ELE 8084 Assignment 1

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① Individual Parameters//

Substrate: (100)

Dry Time: 100mins

Dry Temp: 1050°C

Wet Time: 25mins

Wet Temp: 900°C

a) Thickness After Dry Oxidation Step.

→ Derive the linear rate constant. (B/A)

$$B/A = D_0 \exp\left(\frac{-E_A}{kT}\right)$$

For our substrate, $D_0 = 3.7 \times 10^6$ and $E_A = 2.00eV$

and $T = 1323k$

$$\therefore \quad B/A = 3.7 \times 10^6 \exp\left(\frac{-2.00}{8.62 \times 10^{-5} \times 1323}\right)$$

$$B/A = 0.09 \mu m/hr$$

→ Now we calculate the parabolic Rate constant B.

$$B = D_0 \exp\left(\frac{-E_A}{kT}\right)$$

where $D_0 = 772\ \mu m^2/hr$ and $E_A = 1.23\,eV$

$$\therefore \quad B = 772 \exp\left(\frac{-1.23}{8.85\times10^{-5}\times 1323}\right)$$

$$B = 0.02\ \mu m^2/hr$$

→ Now, we calculate τ using $X_i = 0.025\ \mu m$

$$\tau = \frac{1}{B}\left(X_i^2 + AX_i\right)$$

where $A = 0.22$

$$\tau = \frac{1}{0.02}\left(0.025^2 + (0.22\times0.025)\right)$$

$$\tau = 0.31\,hr \quad // \quad t+\tau = 1.98\,hrs$$

→ Now, we calculate oxide thickness:

$$X_0 = \frac{A}{2}\left[\left(1 + \left(\frac{4B}{A^2}\right)(t+\tau)\right)^{\frac{1}{2}} - 1\right]$$

$$X_o = 0.11\left[(4.28)^{\frac{1}{2}} - 1\right]$$

$$X_o = 0.12\mu m = 120nm$$

Answer to Part (a)

(b) → Moving to wet oxidation step:

→ Follow same overall process.

→ linear Rate constant:

$$B/A = D_o \exp\left(\frac{-E_A}{kT}\right)$$

where $D_o = 9.7\times10^7$, $E_A = 2.05$ and $T = 1173k$

$$B/A = 0.26\ \mu m/hr$$

→ Now get parabolic Rate constant:

$$B = D_o \exp\left(\frac{-E_A}{kT}\right)$$

Were $D_o = 386$ and $E_A = 0.78$

$$B = 0.21\ \mu m^2/hr$$

Thus $A = 0.81$

→ Now we calculate the oxide thickness in Areas that are etched. Ie $X_i = 0, \tau = 0$

$B/A = 0.26$, $B = 0.21$, $A = 0.81$, $t = 0.42$

$$X_0 = \frac{0.81}{2}\left[\left(1 + \frac{4(0.21)}{(0.81^2)}(0.42)\right)^{\frac{1}{2}} - 1\right]$$

$X_0 = 0.097\mu m = 97nm$

→ Now we find the thickness in regions that have not been etched:

X_i is our depth after Dry oxidation ($0.21\mu m$)

→ find τ

$$\tau = \frac{1}{0.21}\left(0.12^2 + (0.81 \times 0.12)\right)$$

$\tau = 0.53$ hrs → $t + \tau = 0.95$ hrs

and so, X_0 can be found

$$X_0 = \frac{0.81}{2}\left[\left(1 + \frac{4(0.21)}{(0.81^2)}(0.95)\right)^{\frac{1}{2}} - 1\right]$$

$X_0 = 0.198\mu m = 198nm$

o To Summarise :

- After the initial Dry oxidation, the oxide thickness is 120nm

o After wet oxidation, and in regions that are etched, the oxide thickness is 97nm

o After wet oxidation, and in regions that are not etched, the oxide thickness is 198nm

o Step height is reduced to ~~100~~ 101nm

(2)

→ We need to iterate through each element.

<u>Element 1</u>

$$\frac{1}{R_E} = \frac{1}{559} - \frac{1}{953} \longrightarrow R_E = 1352\,\Omega$$

→ Now, we calculate the resistivity ρ_e:

$$\rho_e = R_E \times t = 1352 \times 200 \times 10^{-7}$$

$$\rho_e = 0.027\,\Omega\,cm$$

→ We can make a first guess at μ_n as

we know the initial concentration of $1 \times 10^{16}\,cm^{-3}$

→ on the graph, a total dopant concentration

of $10^{16}\,cm^{-3}$ equates to a $\mu_n = 1050$

→ subbing into our equation:

$$n = \frac{1}{q\mu_n\rho_e} = \frac{1}{1.6\times10^{-19} \times 1050 \times 0.027}$$

$$n = 2.2 \times 10^{17}\,cm^{-3}$$

→ From the graph, this is not valid and so we need to iterate again.

→ If we go to $n = 2.2\times10^{17}$ on graph and ~~read~~ Extrapolate to μ_n, we get $\mu_n = 500$

→ Repeating calculation :

$$n = \frac{1}{1.6\times10^{-19}\times500\times0.027}$$

$$n = 4.63\times10^{17}\,cm^{-3}$$

→ This still isn't valid, so we repeat.

We go $\mu_n = 400$

$$\therefore n = 5.79\times10^{17}\,cm^{-3}$$

We go $\mu_n = 350$

$$\therefore n = 6.61\times10^{17}\,cm^{-3}$$

At $\mu_n = 350$, $n = 6.61\times10^{17}\,cm^{-3}$ the results have converged.

The first element concentration (Depth = 100nm)

$$= 6.61\times10^{-17}\,cm^{-3}$$

2nd Element

$$\frac{1}{R_E} = \frac{1}{953} - \frac{1}{2169} \longrightarrow R_E = 1700\ \Omega/\square$$

$\rightarrow$ Resistivity ρ_e

$$\rho_e = 1700 \times 200 \times 10^{-7} = 0.034\ \Omega cm$$

Iterate, start at $\mu_n = 350$

$$n = 5.25 \times 10^{17} cm^{-3} \Rightarrow \text{Not valid}$$

$\mu_n = 400$:

$$n = 4.08 \times 10^{17} cm^{-3} \Rightarrow \text{Not valid}$$

$\mu_n = 450$:

$$n = 4.08 \times 10^{17} cm^{-3} \Rightarrow \text{Valid}$$

∴ 2nd layer concentration (Depth = 300nm)

$$n = 4.08 \times 10^{17} cm^{-3}$$

Element 3

$$\frac{1}{R_E} = \frac{1}{2169} - \frac{1}{7505} \rightarrow R_E = 3051\,\Omega/\square$$

$\rightarrow$ Resistivity ρ_e

$$\rho_e = 3051 \times 200 \times 10^{-7} = 0.061\,\Omega cm$$

Iterating, start with $N_n = 450$

$n = 2.28 \times 10^{17} \Rightarrow$ Not valid.

$N_n = 500$:

$n = 2.05 \times 10^{17} cm^{-3} \Rightarrow$ Not valid

$N_n = 600$:

$n = 1.71 \times 10^{17} cm^{-3} \Rightarrow$ Not Valid

$N_n = 650$:

$n = 1.58 \times 10^{17} cm^{-3} \Rightarrow$ Valid

3rd layer, thickness (500nm)

$$n = 1.58 \times 10^{17} cm^{-3}$$

Element 4

$$\frac{1}{R_E} = \frac{1}{7505} - \frac{1}{54650} \rightarrow R_E = 8700\ \Omega/\square$$

→ Resistivity ρ_e

$$\rho_e = 8700 \times 200 \times 10^{-7} = 0.174\ \Omega cm$$

Iterating, start at $\mu_n = 600$

$$n = 5.99 \times 10^{16}\ cm^{-3} \Rightarrow \text{Not Valid}$$

$\mu_n = 700$

$$n = 5.13 \times 10^{16}\ cm^{-3} \Rightarrow \text{Not Valid}$$

$\mu_n = 800$

$$n = 4.49 \times 10^{16}\ cm^{-3} \rightarrow \text{Not valid}$$

$\mu_n = 900$

$$n = 3.99 \times 10^{16} \rightarrow \text{Valid}$$

4th element conc. (700nm) $= 3.99 \times 10^{16}\ cm^{-3}$

- Element 5 is at the end of the diffusion layer.

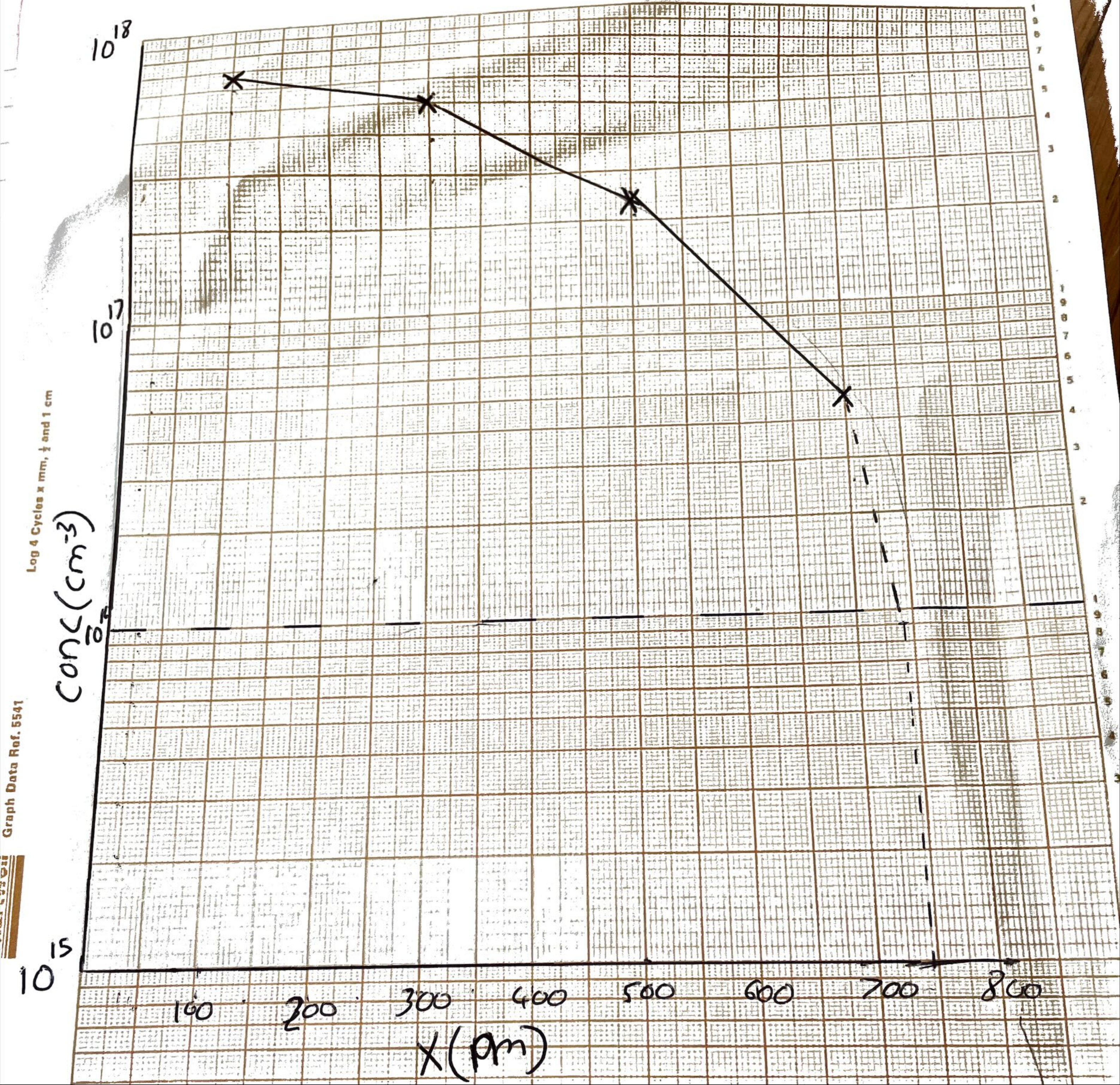
Data Summary

Element	Centre	R_{sheet}	ρ_c	$n\ (cm^{-3})$
1	100	1352	0.027	$6.61 \times 10^{+17}$
2	300	1700	0.034	$4.08 \times 10^{+17}$
3	500	3051	0.061	$1.58 \times 10^{+17}$
4	700	8700	0.174	3.99×10^{16}

→ Plot on graph paper

The junction Depth is the depth where the Dopant concentration is equal to the backround dopant $(1 \times 10^{16} cm^{-3})$

→ We can Estimate the junction Depth to be **~750nm**



10^18
10^17
10^16
10^15
conc (cm^-3)
100
200
300
400
500
600
700
800
X (nm)
Log 4 Cycles x mm, ½ and 1 cm
Graph Data Ref. 5541

③

Individual Parameters:

Oxide: 80nm, Dose: $6 \times 10^{12} cm^{-2}$

Energy: 120keV, Time: 50 mins, Temp: 1000°C

a) Junction Depth immediately after implantation.

o Get Relevent Straggle and Range Data from table.

o At our Energy (120keV), $R_p = 148nm$

and $\Delta R_p = 40nm$

o The junction Depth is the Depth at which our implantation concentration equals the background dopand concentration (2×10^{15})

-> Now, we can solve the Question

=>

$R_p = 148nm = 0.148\,\mu m$

$\Delta R_p = 40nm = 0.04\,\mu m$

→ We can approximate the implanted profile :

$$C_{(x)} = C_p \exp\left(\frac{-(x-R_p)^2}{2\Delta R_p^2}\right)$$

Where : $C_p = \dfrac{Q_T}{\sqrt{2\pi}\,\Delta R_p}$

Calculating C_p from our Straggle Data $\Delta R_p = 40nm$

and dose (Q_T) ≠ $Q_T = 6 \times 10^{12} cm^{-2}$, we get :

$$C_p = \frac{6\times10^{12}\,\mu m}{\sqrt{2\pi}\times 0.04}$$

$$C_p = 5.98\times10^{16} cm^{-3}$$

And Now the full term $C_{(x)}$

$$C_{(x)} = 5.98\times10^{16} \exp\left(\frac{-(0.148-0.148)^2}{2\times(0.04)^2}\right)$$

$$C(x) = 5.98\times10^{16} cm^{-3}$$

→ The junction Depth, with a background doping concentration $2 \times 10^{15}\ cm^{-3}$

We ~~g~~ can get the junction Depth by:

$$X_j = R_p \pm \Delta R_p \sqrt{2 \ln \frac{C_P}{C_B}}$$

$$X_j = 0.148 \pm 0.04 \sqrt{2 \ln \frac{5.98 \times 10^{16}}{2 \times 10^{15}}}$$

$$X_j = 0.148 \pm 2.6\ Nm$$

Two Junctions are formed, ~~at~~ but only one is valid:

$$X_j = 0.148 + 2.6$$

$$X_j = 2.748\ Nm$$

b) Junction Depth after Drive in:

$D_0 = 10.5\ cm^2/s$

$E_A = 3.69eV$

→ We start by calculating the Diffusion coefficients for phosphorus:

$$D = D_0 e^{\left(-\frac{E_A}{kT}\right)}$$

$$D = 10.5 \exp\left(\frac{-3.69}{8.62\times10^{-5}\times1273}\right)$$

$$D = 2.61\times10^{-14}\ cm^2/s$$

Multiplying by the Drive in Time:

$$Dt = 2.61\times10^{-14}\times3000$$

$$Dt = 7.83\times10^{-11}\ cm^2$$

Now we can Equate the concentration Equations:

$$C_B = \frac{Q_T}{\sqrt{2\pi(\Delta R_p^2 + 2Dt)}}\exp\left(\frac{-(x-R_p)^2}{2\Delta R_p^2 + 4Dt}\right)$$

$$2\times10^{15} = \frac{6\times10^{12}}{\sqrt{2\pi(4\times10^{-6})^2 + 2(7.83\times10^{-11})}}\exp\Bigg(\uparrow$$

$$2\times10^{15} = 3.74\times10^{17}\exp\left(-\frac{(x-0.000148)^2}{2((4\times10^{-6})+2(7.83\times10^{-11}))}\right)$$

Now, we need to solve this for x.

$$\frac{2\times10^{15}}{3.74\times10^{17}} = \exp\left(-\frac{(x-0.000148)^2}{2((4\times10^{-6})+2(7.83\times10^{-11}))}\right)$$

$$\ln(0.0053) = -\frac{(x-0.000148)^2}{8\times10^{-6}}$$

$$-4.2\times10^{-5} = -(x-0.000148)(x-0.0001$$

$$-4.2\times10^{-5} = -\left(x^2 - 0.000148x - 0.000148x + 2.19\times10^{-8}\right)$$

$$-4.2\times10^{-5} = -x^2 + 2.19\times10^{-8}$$

$$x = 0.0065\,\text{m} = 6.5\,\text{mm}$$