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

Lecture 37
Etch, part 4

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Reading:
Chapter 11, *Fabrication Engineering at the Micro- and Nanoscale*, 4th edition, Campbell

Etch Chemistry

- A typical plasma contains:
  - Neutral Molecules at a density of 10^{16} cm^{-3}
  - Radicals: 10^{14} cm^{-3}
  - Electrons: 10^{8} cm^{-3}
  - Positive ions: 10^{8} cm^{-3}
- There are a million times more radicals than ions or electrons
  - Radicals form more easily and their lifetime is much longer
- Radicals produce the chemistry of etch
  - Ions add energy to a slow step in the mechanism

Silicon Etch Chemistry

- CF_4 is an inert gas (Freon 14)
- Electron impacts produce fluorine radicals:
  - Dissociative ionization:

$$CF_4 + e^- \rightarrow CF_3{}^+ + F + 2e^-$$

  - Impact dissociation:

$$CF_4 + e^- \rightarrow CF_3 + F + e^-$$

- Then chemically form volatile SiF_4

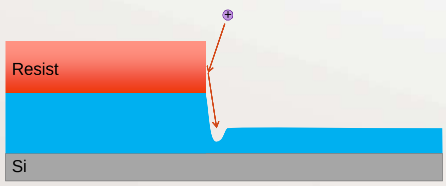
$$Si + 4F \rightarrow SiF_{4\,(gas)}$$

Etch Chemistries

- Polysilicon
  - CF_4/O_2 (H_2 added to create polymerization)
  - HBr, Cl_2 (more anisotropic)
- SiO_2
  - CF_4/H_2 (when on Si)
  - CHF_3/C_4F_8 (when on Si_3N_4)
- Aluminum
  - $Cl_2/CHCl_3$ (AlF_3 is not volatile, so chlorine chemistry is required)
- Photoresist
  - O_2 (etches only organics)

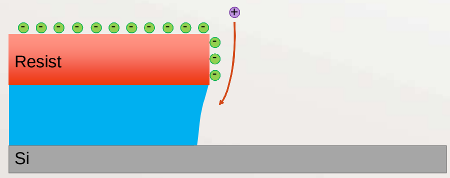
Problems with Dry Etching (1)

- Trenching: higher flux of ions at an edge



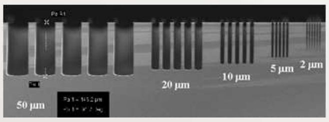
Problems with Dry Etching (2)

- Charging: insulators can become charged (+ or -), changing direction of ions



Problems with Dry Etching (3)

- Ion damage to lattice
- Polymerization that is not fully removed
- Etch Loading
  - Macroloading – overall etch rate changes as a function of percent area of wafer being etched (reactant depletion)
  - Microloading (shadowing and mass transport)



From cmi.epfl.ch/etch/601E.php

WHAT STARTS HERE CHANGES THE WORLD

End Point Detection

- Etch rate is very sensitive to many variables (e.g., macro- and microloading)
- Endpoint detection can reduce the need for overetch
  - Measure film thickness in real time using interferometry
  - Measure spectrum of plasma, look for film peaks disappearing and peaks for etch stop layers appearing

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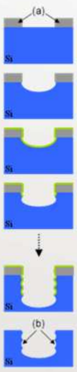
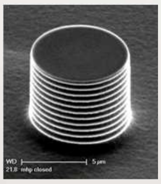
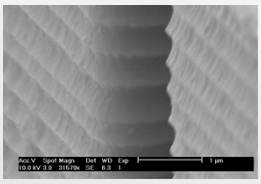


Deep Reactive Ion Etching

- The Bosch process alternates between two steps every few seconds
  - Etch silicon (with SF_6) – mostly isotropic
  - Generate polymers for sidewall passivation





(Images from Wikimedia Commons)

WHAT STARTS HERE CHANGES THE WORLD

Lecture 37: What have we learned?

- Why are free radicals more likely to be involved in etch chemistry than ions?
- Describe trenching and its cause
- Describe charging and its effects
- Define macroloading and microloading
- Why might one use endpoint detection?
- What is the “Bosch process”?

