Silicon dioxide

- What is SiO_2?
- What is SiO_2 used for?
- Advantages and Disadvantages of SiO_2
- How is it grown?
  - Dry
  - Wet
- Numerical Examples

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What is SiO_2?

- Two forms
  - Single crystal (quartz)
  - Amorphous
- We are interested in Amorphous SiO_2
  - Random three dimensional network of SiO_2 constructed from polyhedra of oxygen ions.
  - This material is more porous than Quartz (density of 2.15-2.25g/cm^3 compared to 2.65 25g/cm^3)

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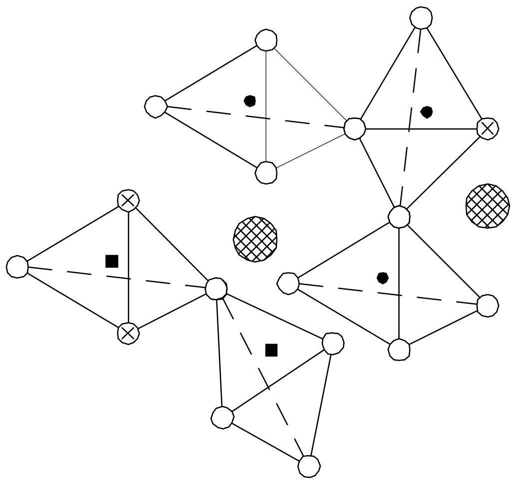
What is SiO_2?



Network modifier

Nonbridging oxygen

Silicon

Network former

Bridging oxygen

The O-Si-O Bond angle is 109°

Tetrahedral distance bewtween Si and O ions is 1.6Å

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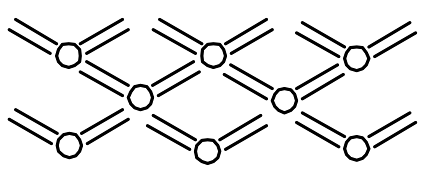
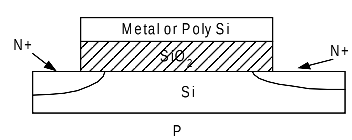
What is SiO_2 used for?

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





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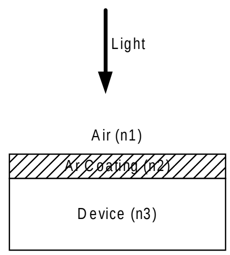
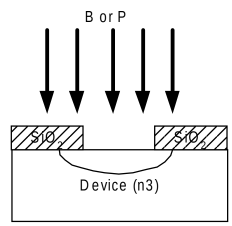
What is SiO_2 used for?

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

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

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





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Advantages and Disadvantages of 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.
- SiO_2 is a native film that is quite easy to grow. All that is required is heat and oxygen or steam.

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Advantages and Disadvantages of SiO_2

- SiO_2 consumes Si while growing. 44% of the 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 2-4×109 dyn cm-1 of compressive strain.
  - This causes dislocations.
- Oxidation-Induced Stacking Faults (these can be removed by a high temp treatment.

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Advantages and Disadvantages of SiO_2

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

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How is it grown?

- The oxidizing species must diffuse through the SiO2 layer that has already grown. This leads to a linear regime of growth and a parabolic regime of growth. Given by the equation:

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

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How is it grown?

- Dry oxidation: Flow dry O2 over sample at elevated temperatures.

$$Si + O_2 \longrightarrow SiO_2$$

- Wet oxidation: Bubble N_2 through a water bubbler @95C^o over sample at elevated temperatures.

$$Si + 2H_2O \longrightarrow SiO_2 + 2H_2$$

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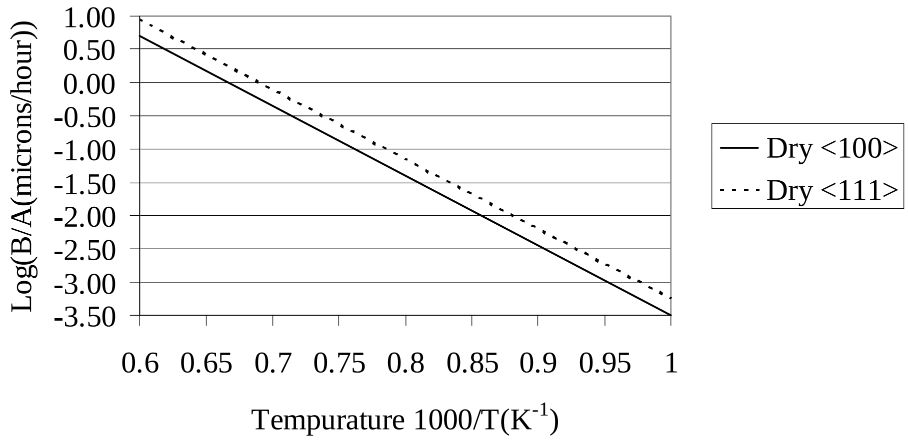
Linear Rate Constant versus Tempurature



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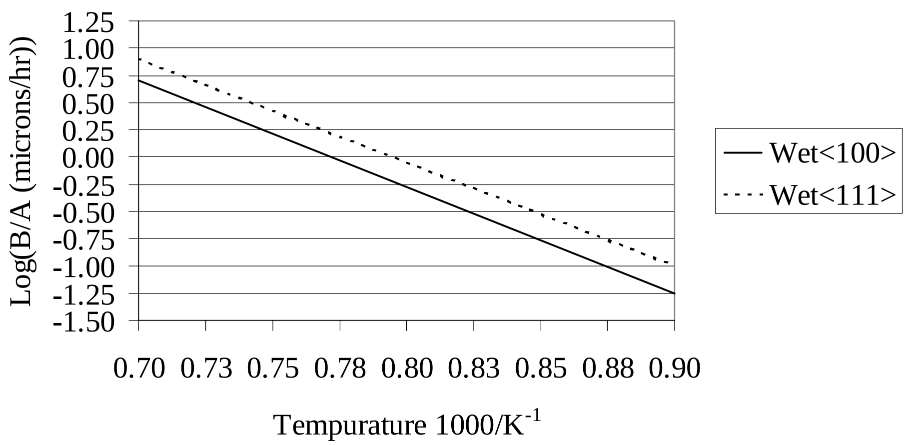
Wet Oxidation



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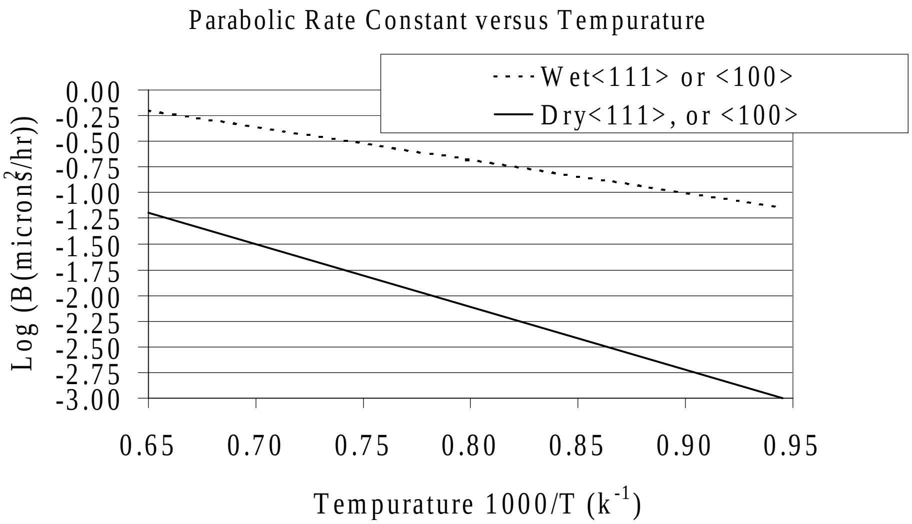

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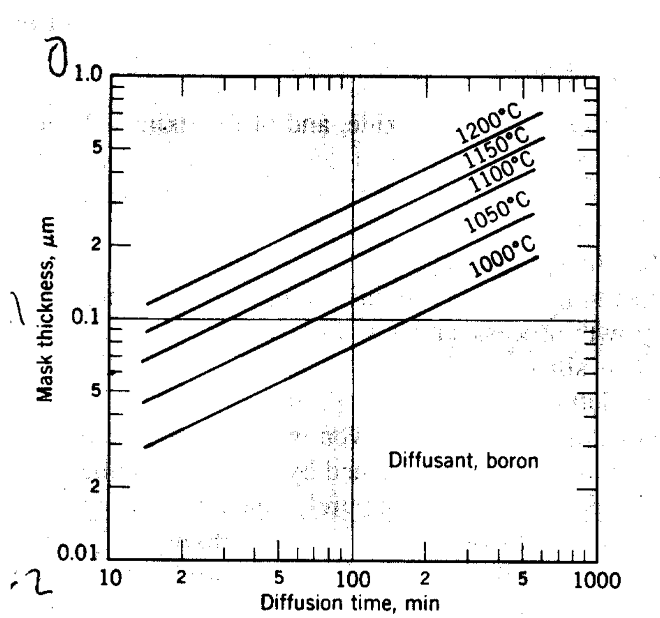

Fig. 7.13 Mask thickness for boron.

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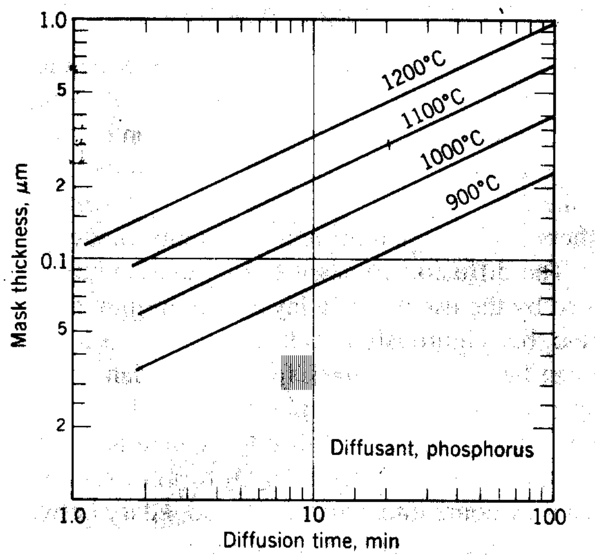

Fig. 7.14 Mask thickness for phosphorus.

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Numerical Examples

- How long do we need to grow SiO_2 at 1155C° using a wet process<111> to protect against a 30 minute1100C° P diffusion?
- How long do we need to grow SiO_2 at 1265C° using a dry process<100> to create a MOS insulator capacitance ($C_i=\varepsilon_i/d$) of 69nF?
  - Note: For SiO2 ε_i=3.9*8.85e-14F/cm

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