金氧半電容元件 作業三 112, 11, 21 學號: R11941039 姓名: 蔡明軒

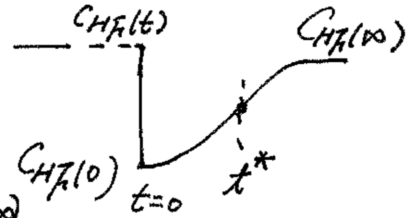
1. 利用高低頻 C-V 求 D_{it}, 已知 MOS(p), $N_A = 4\times10^{14}\,cm^{-3}$, $d_{ox} = 250\,Å$, $\epsilon_{SiO_2} = 3.9\epsilon_0$, $\epsilon_{Si} = 11.9\epsilon_0$, 於某 depletion 區 $C_{HF}/C_{ox} = 0.55$, $C_{LF}/C_{ox} = 0.6$, 其相對應之 $W_D =$ <u>6.2413×10^{-6} (cm)</u> $\psi_s =$ <u>0.0012 (V)</u>, $E_t - E_i =$ <u>0.2651 (V)</u>, $D_{it} =$ <u>2×10^{11} ($cm^{-2}\cdot eV^{-1}$)</u>。

2. 利用 $C_{HF}(t)$ 暫態分析 emission, 在 SiO_2/Si 界面 $E_T = E_c - E_t = 0.3\,eV$ 能階 trap, 已知 $\sigma_n = 2\times10^{-15}\,cm^2$, $v_{th} = 10^7\,cm/s$, $g = 1$, Si 之 $N_c = 2.8\times10^{19}\,cm^{-3}$, 對 MOS(n) 元件, 該 trap 之 $e_n =$ <u>5.221×10^{6} (1/s)</u>, emission time constant $\tau_e =$ <u>1.9154×10^{-7} (s)</u> 先填滿電子, 再偏壓至 depletion 使其 emission, 於 $t = 5\times10^{-8}$ sec 時 $f(t) =$ <u>0.7702</u>。

3. 利用高頻 $C_m = C_{HF}$ 來呈現不均勻 doping 濃度 $N(W)$, 已知 MOS(p) $d_{ox} = 250\,Å$, $\epsilon_{Si} = 11.9\epsilon_0$, $\epsilon_{SiO_2} = 3.9\epsilon_0$, 當 $C_m/C_{ox} = 0.55$ 時, $N(W) = 1\times10^{15}\,cm^{-3}$,

- 若 $D_{it} = 0$, 其 $\frac{d}{dV_{G0}}\left(\frac{C_{ox}}{C_m}\right) =$ <u>-62.2140</u>, $\frac{d}{dV_{G0}}\left(\frac{C_{ox}}{C_m}\right)^2 =$ <u>-226.2328</u>。
- 若 $D_{it} \neq 0$, 且 $C_{LF}/C_{ox} = 0.6$, 其 $\frac{d}{dV_G}\left(\frac{C_{ox}}{C_m}\right) =$ <u>-55.3013</u>, $\frac{d}{dV_G}\left(\frac{C_{ox}}{C_m}\right)^2 =$ <u>-201.0958</u>。

4. MOS(p) 元件參數同題 1, 利用 Zerbst relation 分析 $C_{HF}(t)$ 如右圖, 已知 $t\to\infty$ 時, $\psi_s \simeq 2|\phi_B|$,



$t=0$ 時 $C_{HF}(0) = 0.18\,C_{HF}(\infty)$, 於 t^* 時 $C_{HF}(t^*) = 0.38\,C_{HF}(\infty)$, $n_i = 1.5\times10^{10}\,cm^{-3}$, $\tau = 40\,\mu sec$, 求 t^* 處之 $\frac{dN_I(t^*)}{dt} =$ <u>$8.5314\times10^{10}/cm^2\cdot s$</u>, 空乏區 $\frac{W(t^*)}{W(\infty)} =$ <u>2.726</u>, $\frac{d}{dt}\left(\frac{C_{ox}}{C_{HF}}\right) =$ <u>-0.58 ($\frac{1}{s}$)</u>, $\frac{d}{dt}\left(\frac{C_{ox}}{C_{HF}}\right)^2 =$ <u>-55.92 (s^{-1})</u>。

5. MOS(p), $d_{ox} = 250\,Å$, 內含 mobile charge $Q_m/q = 6\times10^{12}\,cm^{-2}$, 利用 bias-temperature 來回趕動 Q_m, 其 CV 最大平移量 $|\Delta V_{FB}|_{max} =$ <u>6.9535 (V)</u>, 若某次量測得到 $|\Delta V_{FB}| = \frac{1}{4}|\Delta V_{FB}|_{max}$, 則 Q_m 之 $\bar{x} =$ <u>6.25×10^{-7} (cm)</u>, 以 TVS 測電流, 令 $\frac{dV_G}{dt} = 5\,V/s$, 則 J-V peak 面積 = <u>4×10^{-6} ($\frac{V}{s}\cdot cm^{2}$)</u>。

(請於 112, 11, 28 前將 pdf 檔上傳繳交, 逾期不收!)

1.

depletion $C_S(\psi_S) \simeq C_D$

$$\frac{C_{LF}}{C_{ox}} = 0.55 = \frac{C_D}{C_{ox}+C_D}$$

$$C_{ox} = \frac{\varepsilon_{SiO_2}}{d_{ox}} = 1.3806\times10^{-7}\,(F/cm)$$

$$\frac{C_D}{1.3806\times10^{-7}+C_D} = 0.55$$

$$\Rightarrow C_D = \frac{1.3806\times10^{-7}\times0.55}{0.45}$$

$$\Rightarrow C_D = 1.6874\times10^{-7}\,(F/cm)$$

$$W_D = \frac{\varepsilon_S}{C_D} = 6.2413\times10^{-6}\,(cm)$$

$$W_D = \sqrt{\frac{2\varepsilon_S\psi_S}{qN_A}} \Rightarrow \psi_S = \frac{W_D^2 qN_A}{2\varepsilon_S}$$

$$\Rightarrow \psi_S = \boxed{0.0012\,(V)}$$

$$\frac{C_{LF}}{C_{ox}} = \frac{C_{it}+C_D}{C_{it}+C_{ox}+C_D} = 0.6$$

$$\Rightarrow C_{it}+C_D = 0.6C_{it}+0.6C_{ox}+0.6C_D$$

$$\Rightarrow C_{it} = \frac{0.6C_{ox}-0.4C_D}{0.4}$$

$$\Rightarrow C_{it} = 3.835\times10^{-8}\,(F/cm)$$

$$D_{it} = \frac{C_{it}}{q} = \boxed{2.5\times10^{11}\,(cm^{-2}\cdot eV^{-1})}$$

$$E_t - E_i = \psi_S + \phi_B$$

$$\Rightarrow \phi_B = -kT\ln\frac{N_A}{n_i}$$

$$\Rightarrow E_t - E_i = \boxed{-0.2658\,(V)}$$

2.

$$e_n = q\times V_{th}\times\sigma_n\times N_c\times e^{-\frac{E_T}{kT}}$$

$$\Rightarrow e_n = \boxed{5.221\times10^{6}}\,(\tfrac{1}{s})$$

$$\tau_e = \frac{1}{e_n} = \boxed{1.9154\times10^{-7}}\,(s)$$

$$f(t) = e^{-(e_n t)}$$

$$\Rightarrow f(t) = \boxed{0.7702}$$

3.

$$N(W) = -2\left\{ q\epsilon_s \frac{d}{dV_{G0}} \left(\frac{1}{C_{HF}^2} \right) \right\}^{-1} = 1\times10^{15} \ (cm^{-3})$$

$$C_{HF} = 0.55\, C_{ox} = C_m$$

$$\frac{d}{dV_{G0}} \left(\frac{1}{C_m^2} \right) = -2\left[q\epsilon_s (1\times10^{15}) \right]^{-1}$$

$$\Rightarrow \frac{d}{dV_{G0}} \left(\frac{1}{C_m^2} \right) = 1.1869\times10^{16}$$

$$\frac{d}{dV_{G0}} \left(\frac{C_{ox}}{C_m} \right)^2 = 1.1869\times10^{16} \times C_{ox}^2$$

$$\Rightarrow \frac{d}{dV_{G0}} \left(\frac{C_{ox}}{C_m} \right)^2 = \boxed{-226.2328}$$

$$\frac{d}{dV_{G0}} \left(\frac{C_{ox}}{C_m} \right) = \frac{C_m}{C_{ox}} \times \frac{d}{dV_{G0}} \left(\frac{C_{ox}}{C_m} \right)^2 \times \frac{1}{2} = \boxed{-62.2140}$$

Ditto $\Rightarrow N(W) = -2\left\{ \frac{1 - C_{LF}/C_{ox}}{1 - C_{HF}/C_{ox}} \right] \left[q\epsilon_s \frac{d}{dV_G} \left(\frac{1}{C_{HF}^2} \right) \right]^{-1} = 1\times10^{15}$

$$\Rightarrow \frac{d}{dV_G} \left(\frac{1}{C_m^2} \right) = -2\left[\frac{1 - C_{LF}/C_{ox}}{1 - C_{HF}/C_{ox}} \right] \left[q\epsilon_s (1\times10^{15}) \right]^{-1} = -1.055\times10^{16}$$

$$\frac{d}{dV_G} \left(\frac{C_{ox}}{C_m} \right)^2 = -1.055\times10^{16} \times C_{ox}^2 = \boxed{-201.0958}$$

$$\frac{d}{dV_G} \left(\frac{C_{ox}}{C_m} \right) = \frac{C_m}{C_{ox}} \times \frac{d}{dV_{G0}} \left(\frac{C_{ox}}{C_m} \right)^2 \times \frac{1}{2} = \boxed{-55.3013}$$

4.

$$\frac{dN_I}{dt^*} = \frac{n_i \epsilon_s}{\tau}\left[\frac{1}{C_{HF}(t^*)} - \frac{1}{C_{HF}(\infty)}\right]$$

$$\Rightarrow \frac{dN_I}{dt^*} = \frac{n_i}{\tau}\left[\frac{1}{0.38\,C_{HF}(\infty)} - \frac{1}{C_{HF}(\infty)}\right]$$

$t \to \infty$, $\psi_s = 2|\phi_B| = 0.2640 \times 2 = 0.5280\ (V)$

$$W_D = \sqrt{\frac{2\epsilon_s \psi_s}{q N_A}} = 1.3181 \times 10^{-4}\ (cm)$$

$$C_D = \frac{\epsilon_s}{W_D} = 7.9899 \times 10^{-9}\ (F/cm)$$

$$C_{ox} = 1.3806 \times 10^{-7}\ (F/cm)$$

$$C_{HF} = \left[\frac{1}{C_{ox}} + \frac{1}{C_D}\right]^{-1} = 7.5528 \times 10^{-9}\ (F/cm)$$

$$\frac{dN_I}{dt^*} = \boxed{8.5314 \times 10^{10}\ /cm^2 \cdot s}$$

$$W(t^*) = \epsilon_s\left[\frac{1}{C_{HF}(t^*)} - \frac{1}{C_{ox}}\right]$$

$$\Rightarrow W(t^*) = \epsilon_s\left[\frac{1}{0.38\,C_{HF}(\infty)} - \frac{1}{C_{ox}}\right]$$

$$\Rightarrow W(t^*) = 3.5931 \times 10^{-4}\ (cm)$$

$$\frac{W(t^*)}{W(\infty)} = \frac{3.5931 \times 10^{-4}}{1.3181 \times 10^{-4}} = \boxed{2.726}$$

$$N_B(W) = N_A = 4 \times 10^{14}\ cm^{-3}$$

$$\frac{dN_I}{dt} = \frac{-N_B(W)\,\epsilon_s}{2C_{ox}} \frac{d}{dt}\left(\frac{C_{ox}}{C_{HF}}\right)^2$$

$$\Rightarrow \frac{d}{dt}\left(\frac{C_{ox}}{C_{HF}}\right)^2 = \frac{dN_I}{dt} \times -\frac{2C_{ox}}{N_B(W)\,\epsilon_s}$$

$$\Rightarrow \frac{d}{dt}\left(\frac{C_{ox}}{C_{HF}}\right)^2 = \boxed{-55.92}$$

$$\frac{d}{dt}\left(\frac{C_{ox}}{C_{HF}}\right) = \frac{C_{HF}}{C_{ox}} \times \frac{d}{dt}\left(\frac{C_{ox}}{C_{HF}}\right)^2 \times \frac{1}{2}$$

$$\Rightarrow \frac{d}{dt}\left(\frac{C_{ox}}{C_{HF}}\right) = \boxed{-0.58}$$

5.

$$C_{ox} = \frac{\varepsilon_{SiO_2}}{d_{ox}} = 1.3806\times10^{-7} \,(F/cm)$$

$$Q_m = \frac{Q_m}{q} \times q = 9.6\times10^{-7} \,(cm^{-2}\cdot eV)$$

$$\Delta Q_{eff} = Q_m = 9.6\times10^{-7} \,(cm^{-2}\cdot eV)$$

$$|\Delta V_{FB}|_{max} = \frac{\Delta Q_{eff}}{C_{ox}} = \boxed{6.9535 \,(V)}$$

$$|\Delta V_{FB}| = \frac{1}{4}|\Delta V_{FB}|_{max} \Rightarrow \bar{x} = \frac{1}{4}x_0$$

$$\Rightarrow \bar{x} = \frac{1}{4}\times2.5\times10^{-6} = \boxed{6.25\times10^{-7} \,(cm)}$$

$$area = V\times q\times N_m = 5\times1.6\times10^{-19}\times\frac{Q_m}{q}$$

$$\Rightarrow area = \boxed{4\times10^{-6} \,(\tfrac{V}{s}\cdot cm^{-2})}$$