Lecture:

Deposition:
Chemical-Vapor Deposition

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Lecture Outline

• Topics:
  – Mechanics of CVD
  – Fundamental Equations
    • Growth Regimes
    • Graphs, Extras
  – Processes
**Chemical-Vapor Deposition**

![Chemical-Vapor Deposition Diagram]

- Slowest Step Dominates
  - reaction-rate limited process
  - mass-transport limited process

**Types of CVD**

- **Atmospheric-Pressure**
  Chemical-Vapor Deposition (APCVD)
  - high temperature, not commonly used

- **Low-Pressure**
  Chemical-Vapor Deposition (LPCVD)
  - high temperature (480 to 1200 °C)
  - pressure typically 100 to 300 mtorr
  - commonly used for MEMS & IC fabrication

- **Plasma-Enhanced**
  Chemical-Vapor Deposition (PECVD)
  - plasma used instead of heat to crack molecules
  - lower temperature (~100 to 400 °C)
Modeling CVD

• Reaction occurs at the surface:
  - gas concentrations ($N_g$) drops to the surface concentration ($N_s$) across the boundary layer (or stagnant layer) of thickness ($d$
  - Controlled by the reaction-rate constant ($k_s$) and the mass transport constant ($h_g$)

Fluxes $J$ and Growth Rates ($v$):

$$J_s = k_s N_s$$

$$J_g = \left( \frac{D_g}{d} \right) (N_g - N_s) = h_g (N_g - N_s)$$

$$v = \frac{J_s}{N} = \left[ \frac{k_s \cdot h_g}{(k_s + h_g)} \right] \left( \frac{N_g}{N} \right)$$

$$v = k_s \left( \frac{N_g}{N} \right) \text{ limited by???}$$

$$v = h_g \left( \frac{N_g}{N} \right) \text{ limited by???}$$

LPCVD Deposition Rate

• Slowest Step Dominates
  - reaction-rate limited process (which region, A or B?)
  - mass-transport limited process (which region, A or B?)
Acceptance Angle

- When mass-transport limited, the growth rate is dependent on the flux density of gas molecules incident on the surface, which is a function of acceptance angle.

Acceptance Angle and Conformal Films
Surface-Micromachined Sealed Cavities

Molded Polysilicon Microstructures

- HEXSIL
  - width of etched feature determines the composition of the molded feature
Molded Polysilicon Microstructures

- enables 3-D structures with a 2-D process
- helps to bridge the gap between the micro world and the macro word

Polycrystalline Silicon ("Poly")

- grain size depends on deposition temperature
  - hotter deposition leads to larger grain structure
Stress in As-Deposited Films

Wolf and Tauber

LPCVD Systems
CVD Reactors

(a) Barrel reactor
(b) Multiple-wafer parallel-plate reactor
(c) Single-wafer reactor
(d) Hex reactor
(e) Afterglow reactor
(f) Ion beam milling or reactive ion beam etching

PECVD Systems