

EE486 Integrated Circuit Fabrication

Homework 3

Due in class on Monday, April 24, 2017

1. According to the Deal Grove model, oxidation kinetics start out linear and become parabolic as the oxidation proceeds. Calculate the oxide thickness at which this transition takes place and plot this versus oxidation temperature.
2. Suppose an oxidation process is used in which (100) wafers are oxidized in O_2 for two hours at $1100^\circ C$, followed by two hours in H_2O at $900^\circ C$, followed by 30 minutes in O_2 at $1200^\circ C$. Use the figures in notes for oxide thickness vs time to estimate the resulting final oxide thickness. Explain how you used these figures to calculate the results of a multi-step oxidation like this.
3. A $1000^\circ C$ oxidation is performed on $\langle 100 \rangle$ lightly-doped silicon in an ambient of 1 part dry O_2 to 4 parts Ar_2 (an inert gas, $p_{O_2} = 0.2$).
 - (a) Using the linear/parabolic model, determine the oxide thickness grown after a 30 minute oxidation and after a 2 hour (total time) oxidation. Assume $x^2/A \propto p_{O_2}^{0.75}$.
 - (b) Compare your results to those given by a Sentaurus simulation and comment on the differences.
4. A uniform oxide layer of $0.4\mu m$ thickness is selectively etched to expose the silicon surface in some locations on a 111 wafer surface. A second oxidation at $1000^\circ C$ in H_2O grows $0.2\mu m$ on the bare silicon. Sketch a cross-section of the SiO_2 across the wafer spanning these two regions, including the position of the Si/ SiO_2 interface.
5. **For EE/MSE 528 students (extra credit for EE/MSE 486).** Consider a system which includes substitutional As^+ and B^- (immobile) and neutral I^0 (mobile). The dopants pair with the neutral I^0 to form mobile pairs. In addition, As and B pair to form a neutral immobile complex. These pairs form via the diffusion of a dopant/interstitial pair to react with the opposite type substitutional dopant, releasing an interstitial. You may ignore vacancy interactions and charging reactions.
 - (a) If the reactions to form dopant/interstitial pairs are fast (but not the reactions to form AsB complex), write a minimal set of continuity equations describing the system. (You do not need to expand the reaction rates and material fluxes)
 - (b) For this system, write an expression for the rate of AsB pair formation in terms of the concentrations of As^+ , B^- and I^0 and the diffusivities and equilibrium constants. Assume diffusion-limited rates with $a = 0.5nm$.
 - (c) Given the following assumptions:
 - i The interstitial concentration is at equilibrium.
 - ii The concentrations of dopant/interstitial pairs are small compared to the concentrations of the dopants.
 - iii The reactions to form AsB are fast.
 - iv The concentration of arsenic is much much larger than that of boron (and thus also AsB pairs).

Derive an expression for the effective diffusivity of boron as a function of the concentrations of As^+ and I^0 , the diffusivities and the equilibrium constants. In other words, what is D_B^{eff} in

$$\frac{\partial C_B^{total}}{\partial t} = -\nabla \cdot D_B^{eff} \nabla C_B^{total}$$