CHE323/384 Chemical Processes for Micro- and Nanofabrication
Chris Mack, University of Texas at Austin

Homework #3

1. Given the parameters in Table 4.1 and the activation energies in Figures 4.2 and 4.3 of the Campbell textbook (also found in the Lecture 12 notes), determine the Arrhenius coefficients for B and B/A for both wet (640 torr) and dry oxidation.

I used Excel to fit the data in Table 4.1 to the Arrhenius equation. Taking the log of the Arrhenius equation for B, as an example, $\ln(B) = \ln(Ar) - \frac{E_A}{kT}$. Thus, if I plot ln(*B*) versus $1/kT$ the slope will $-E_A$ and the intercept will be ln(*Ar*), where *Ar* is the Arrhenius coefficient I am looking for. Here are the results, in table form.

	Dry B (μm^2/hr)	Dry B/A (μm/hr)	Wet B (μm^2/hr)	Wet B/A (μm/hr)
Ar	1298	7.98×10^6	189	5.79×10^7
E_A (eV)	1.29	2.02	0.71	1.93

Alternately, if I fix the activation energy to be the value found in Campbell figures 4.2 and 4.3, I'll get a slightly different result for Ar. These results are in the following table.

	Dry B (μm^2/hr)	Dry B/A (μm/hr)	Wet B (μm^2/hr)	Wet B/A (μm/hr)
Ar	850	6.64×10^6	197	7.39×10^7
E_A (eV)	1.24	2.0	0.71	1.96

2. Does the oxide thickness at which there is a transition from linear to parabolic rates change if we perform an oxidation at a pressure of 20 atmospheres rather than at 1 atmosphere?

The transition from linear to parabolic regimes occurs at a thickness of A/2. Since A is not a function of pressure, there will be no change in the thickness at which the transition occurs when the pressure is changed.

3. A certain technology requires a gate oxide of 95 nm, and this oxidation will be carried out in dry O_2 at 1000 C. There is no initial oxide on the (111) wafer. What oxidation

time is required? Does this oxidation process end in the linear regime, the parabolic regime, or in between?

From Table 4.2, A = 0.165 μm, B = 0.0117 μm^2/hr, τ = 0.37. Solving the Deal-Grove equation for t_{ox},

$$t_{ox}{}^2 + At_{ox} = B(t+\tau),\quad t = \frac{t_{ox}{}^2 + At_{ox}}{B} - \tau = \frac{0.095^2 + (0.165)(0.095)}{0.0117} - 0.37 = 1.74\,hr$$

Note: one could also use the graphs in Campbell to read off the values of A and B at this temperature.

Since t_{ox} is about the same as A/2, this oxidation process is in between the linear and parabolic regime.

4. Repeat problem 3 for wet oxidation.

From Table 4.2, A = 0.226 μm, B = 0.287 μm^2/hr, τ = 0. Solving the Deal-Grove equation for t_{ox},

$$t_{ox}{}^2 + At_{ox} = B(t+\tau),\quad t = \frac{t_{ox}{}^2 + At_{ox}}{B} - \tau = \frac{0.095^2 + (0.226)(0.095)}{0.287} = 0.11\,hr$$

(Note that a 6 minute oxidation time is too fast to control!!) Since t_{ox} is about the same as A/2, this oxidation process is in between the linear and parabolic regime.

5. Repeat problem 3 for the case where the wafer already contains a 45-nm thick oxide film.

Calculating $\tau = \frac{t_o{}^2 + At_o}{B} = \frac{0.045^2 + (0.165)(0.045)}{0.0117} = 0.81\,hr$. Thus,

$$t = \frac{t_{ox}{}^2 + At_{ox}}{B} - \tau = \frac{0.095^2 + (0.165)(0.095)}{0.0117} - 0.81 = 1.30\,hr$$

Alternately, one could calculate how long it would take to grow a 45-nm thick oxide film, and subtract that time from the answer to problem 3.

$$t_{45nm} = \frac{t_{ox}{}^2 + At_{ox}}{B} - \tau = \frac{0.045^2 + (0.165)(0.045)}{0.0117} - 0.37 = 0.44\,hr$$

$$t = t_{95nm} - t_{45nm} = 1.74 - 0.44 = 1.30\,hr$$