CHE323/CHE384
Chemical Processes for Micro- and Nanofabrication
www.lithoguru.com/scientist/CHE323

Lecture 30
Chemical Mechanical Polishing (CMP)

Chris A. Mack
Adjunct Associate Professor

Reading:
Section 11.2, *Fabrication Engineering at the Micro- and Nanoscale*, 4th edition, Campbell
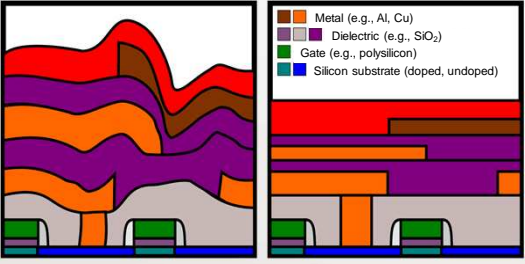
© Chris Mack, 2013   1

The Need for Planarization

- Patterning (deposition, lithography, and etch) leaves topography on the wafer
- Topography complicates subsequent processing
  - Coating over topography is hard (step coverage, shadowing)
  - Lithography suffers from depth of focus loss
- Some processes absolutely require planarization (STI, tungsten plugs, copper damascene process)

© Chris Mack, 2013   2

With and Without CMP

Metal (e.g., Al, Cu)
Dielectric (e.g., SiO$_2$)
Gate (e.g., polysilicon)
Silicon substrate (doped, undoped)

without CMP   with CMP

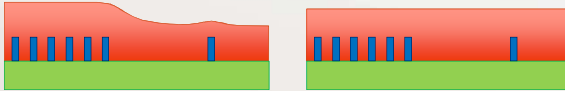© Chris Mack, 2013   Image from Wikimedia Commons   3

Planarization Techniques

- *Reflow* – add dopants to glass (e.g., BPSG) to lower T_g, then reflow the glass after contact formation by heating
- *Etchback* – coat wafer with planarizing resist, then etch with nonselective sputtering to transfer top resist profile into underlying film
- Both achieve only local planarization

© Chris Mack, 2013   4

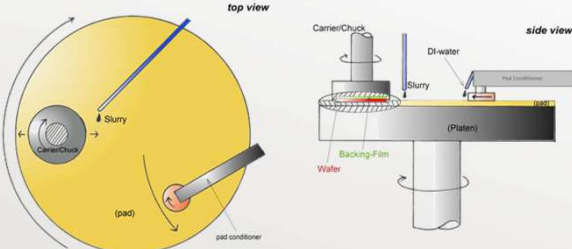# Chemical Mechanical Polishing

- Today, CMP is the preferred planarization approach
  - Can achieve global planarization, not just local planarization

etchback   CMP

© Chris Mack, 2013   5

CMP System

© Chris Mack, 2013   Image from Wikimedia Commons   6

CMP Process

- Rotate table and wafer at about 10 rpm
  - Polish rate depends on relative speed between polishing pad and wafer (v)
  - Average v ≈ 5 m/s
- Adjustable pressure (P) applied to wafer
  - Typically about 6 psi
- Typical polish times of about 10 min

$$Polish\ Rate \propto vP$$

© Chris Mack, 2013   7

CMP Process

- Slurry is colloidal silicon or alumina with composition and particle size dependent on material being polished
- Chemistry used to soften the material and increase its mechanical abrasion rate
  - For oxides: silica + high pH
  - For metals: alumina + low pH

© Chris Mack, 2013   8

CMP Uses

- The basic CMP use case is for additive patterning
  - Etch a hole
  - Fill the whole with material (but also coat the rest of the wafer)
  - Polish away the material not in the hole
- Common processes using CMP
  - Shallow Trench Isolation (STI)
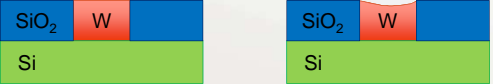 - Tungsten plug
  - Copper damascene process

© Chris Mack, 2013   9

CMP Problems

- Dishing
  - Overpolish required due to thickness variations
  - Plug material has higher polish rate

ideal   overpolish

- Erosion – removal of unintended material

© Chris Mack, 2013   10

Lecture 30: What have we learned?

- Name three planarization techniques. Which technique is better, and why?
- What two adjustable polishing parameters control the polish rate?
- Name three CMOS process steps that require CMP
- What are the two biggest problems associated with CMP?

© Chris Mack, 2013   11