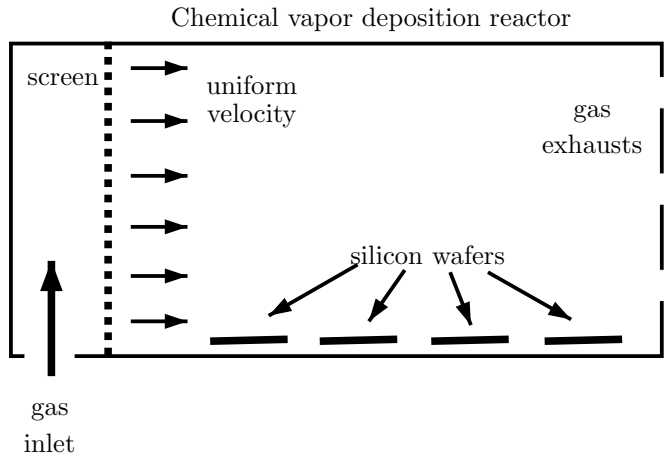
1. Chemical vapor deposition



A CVD reactor, pictured above, pases a dilute mixture of silane gas (SiH_4) in argon over heated substrates to deposit a layer of silicon. The screen at the entrance distributes the flow evenly over the entrance, so the velocity profile there is uniform. Assume the deposition is diffusion-limited, so the equilibrium SiH_4 concentration at the substrates is zero, and ignore exit conditions and natural convection instabilities (due to the placement of hot substrates below the cooler gas).

Data:

- chamber dimensions: 0.75m high $\times$ 2m wide $\times$ 2m long
- argon viscosity $\eta = 3 \times 10^{-5} \frac{\mathrm{N \cdot s}}{\mathrm{m}^2}$
- silane diffusivity in argon $D_{\mathrm{SiH_4}} = 2 \times 10^{-4} \frac{\mathrm{m}^2}{\mathrm{s}}$
- silicon density $\rho_{\mathrm{Si}} = 2500 \frac{\mathrm{kg}}{\mathrm{m}^3}$

(a) Calculate the mass transfer Prandtl number in the (mostly argon) gas at an operating temperature of 500K and pressure of 0.1 atm (you may need the ideal gas law for the argon density).

(b) Given a flow rate of $0.3 \frac{\mathrm{m}^3}{\mathrm{s}}$, calculate the Reynolds number Re_H. Is the flow likely to be laminar or turbulent?

(c) Treating the entire bottom of the chamber as a substrate, sketch the velocity and concentration boundary layers over the region as accurately as you can.

(d) Using a concentration of 1 mol% silane in the gas, calculate the diffusive flux of silane to the substrates at distances of 10 cm and 30 cm from the entrance.

(e) Calculate the deposition rate in $\frac{\mathrm{nm}}{\mathrm{sec}}$ at a location 10 cm from the entrance, and another 30 cm from the entrance. If a wafer is placed near the entrance, how uniform will the deposited layer be (qualitatively)?

(f) How would you change the design to make the deposited layer more uniform?