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

Lecture 26
Deposition Processes

Chris A. Mack
Adjunct Associate Professor

© Chris Mack, 2013

Deposition Techniques

- Physical vapor deposition (PVD)
  - Sputtering
  - Evaporation
- Chemical vapor deposition (CVD)
  - Chemical reactions on the wafer surface result in film deposition
- Electrochemical Deposition
  - Copper for multilevel metallization
- Spin Coating
  - Polymers, spin-on glass

© Chris Mack, 2013

Epitaxial Silicon

- Silicon deposited on single crystal silicon
  - Takes on the crystal structure of the substrate

$$SiH_{4(g)} \rightarrow Si_{(s)} + 2H_{2(g)}$$

$$SiCl_{4(g)} + 2H_{2(g)} \rightarrow Si_{(s)} + 4HCl_{(g)}$$

- Actually, intermediate products are formed (e.g., SiH_2)
- Chlorine is useful for reducing defects and removing metals
- Cold-wall, atmospheric pressure reactors at high temperatures (1000ºC for SiH_4, 1250ºC for $SiCl_4$)
- In situ doping is possible
- In situ HCl clean of surface is often used

© Chris Mack, 2013

Polysilicon

- Used for CMOS gate and short-length wiring
- Grains of single crystals, oriented arbitrarily
- LPCVD using Silane (SiH_4)
  - P = 0.2 – 1 torr
  - T ≈ 600ºC
- Low temperatures give small grain size
  - Below 600ºC, the film will be amorphous
  - Annealing above 600ºC will grow the grain size
- Films are usually doped heavily to make a good conductor (either during deposition or after using ion implantation)
  - Doping during deposition slows the deposition rate

© Chris Mack, 2013

Silicon Nitride (Si_3N_4)

- Used as oxidation mask (LOCOS), etch stop layer for ILD, and as final passivation layer
- For LOCOS, high temperatures can be used (LPCVD, T = 650 – 800ºC)
- For later process steps low temps are required (PECVD, T < 450ºC)
  - Films are not stoichiometric

$$3SiH_2Cl_2 + 4NH_3 \rightarrow Si_3N_4 + 6HCl + 6H_2$$

$$3SiH_4 + 4NH_3 \rightarrow Si_3N_4 + 12H_2$$

© Chris Mack, 2013

Silicon Dioxide (SiO_2)

- Used as when low temperatures are needed, and for interlayer dielectrics
  - Oxide is not as dense as thermally grown oxide, etch rate can be much higher

$$SiH_4 + O_2 \rightarrow SiO_2 + 2H_2$$

- Alternate source: TEOS (tetraethooxysilane), $Si(OC_2H_5)_4$
- Use LPCVD (T = 650 – 800ºC), or PECVD + bias sputtering (T < 400ºC) for LTO, low temperature oxide

© Chris Mack, 2013

THE UNIVERSITY OF TEXAS AT AUSTIN — WHAT STARTS HERE CHANGES THE WORLD

Aluminum Metallization

- Aluminum alloy deposition
  - Al + 1-2% Si + 0.5-1% Cu
- Planar DC magnetron sputtering
  - High deposition rate (up to 1μm/min)
  - O_2 and N_2 in chamber must be kept very low
  - Wafer temperature kept at 150 – 300°C to improve step coverage

© Chris Mack, 2013

THE UNIVERSITY OF TEXAS AT AUSTIN — WHAT STARTS HERE CHANGES THE WORLD

Tungsten

- Tungsten plug for vias

$$WF_6 + 3H_2 \rightarrow W + 6HF$$

- Hot wall LPCVD
  - P = 0.1 – 2 torr
  - T ≈ 250 – 500°C
- Good thickness uniformity not required because of planarization process

© Chris Mack, 2013

THE UNIVERSITY OF TEXAS AT AUSTIN — WHAT STARTS HERE CHANGES THE WORLD

Other Metals

- Titanium and TiW
  - Used as an underlayer for contacts and vias
    - Good adhesion and low contact resistance
  - DC magnetron sputtering, often with collimated or ionized sputtering
- Titanium Nitride (TiN)
  - Antireflective layer on top of aluminum
  - Reactive sputtering: sputter Ti target in the presence of reactive N_2 gas.

© Chris Mack, 2013

THE UNIVERSITY OF TEXAS AT AUSTIN — WHAT STARTS HERE CHANGES THE WORLD

Lecture 26: What have we learned?

- Name four common methods of depositing thin films on a wafer.
- What is epitaxial silicon?
- What important metal is commonly deposited using CVD?
- How is CVD oxide different from thermally grown oxide?

© Chris Mack, 2013