Homework #5 Solutions

1. (a) $x_0^2 + Ax_0 + B(t+\tau) = 0$

Assume $\tau \cong 0$ $(x_i \cong 0)$ $\qquad B = 7.72\times10^2 \frac{\mu m^2}{h} \exp\left(-\frac{1.23eV}{kT}\right) = 1.05\times10^{-2} \frac{\mu m^2}{h}$

At 1 atm., $\frac{B}{A} = \frac{6.23\times10^6 \mu m/h}{1.68} \exp\left(-\frac{2.0eV}{kT}\right) = 4.5\times10^{-2} \frac{\mu m}{h}$

for 100 (1.68)

$B \propto p_{O_2}$, $\frac{B}{A} \propto P_{O_2}^{0.75}$, so at 0.25 atm: $B = 2.6\times10^{-3} \mu m^2/h$

$\frac{B}{A} = 1.6\times10^{-2} \mu m/h$

$$x_0 = \frac{-A + \sqrt{A^2+4Bt}}{2} \qquad A = \frac{B}{B/A} = 0.16\mu m = 160nm$$

$$= \begin{cases} 0.015\ \mu m \text{ for } t=1h & (150 Å) \\ 0.028\ \mu m \text{ for } t=2h & (280 Å) \end{cases}$$

(b) From TCAD Software, $x_0 = \begin{cases} 267 Å & \text{for } 1h \\ 394 Å & \text{for } 2h \end{cases}$

These thicknesses are substantially larger than hand calculation due to

1) Initial thickness of ~20 Å is assumed

2) Thin oxides are assumed to grow faster than linear-parabolic model indicates as observed experimentally (Figs 6.23 and Eq. 6.37).

3. From Problem #1, TCAD software values should be the most accurate as they include thin oxide kinetics

For first hour, oxidation rate is $\frac{267\text{Å}}{1\,h} = 0.027\,\mu m/h$

For second hour, $\left\langle \frac{dx_o}{dt} \right\rangle = \frac{\Delta x}{\Delta t} = \frac{394\text{Å} - 267\text{Å}}{2h - 1h} = 0.013\,\mu m/h$

From Fig. 11 (in notes), for $\left\langle \frac{dx_o}{dt} \right\rangle = \begin{cases} 0.027\,\frac{\mu m}{h} \\ 0.013\,\frac{\mu m}{h} \end{cases}$ $\quad \frac{\langle D \rangle}{D^*} = \begin{cases} 4.7 \\ 4.0 \end{cases}$

$$\frac{\langle D_p \rangle}{D_p^*} = f_I^P \frac{\langle C_I \rangle}{C_I^*} + (1 - f_I^P) \frac{C_I^*}{\langle C_I \rangle} \qquad \frac{\langle C_I \rangle}{C_I^*} = \begin{cases} 4.94 \\ 4.20 \end{cases}$$

$f_I^P = 0.95 \quad (C_I C_V = C_I^* C_V^*)$

$f_I^{As} = 0.4$

$$\frac{\langle D_{As} \rangle}{D_{As}^*} = 0.4 \left(\frac{\langle C_I \rangle}{C_I^*} \right) + 0.6 \left(\frac{C_I^*}{\langle C_I \rangle} \right) = \begin{cases} 2.10 \\ 1.82 \end{cases}$$

$f_I^{Sb} = 0.05$

$$\frac{\langle D_{Sb} \rangle}{D_{Sb}^*} = 0.05 \left(\frac{\langle C_I \rangle}{C_I^*} \right) + 0.95 \left(\frac{C_I^*}{\langle C_I \rangle} \right) = \begin{cases} 0.44 \\ 0.44 \end{cases}$$

Note above that since $I + V \rightleftharpoons \phi$ is near equil (e.g. fast)

$C_I C_V \approx C_I^* C_V^*$ and $\frac{\langle C_V \rangle}{C_V^*} \cong \frac{C_I^*}{\langle C_I \rangle}$