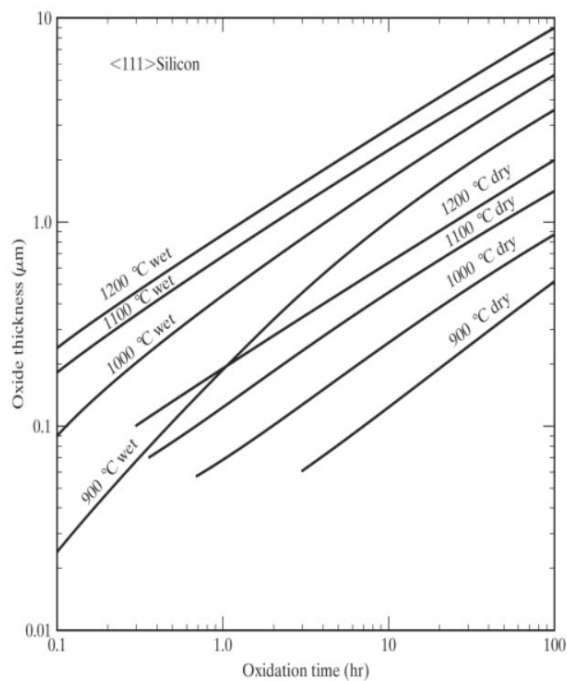
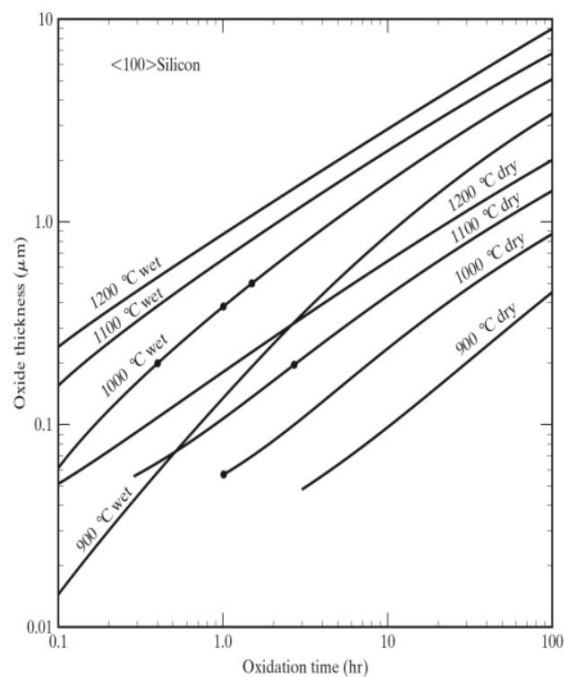


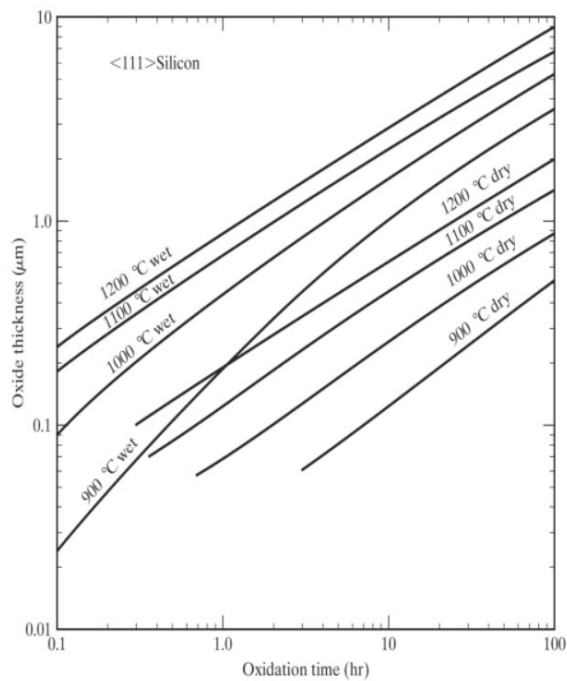
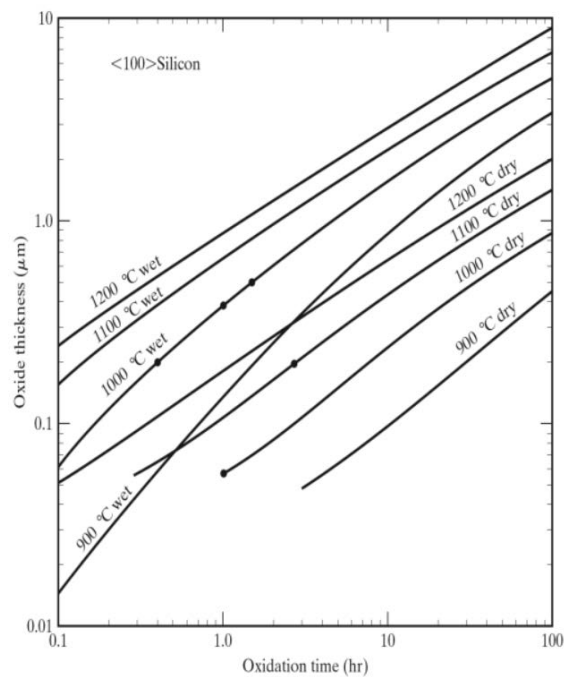
Homework 4

1. A $\langle 100 \rangle$ Si wafer has only native oxide (about 0.6nm after 1 minute air exposure) before going into the furnace.
 - a. We want an oxide thickness of 70nm, grown via dry oxidation at 1100C. Demonstrate how the time to obtain this thickness using the mathematical approach of the Deal-Grove model.
 - b. Demonstrate the time to obtain this thickness using the graphical (chart) approach. The charts are attached in the next page, for ease of demonstration.
 - c. We want to grow an additional 200nm of oxide via wet oxidation, at a lower temperature of 900C. Demonstrate what time is required to obtain this additional thickness via the mathematical approach.
 - d. Demonstrate what time is required to obtain this additional oxide thickness via the graphical approach. (Charts duplicated on the next page)

b)



d)

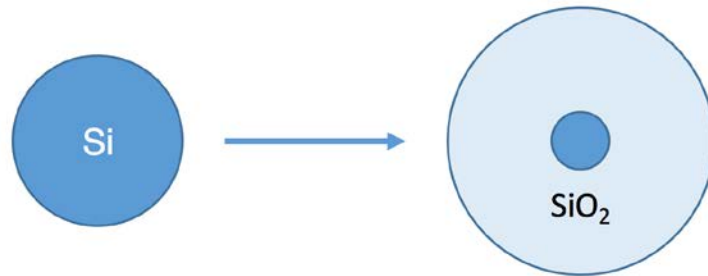


- a. What changes if the wafer is changed to $\langle 111 \rangle$? List parameters for the mathematical model, and state the time required for the initial 50nm dry oxidation via the graphical approach (indicate on plots).

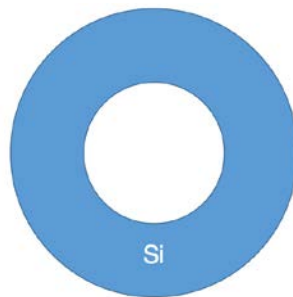
2.

- a. What are the 3 mechanistic steps of the oxidation process?
- b. What step will be rate limiting at short times, and for thin initial oxides? Explain why.
- c. What step is rate limiting for long oxidation times? Explain your reasoning.
- d. The Deal-Grove model for dry oxidation often deviates from the ideal situation at low oxide thicknesses (note the absence of these points on the plot). The initial growth is faster than expected for dry oxidation: Name the rate limiting step in this regime and list 2 possible reasons for this deviation.

3. For this problem, assume all exposed surfaces are $\langle 100 \rangle$



- a. A long cylindrical Si rod of radius $3\text{ }\mu\text{m}$ is oxidized and a $1\text{ }\mu\text{m}$ diameter Si core is left (shown above). What is the thickness of SiO_2 shell? Assume cylindrical symmetry is maintained during thermal oxidation and ignore any effects caused by stress.



- b. A long cylindrical Si tube of inner radius $3\text{ }\mu\text{m}$ and outer radius $4\text{ }\mu\text{m}$ is placed in an oxidation chamber (shown above). Assume oxidation proceeds identically from the outside and the inside of the tube. At what distance from the center will the two Si/SiO_2 interfaces meet? What if the inner radius is $1\text{ }\mu\text{m}$ instead?

- c. The Deal-Grove model predicts the thickness of SiO_2 as a function of time, $X_{\text{ox}}(t)$. We want to determine how to modify this function if we are oxidizing a silicon sphere with initial radius R . Assume the flux per unit surface area of the SiO_2 /air interface is constant. Write down an equation for $dY_{\text{ox}}(t)/dt$ in terms of R , $Y_{\text{ox}}(t)$, and $dX_{\text{ox}}(t)/dt$. Is the growth rate higher or lower?