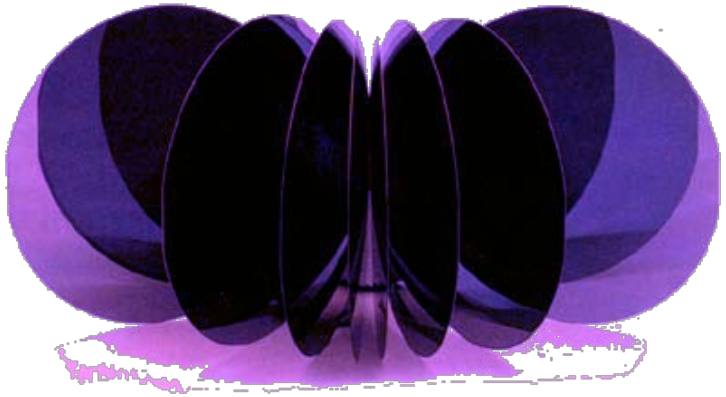
Thermal Oxidation of Silicon

Surface of silicon wafer oxidizes to form Silicon Dioxide upon exposure to oxygen.

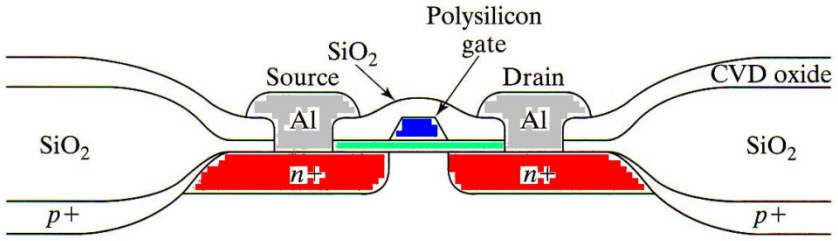
- Different thickness of the silicon dioxide layer produce different colours.

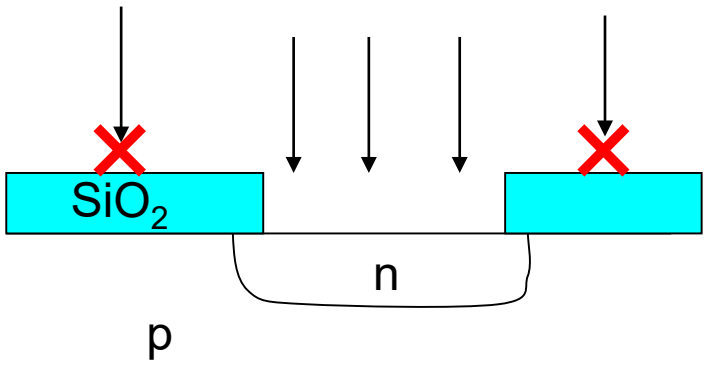


Thermal Oxidation of Silicon

Uses of silicon dioxide:

- ✓ Gate or Dielectric oxide
- ✓ Electrical insulator
- ✓ Barrier material during diffusion (introduce dopants into a region of the silicon wafer)





Oxidation Process

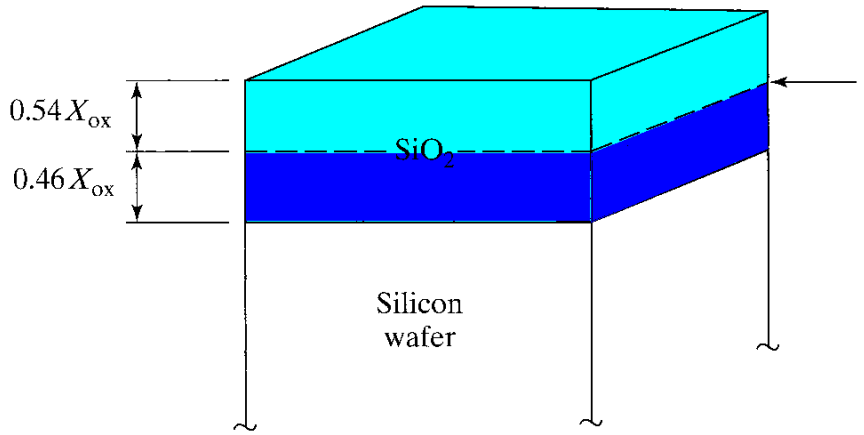
Thermal oxidation is achieved by heating the silicon wafer to a high temperature, usually 900 to 1200C.

Wet oxidation

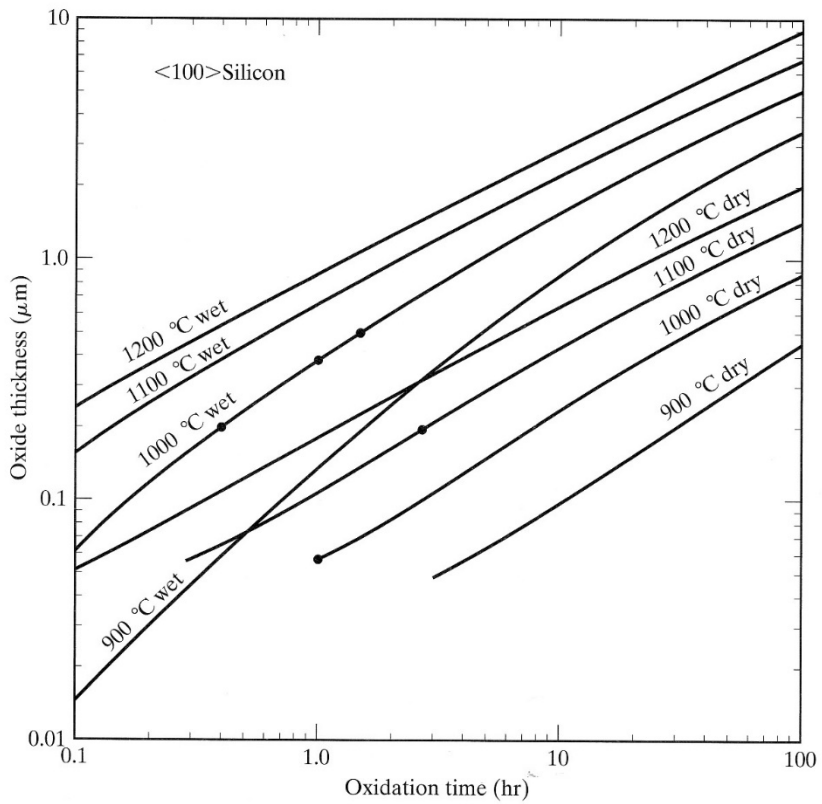
$Si + 2H_2O \rightarrow SiO_2 + 2H_2$

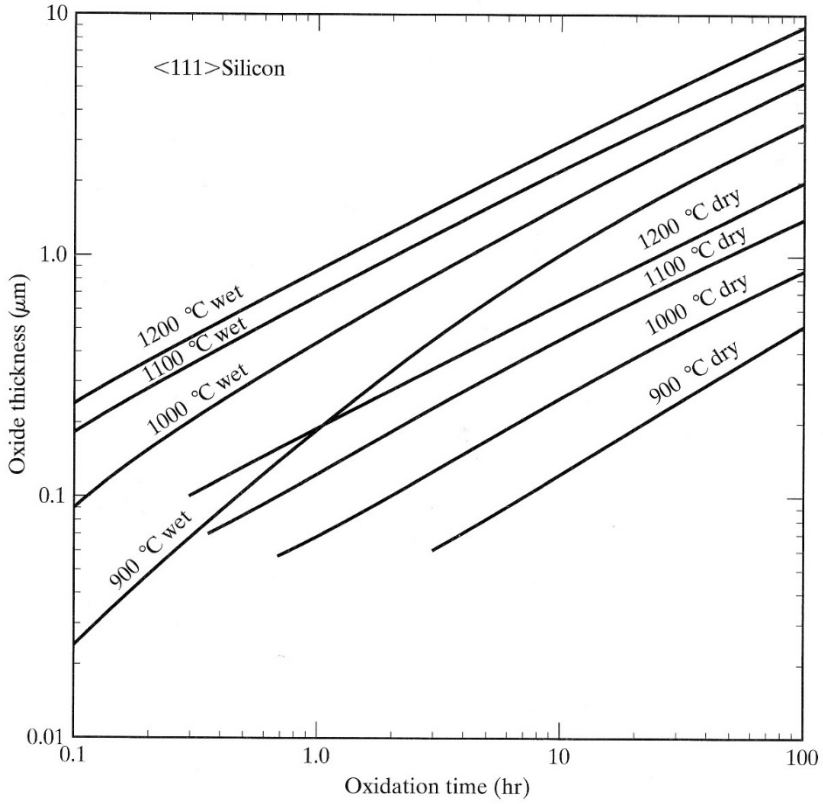
Dry oxidation

$Si + O_2 \rightarrow SiO_2$



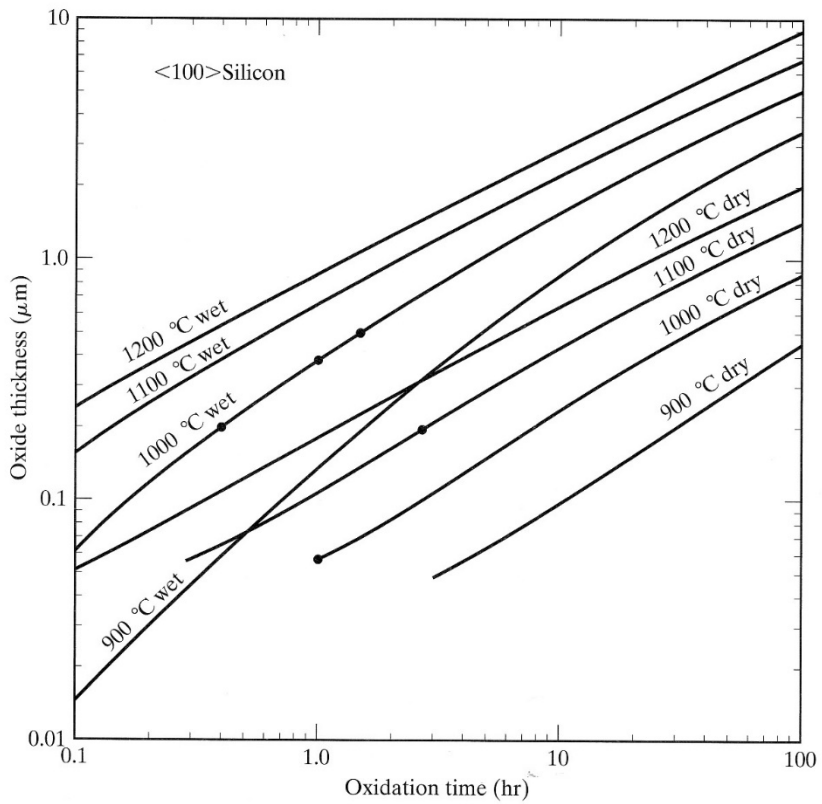
Oxidation Growth

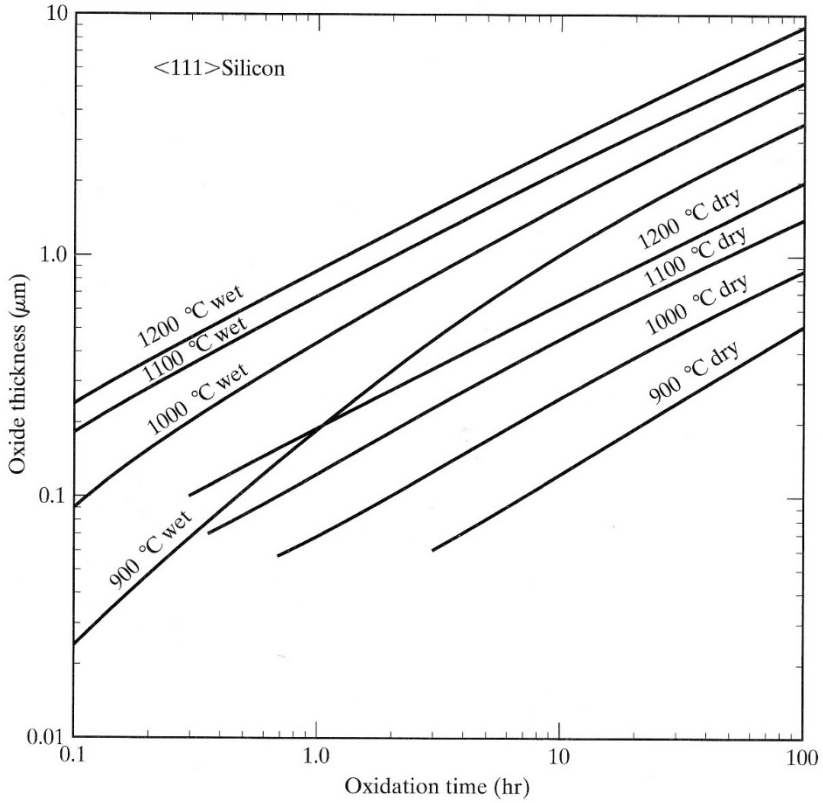




- Growth rate of <111> and <100> silicon wafer is different.
  - ✓ Silicon wafers are classified into <111> or <100> orientations to be covered in Advanced Wafer Fabrication Technology
  - ✓ MOS devices are usually fabricated using <100> silicon because it yields lower interface traps while BJT devices are fabricated using <111> silicon

Oxidation Growth



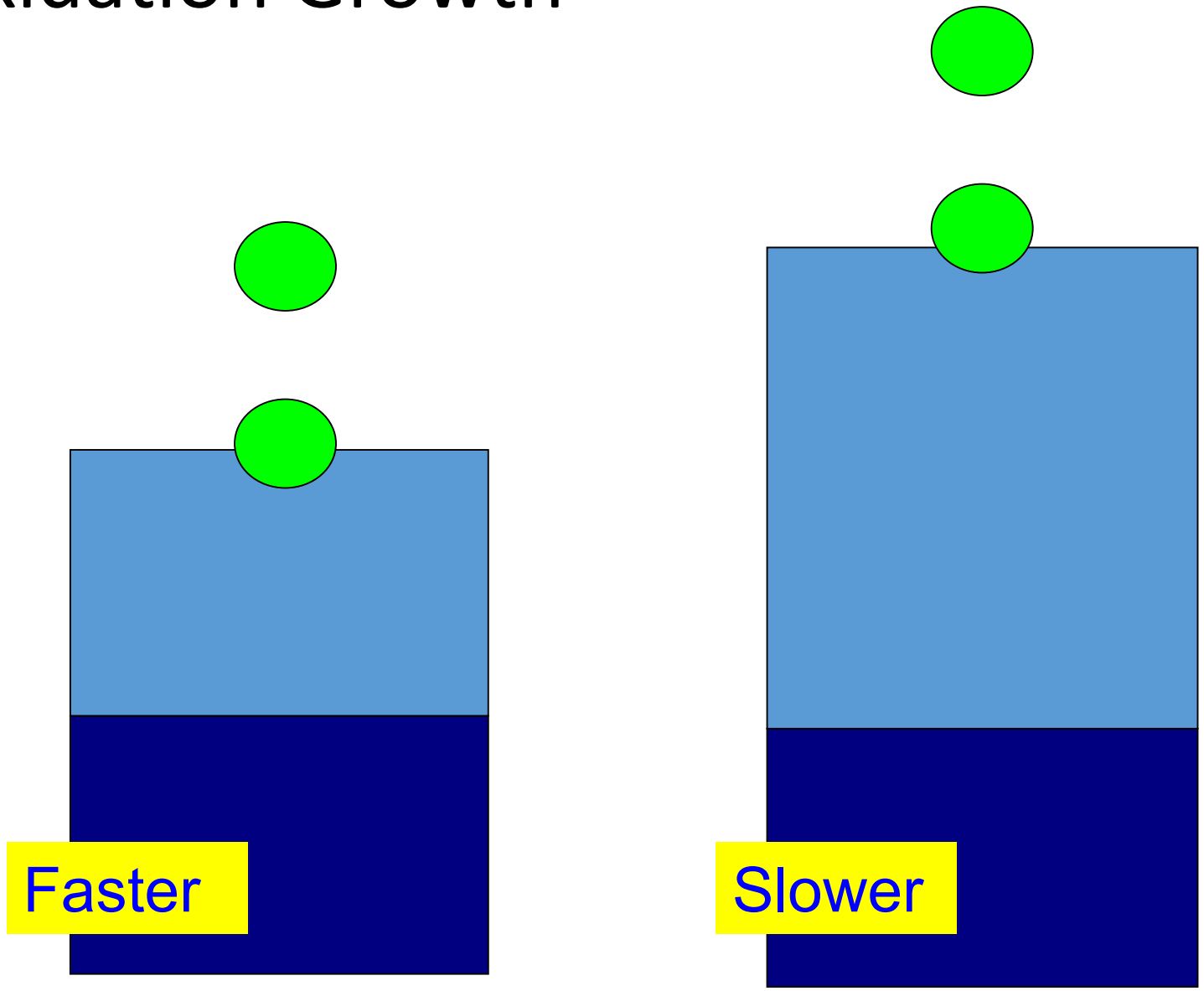


- Wet oxidation is faster than Dry oxidation.
- The longer the time the thicker is the oxide.
- The higher the temperature the thicker is the oxide.
- The growth rate is different at different thickness.

Oxide thickness calculations to be covered in Advanced Wafer Fabrication Technology

Oxidation Growth

- As new oxide is being formed, the newest layer is always at the bottom as the oxygen molecules travel through the oxide to react with the silicon to form new oxide.
- Growth rate is therefore different for different oxide thickness & slower with thicker oxide as the oxygen molecules takes longer time to travel through the oxide.

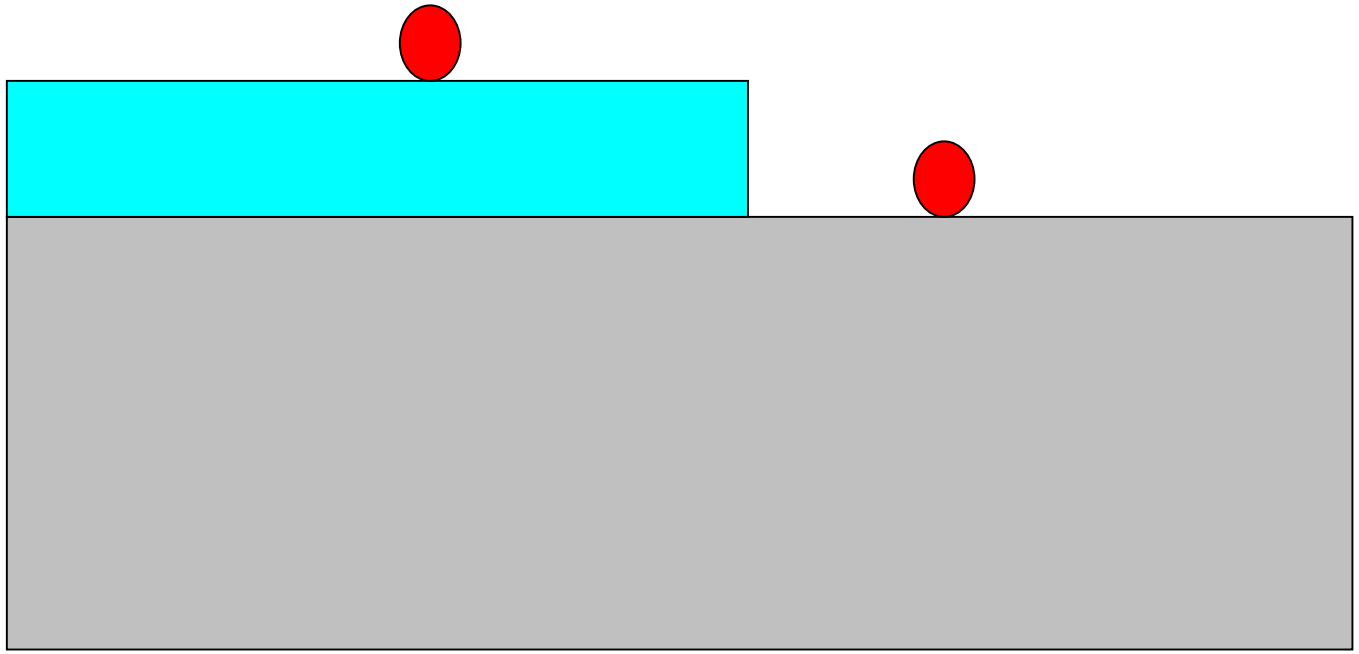


Oxide Quality & Applications

- Wet oxidation is faster but the density of oxide is lower.
- Dry oxidation is slower but the density of oxide is higher.

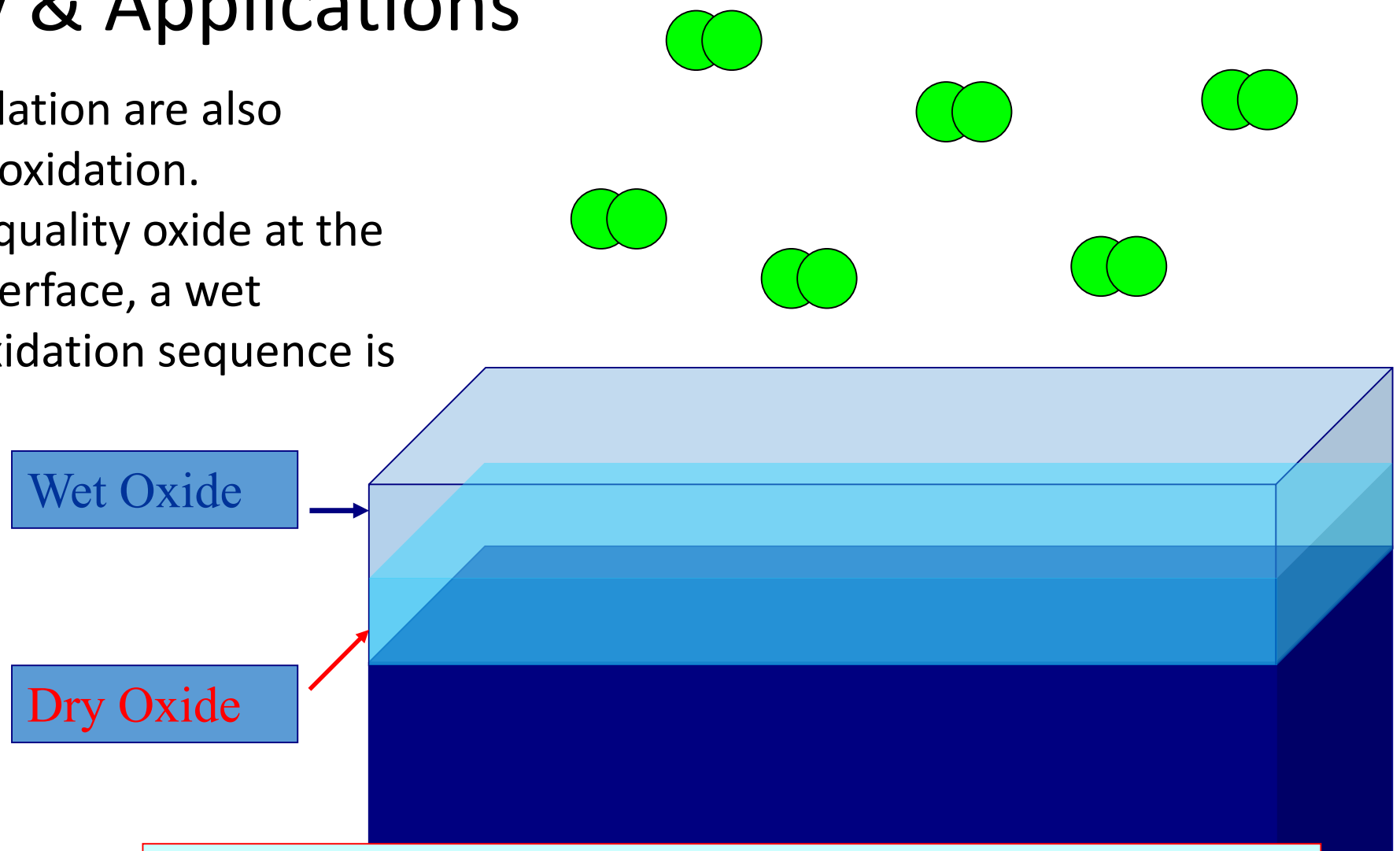
Therefore wet and dry oxide are used for different applications.

- ✓ Wet oxidation is much more feasible & used to grow thick masking or barrier oxide.
- ✓ One of the most important properties of SiO_2 is its ability to mask or block dopants during high-temperature diffusion to form p or n regions.



Oxide Quality & Applications

- ✓ Thick oxide for isolation are also formed using wet oxidation.
- ✓ To achieve better quality oxide at the silicon to oxide interface, a wet followed by dry oxidation sequence is employed.



Newest oxide grows at silicon–oxide interface

Oxide Quality & Applications

- Thin gate oxide of MOS devices are formed using dry oxidation:
  - ✓ Better quality oxide
  - ✓ Difficult to control the fast rate of wet oxidation for thinness
- Dielectric for capacitors are formed using dry oxidation.
- A typical & more reasonable shorter process time for thick oxide oxidation cycle usually consists of a dry-wet-dry sequence so that the poorer but thick quality oxide is sandwiched by good quality oxide.

Oxidation Technology

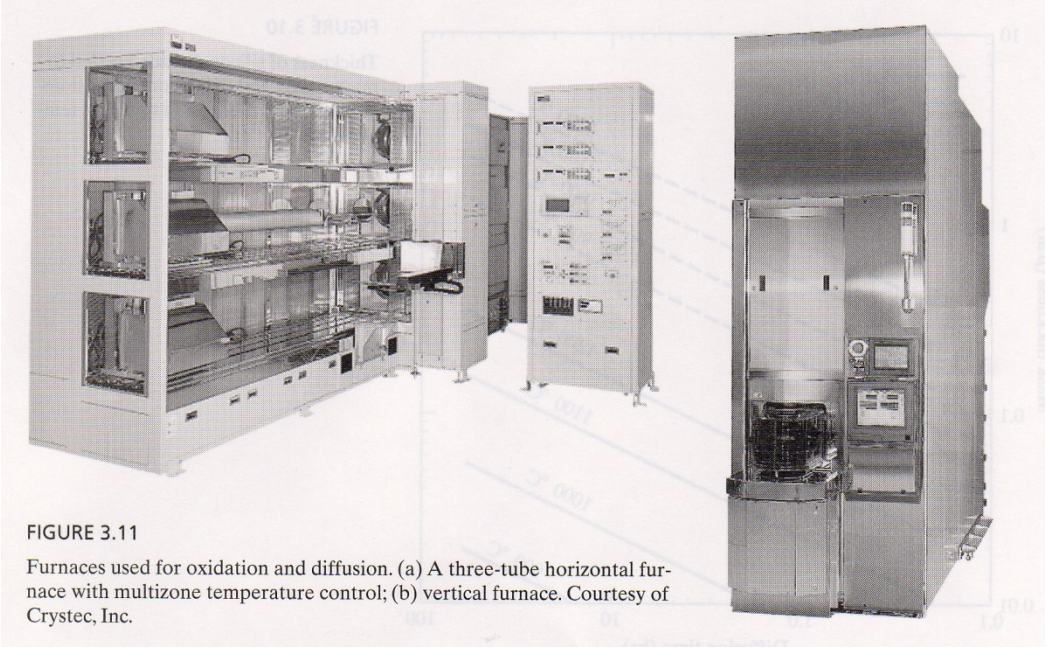


FIGURE 3.11

Furnaces used for oxidation and diffusion. (a) A three-tube horizontal furnace with multizone temperature control; (b) vertical furnace. Courtesy of Crystec, Inc.

Oxidation Furnace
(Silicon Valley Group - Thermco Systems)

Summary

Dry Oxidation, good quality but slow,
good for gate oxide or dielectric

Simply $Si + O_2 \rightarrow SiO_2$

Wet Oxidation, fast but bad quality, for
isolation and diffusion masking

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