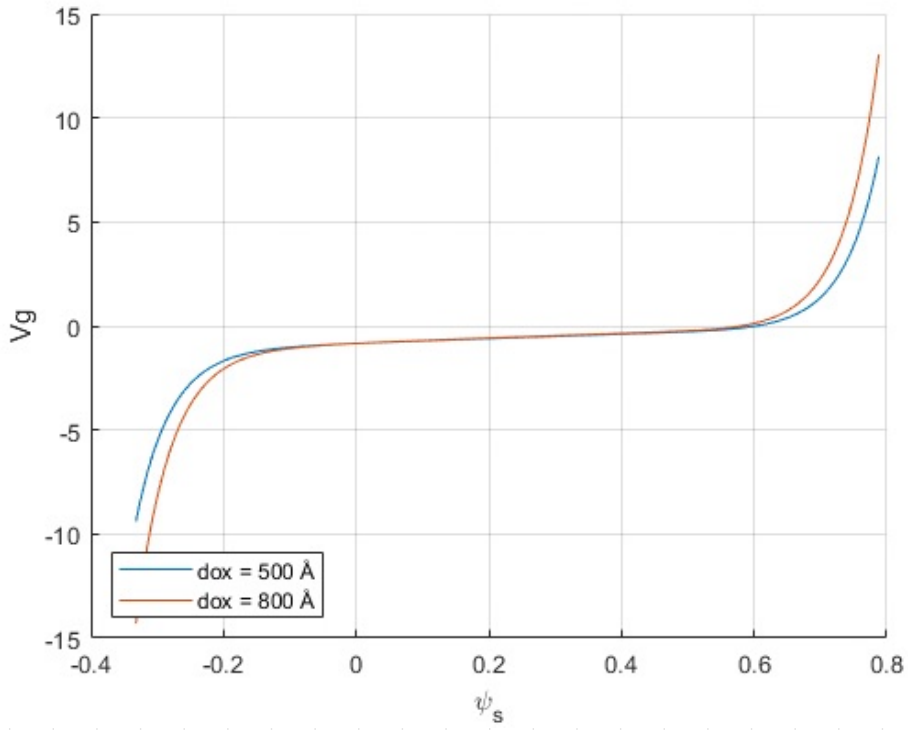
$\phi_S = 4.15 + 0.56 + |KT| \ln \frac{N_a}{n_i}$

$= 4.9380$

$V_{FB} = \phi_m - \phi_S = -0.838$

$C_{ox} = \frac{\varepsilon_{SiO_2}}{dox} = 6.9 \times 10^{-8}$ ($dox = 500\text{Å}$)

4.3×10^{-8} ($dox = 800\text{Å}$)



4.

$d_{ox} = 800\text{Å}$

$N_A = 10^{14}\ cm^{-3}$

intrinsic $\Rightarrow \psi_S = |\phi_B|$

$\Rightarrow \phi_B = -0.228\ (V)$

$\Rightarrow \psi_S = 0.228\ (V)$

$V_{FB} = -0.838\ (V)$

$\psi_S = \phi_S - \phi_B \Rightarrow \phi_S = 0$

$C_{ox} = \frac{\epsilon}{d_{ox}} = \frac{3.9 \times 8.85 \times 10^{-14}}{8 \times 10^{-6}}$

$= 4.314 \times 10^{-8}$

$u_S = \frac{\phi_S}{kT} = 0$

$u_B = \frac{\phi_B}{kT} = -8.831$

$F_S = -2.476 \times 10^3$

$Q_S = \epsilon_S F_S = -2.608 \times 10^{-9}$

$V_g = V_{FB} - \frac{Q_S}{C_{ox}} + \psi_S$

$= -0.382 + \frac{2.608 \times 10^{-9}}{4.314 \times 10^{-8}} + 0.228$

$= -0.5496$ //

5.

$N_D = 10^{14}$

$d_{ox} = 800\text{Å}$

$V_{FB} = -0.382$

$\psi_S = |\phi_B|$

$\phi_B = E_F - E_i = kT \ln \frac{N_D}{n_i}$

$\Rightarrow \phi_B = 0.228$

$\Rightarrow \psi_S = -0.228$

$\phi_B - \phi_S = \psi_S$

$\Rightarrow \phi_S = 0$

$C_{ox} = 4.314 \times 10^{-8}$

$u_S = \frac{q\phi_S}{kT} = 0$

$u_B = \frac{q\phi_S}{kT} = 8.831$

$F_S = 2.4759 \times 10^3$

$Q_S = \epsilon_S F_S = 2.6075 \times 10^{-9}$

$V_g = V_{FB} - \frac{Q_S}{C_{ox}} + \psi_S$

$\Rightarrow V_g = -0.6704\ (V)$ //