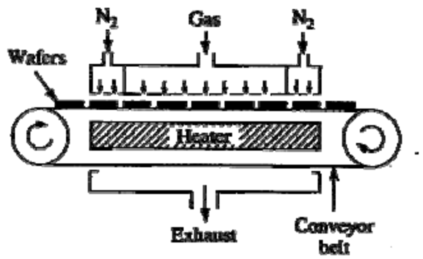
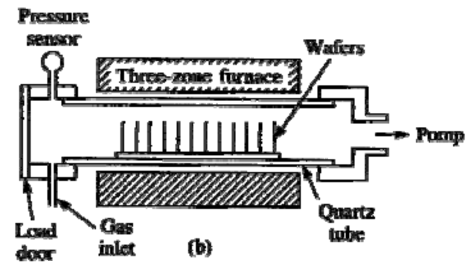
Atmospheric Pressure Reactor (APCVD)



- Once used for silicon dioxide passivation in integrated circuits
- Substrates fed continuously
- Large diameter wafers
- Need high gas flow rates
- Mass transport-limited regime (high pressure, so tougher for gas to get to the wafer surface)
- Problems/Issues:
  - Wafers lay flat, and thus, incorporate foreign particles
  - Poor step coverage

Low Pressure Reactor (LPCVD)

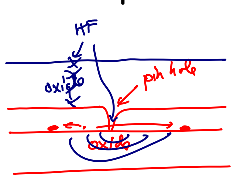
- Many films available: polysilicon, SiGe, Si_3N_4, SiO_2, phosphosilicate glass (PSG), BPSG, W
- Temp.: 300 → 1150°C
- Press.: 30 → 250 Pa (200mTorr → 2Torr)
- Reaction rate limited; reduced pressure gives gas molecular high diffusivity; can supply reactants very fast!
- Can handle several hundred wafers at a time
- Excellent uniformity

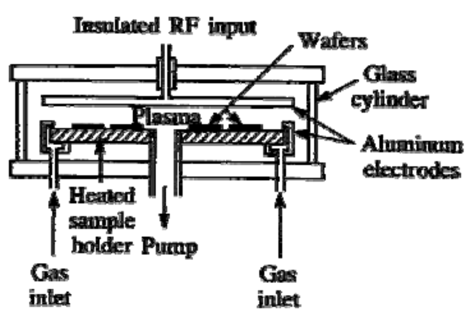


- Problems:
  - Low dep. rate (compared to atm.)
  - Higher T (than atmospheric)
  - In hot wall reactors, get deposition on tube walls (must clean)

Plasma-Enhanced CVD Reactor (PECVD)

- RF-induced glow discharge + thermal energy to drive reactions → allows lower temperature deposition with decent conformability
- Still low pressure

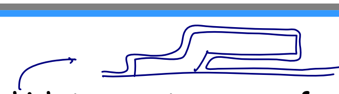




- Problems:
  - Pin-holes
  - Non-stoichiometric films
  - Incorporation of H_2, N_2, O_2 contaminants in film; can lead to outgassing or bubbling in later steps

Polysilicon CVD

Polysilicon Deposition:



→ Fairly high temperature → conformal

600°C

$SiH_4 \rightarrow Si + 2H_2$ (thermal decomposition of silane)

(conformal → high T)

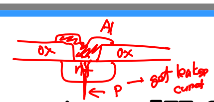
LPCVD (25 to 150 Pa) → 100-200Å/min

- In situ doping of polysilicon:
  - n-type: add PH_3 (phosphine) or Arsine gases (but greatly reduces dep. rate)
  - p-type: add diborane gas (greatly increases dep. Rate)

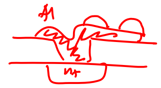
Silicon Oxide CVD

Silicon Dioxide Deposition:

- After metallization (e.g., over aluminum)
  - Temperature cannot exceed the Si-Al eutectic pt.: 577°C
  - Actually, need lower than this (<500°C) to prevent hillocks from growing on Al surfaces
  - Similar issues for copper (Cu) metallization



- Low temperature reactions:



LPCVD LTO Reactions:

$$SiH_4 + O_2 \xrightarrow{300\text{-}500°C} SiO_2 + 2H_2$$

(silane)

$$4PH_3 + 5O_2 \xrightarrow{300\text{-}500°C} 2P_2O_5 + 6H_2$$

(phosphine)

$2P_2O_5$ ← Phosphosilicate glass (PSG)

- Above reactions: not very conformal step coverage → need higher T for this