CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication

Lecture 10
Thermal Oxidation, part 1

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Reading:
Chapter 4, *Fabrication Engineering at the Micro- and Nanoscale*, 4th edition, Campbell

(some images obtained from Wikimedia Commons)

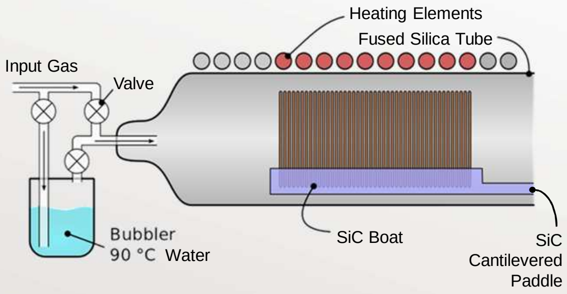
Silicon Dioxide

- Two Main purposes of SiO_2:
  - Electrical insulator
  - Dopant diffusion barrier
- Used in the process at these steps:
  - Device isolation (LOCOS or STI)
  - Gate Oxide
  - Poly gate spacer (for LDD)
  - Interlayer dielectric (ILD) for metal levels
  - Sacrificial oxide
- Deposition Methods:
  - Thermal growth
  - Chemical Vapor Deposition (CVD)

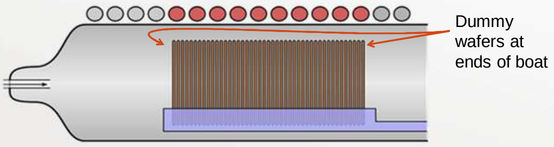
Thermal Oxidation

- Oxide is “grown” by supplying an oxygen source that reacts with the silicon wafer at high temperatures to form SiO_2 at the wafer surface
- Thermal oxides are valuable because they are:
  - Stable, intrinsically good insulators
  - Very clean/pure when thermally grown
  - Have excellent Si/SiO_2 interface with low electrical defects (good for gate oxide)

Oxidation Furnace



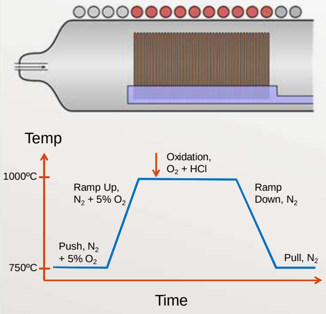
Temperature Control



±0.5 ºC temp. control required

600 – 1200 ºC range for furnace

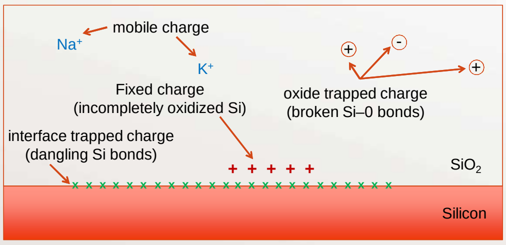
Thermal Cycle



Thermal Oxidation Cycle

- Push
  - Low temp to reduce thermal stress (wafer warpage)
  - O_2 included to prevent nitride formation
- Dry Oxidation
  - O_2 + HCl
  - Slow, used for thin oxides or where high quality is required
- Wet Oxidation
  - O_2 + H_2O
  - Fast, used for thick oxides
- N_2 Anneal
  - Reduces surface states
- Ramp down and Pull
  - Low Stress, low surface states, low fixed charge

Electrical Defects



Quality Control

- Mobile Ions – introduced by contamination
  - Use good pre-clean
  - Careful backside handling
  - Clean furnace components
  - Use HCl during oxidation (Cl reacts with mobile ions; results in excess Cl in oxide film)
- Interface States – fixed charge and interface trapped charge
  - Avoid stress, which causes oxide-induced stacking faults
  - Use N_2 or Ar during pull
  - Use HCl during oxidation
- Thickness Control
  - Across wafer, wafer-to-wafer, and lot-to-lot
  - Vertical furnaces have better temperature uniformity

Lecture 10: What have we learned?

- What is oxide used for in a CMOS process?
- What are the advantages of thermal oxidation?
- Explain the basic workings of an oxidation furnace
- Why is HCl used in the oxidation process?
- How does one insure good oxide thickness uniformity?