

# Oxidation

D. W. Parent

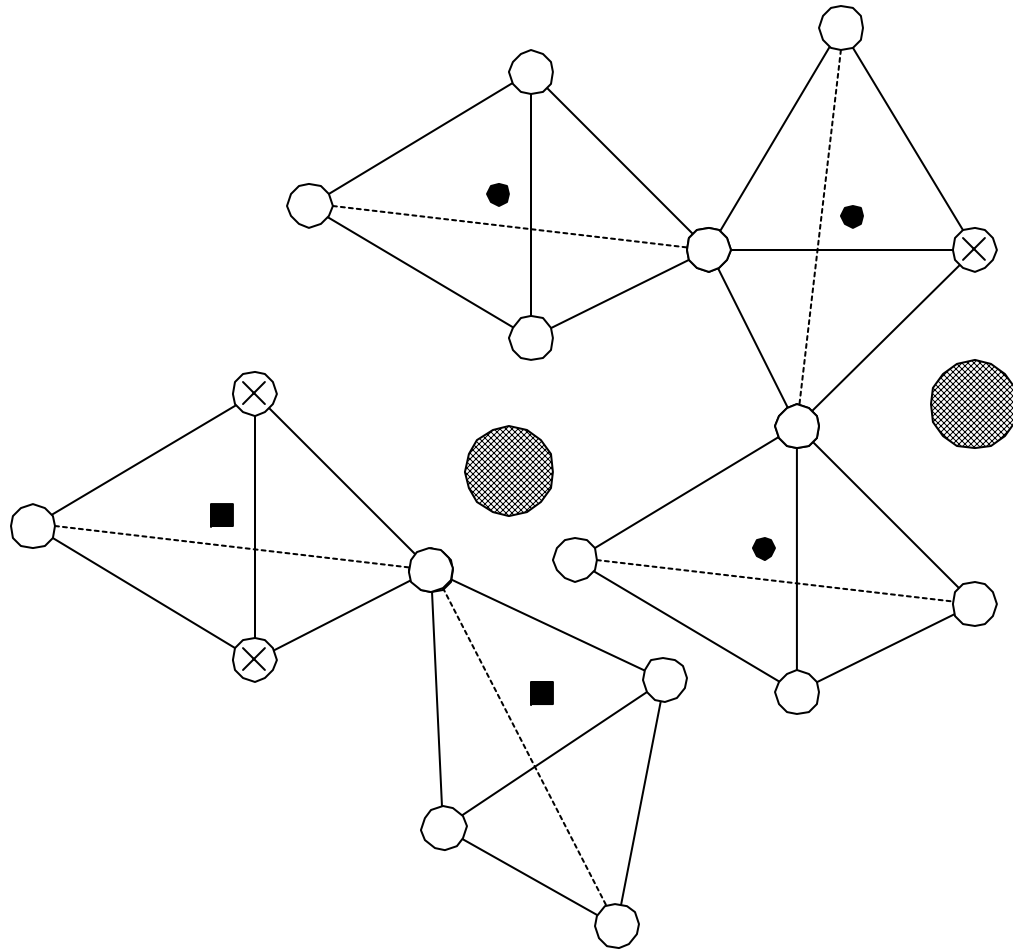
# Silicon dioxide






- What is  $\text{SiO}_2$ ?
- What is  $\text{SiO}_2$  used for?
- Advantages and Disadvantages of  $\text{SiO}_2$
- How is it grown?
  - Dry
  - Wet
- Numerical Examples

# What is SiO<sub>2</sub>?

- Two forms
  - Single crystal (quartz)
  - Amorphous
- We are interested in Amorphous SiO<sub>2</sub>
  - Random three dimensional network of SiO<sub>2</sub> constructed from polyhedra of oxygen ions.
  - This material is more porous than Quartz (density of 2.15-2.25g/cm<sup>3</sup> compared to 2.6525g/cm<sup>3</sup> )

# What is $\text{SiO}_2$ ?



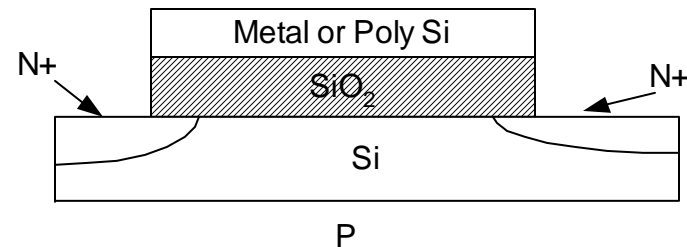
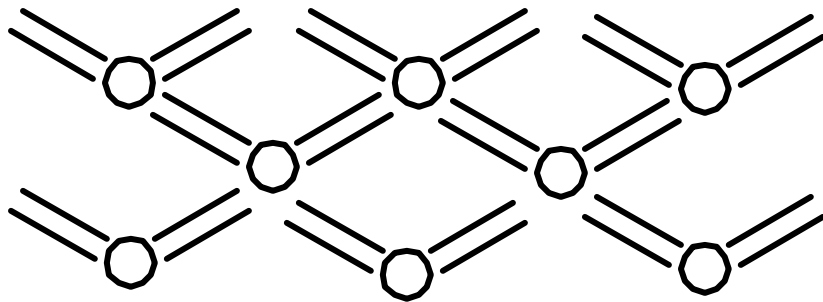
-  Network modifier
-  Nonbridging oxygen
-  Silicon
-  Network former
-  Bridging oxygen

The O-Si-O Bond angle is  $109^\circ$

Tetrahedral distance between Si and O ions is  $1.6\text{\AA}$

# What is $\text{SiO}_2$ used for?

- MOS Metal Oxide Semiconductor
- Device passivation
  - Combines with dangling bonds to reduce surface states

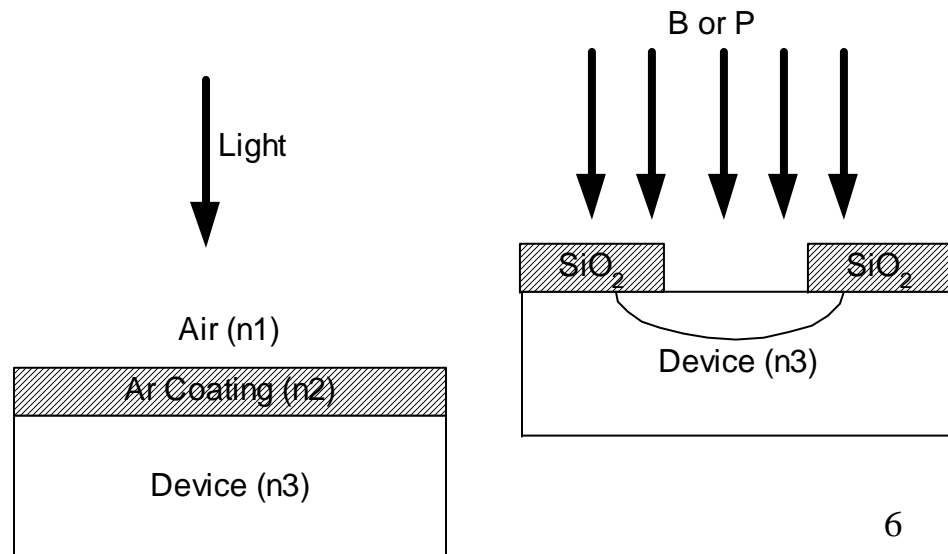


# What is SiO<sub>2</sub> used for?

- Diffusion Masks
  - Block the diffusion of B and P for example
- Antireflective coating for Photodevices

$$n_2 = \sqrt{n_1 n_3},$$

$$\text{thickness} = \frac{\lambda}{4n_2}$$



# Advantages and Disadvantages of $\text{SiO}_2$

- CMOS digital logic gates use little power when not switching logic state, thus high levels of integration are possible because the standby power consumption is low.
- $\text{SiO}_2$  is a native film that is quite easy to grow. All that is required is heat and oxygen or steam.

# Advantages and Disadvantages of $\text{SiO}_2$

- $\text{SiO}_2$  consumes Si while growing. 44% of the  $\text{SiO}_2$  layer comes from the original Si.
  - This leads to a non-planer structure after each oxidation step.
- Due to the large increase in volume there is  $2\text{-}4 \times 10^9$  dyn cm<sup>-1</sup> of compressive strain.
  - This causes dislocations.
- Oxidation-Induced Stacking Faults (these can be removed by a high temp treatment.

# Advantages and Disadvantages of $\text{SiO}_2$

- The large dielectric constant leads to larger capacitance values for a given thickness (compared to silicon nitride).

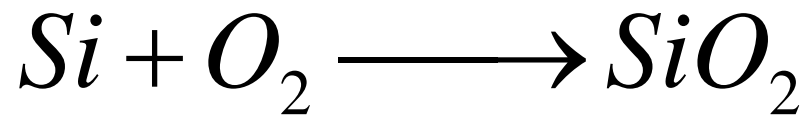
# How is it grown?

- The oxidizing species must diffuse through the SiO<sub>2</sub> layer that has already grown. This leads to a linear regime of growth and a parabolic regime of growth. Given by the equation:

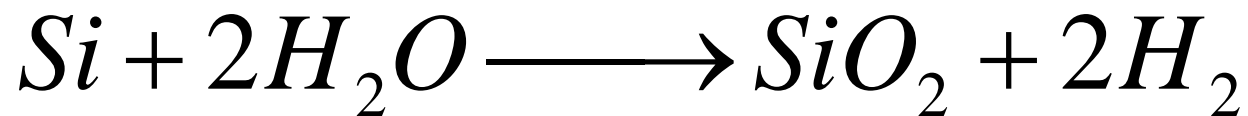
$$X^2 + A(\mu m)X = B(\mu m^2 / hr)t(hr)$$

# How is it grown?

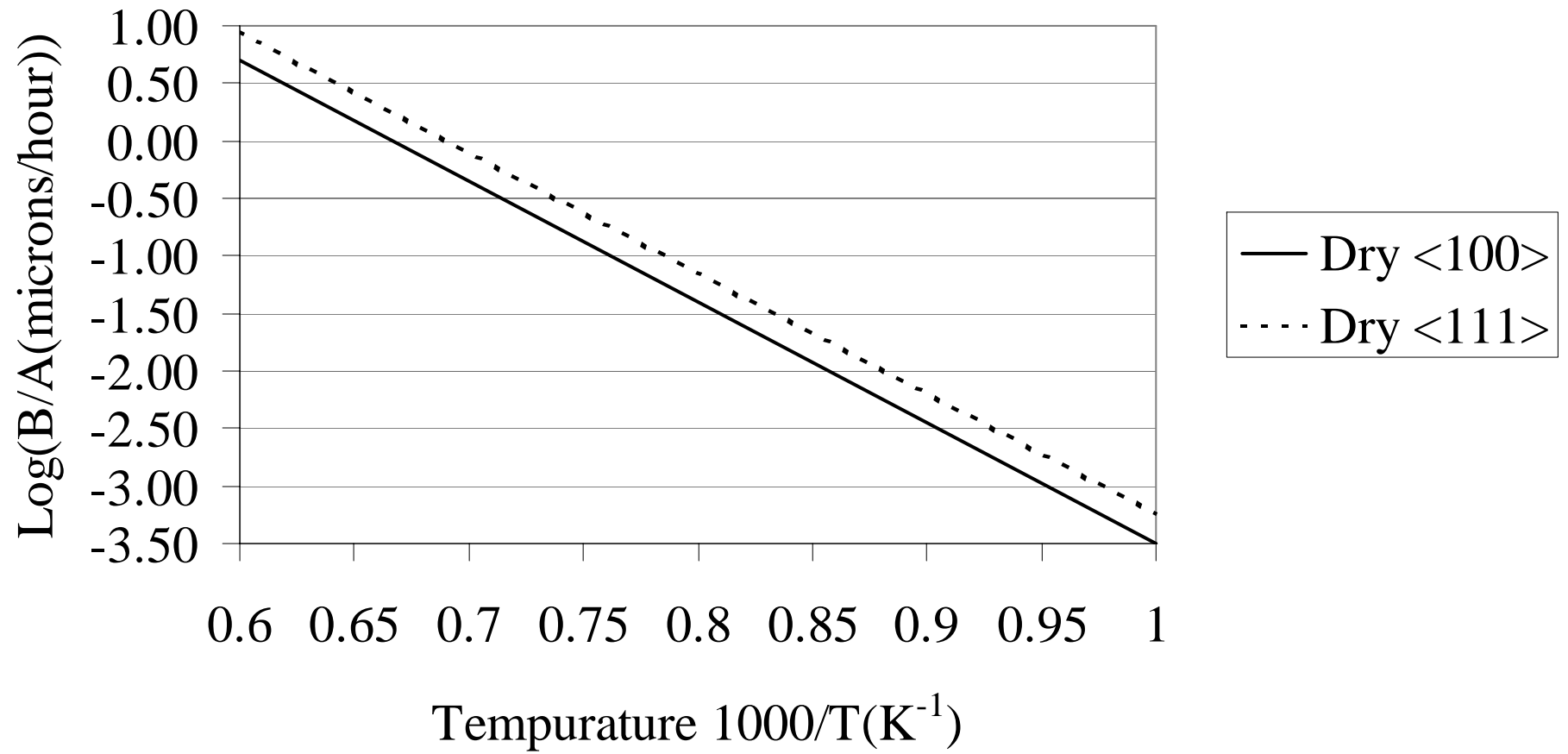
- Dry oxidation: Flow dry O<sub>2</sub> over sample at elevated temperatures.



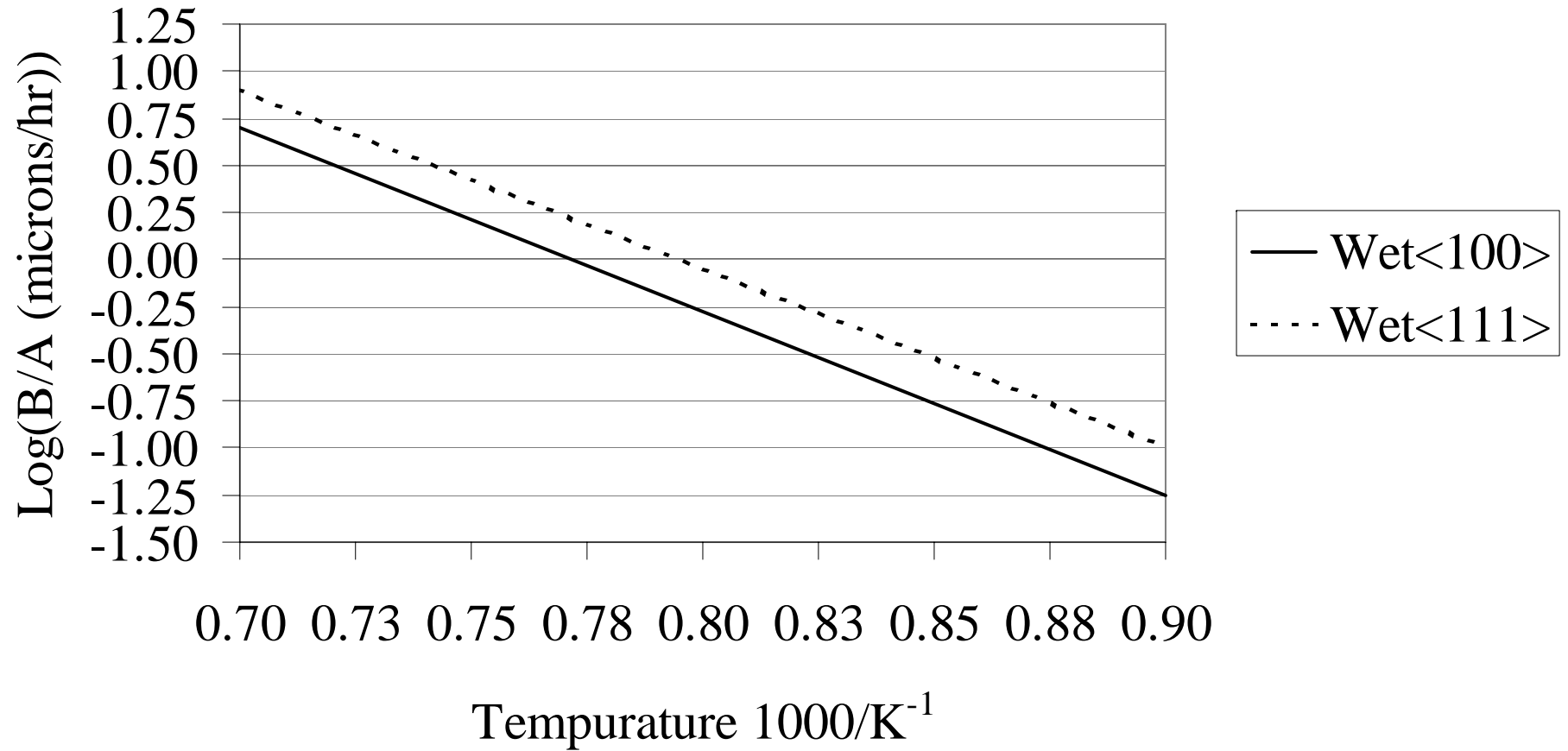
- Wet oxidation: Bubble N<sub>2</sub> through a water bubbler @95C° over sample at elevated temperatures.



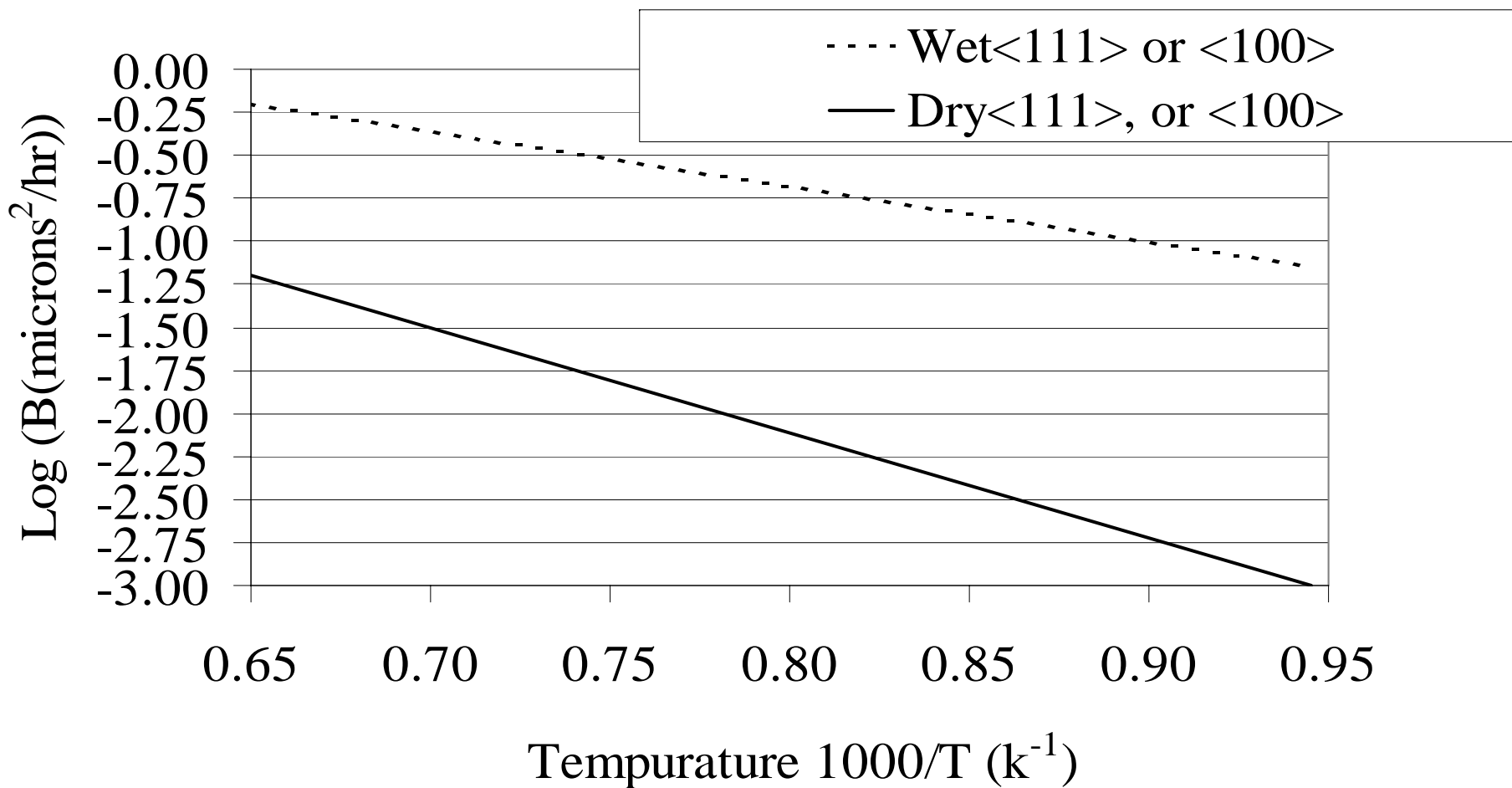
# Linear Rate Constant versus Temperature



# Wet Oxidation



Parabolic Rate Constant versus Temperature



# Numerical Examples

- How long do we need to grow  $\text{SiO}_2$  at  $1155^\circ\text{C}$  using a wet process  $\langle 111 \rangle$  to protect against a 30 minute  $1100^\circ\text{C}$  P diffusion?
- How long do we need to grow  $\text{SiO}_2$  at  $1265^\circ\text{C}$  using a dry process  $\langle 100 \rangle$  to create a MOS insulator capacitance ( $C_i = \epsilon_i/d$ ) of  $69\text{nF}$ ?
  - Note: For  $\text{SiO}_2$   $\epsilon_i = 3.9 * 8.85\text{e-}14\text{F/cm}$