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

Lecture 25
Chemical Vapor Deposition, part 2

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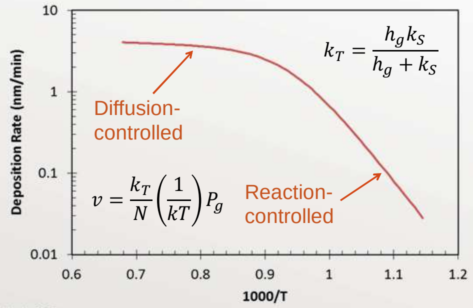
Reading:
Chapter 13, *Fabrication Engineering at the Micro- and Nanoscale*, 4th edition, Campbell

CVD Rate vs. Temp

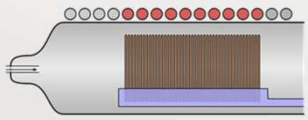


Designing a CVD Chamber

- In the reaction-controlled regime, deposition rate is very sensitive to variations in temperature
  - Chamber must be designed to achieve best possible temperature uniformity and control
- In the diffusion-controlled regime, deposition rate is very sensitive to variations in gas flow
  - Chamber must be designed to achieve best possible flow uniformity and control

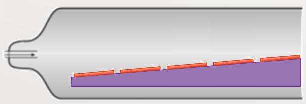
Reaction-Controlled CVD Chamber

- Hot Wall System
  - Like furnace, heat with zone heating
  - Very good temperature control possible (1ºC)
  - Deposition occurs on chamber walls
    - Must dedicate each tube to one material
    - Tubes must be cleaned regularly



Diffusion-Controlled CVD Chamber

- Cold Wall System
  - Lay wafers flat on a susceptor (e.g., graphite) which is inductively heated
  - Poor temperature control, but no deposition on walls
  - Susceptor tilted to keep boundary layer thickness constant



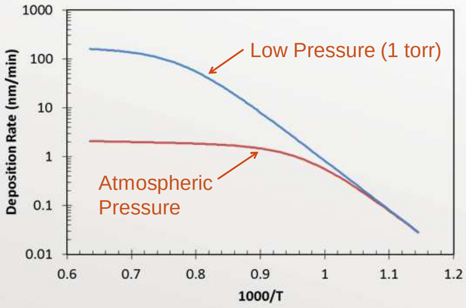
Effect of Pressure

- Keeping partial pressure of reactants constant, what is the impact of changing total pressure (P_T)?

$D_g \propto \frac{1}{P_T}$, δ decreases more slowly with pressure

- Result: Decreasing P_T from 1 atm (760 torr) to 1 torr causes h_g to increase by ~100

CVD Rate vs. Pressure



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Atmospheric CVD

- Cold-walled, diffusion-controlled regime
- Simple system, high deposition rates
- Difficult to get good film uniformity
- Not very common today
- Example: BPSG (boro-phospho-silicate glass)
  - SiO_2 doped with B and P to lower the glass transition temperature, allowing for reflow

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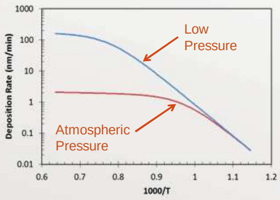
Low Pressure CVD (LPCVD)

- It is easier to control temperature than gas flow
  - We like working in the reaction-controlled regime
- Problem: If we lower the temperature to get into this regime, deposition rates are low
- Solution: Lower the pressure so that the reaction-controlled regime extends to higher temperatures



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Low Pressure CVD (LPCVD)

- Use hot-walled reactor
- Depletion of reactants along tube is compensated by increasing temperature
- Reduced pressure means long mean-free paths
  - Shadowing effects are possible
  - Diffusion length of adsorbed species can compensate, improving step coverage and uniformity and via filling
- Commonly used for polysilicon and most dielectrics

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Plasma-Enhanced CVD (PECVD)

- Some deposition processes require low temperatures
  - Ex: SiO_2 deposited on Al (<450ºC required to prevent diffusion of Si into Al)
- At low temperatures, deposition rate is low
- Solution: add energy to reactants using RF plasma
  - Added benefit: ion bombardment increases diffusion of adsorbed species
- PECVD has lower throughput than LPCVD

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Lecture 25: What have we learned?

- How does one switch between reaction-controlled and diffusion-controlled regimes?
- How does the regime (reaction- vs. diffusion-controlled) affect CVD system design?
- How does pressure affect deposition rate?
- Explain the advantages and disadvantages of atmospheric CVD, LPCVD, and PECVD

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