Lecture 12: Film Deposition II

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- Lecture Topics:
  - Film Deposition
    - Evaporation
    - Sputtering
    - Chemical Vapor Deposition
    - CVD Reactions
    - Epitaxial Growth
    - Atomic Layer Deposition (ALD)
  - Metal Electroplating
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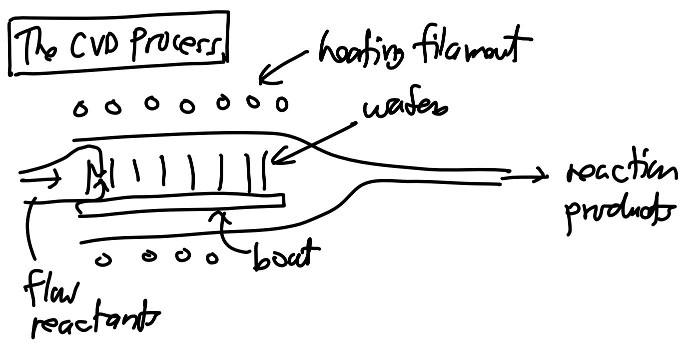
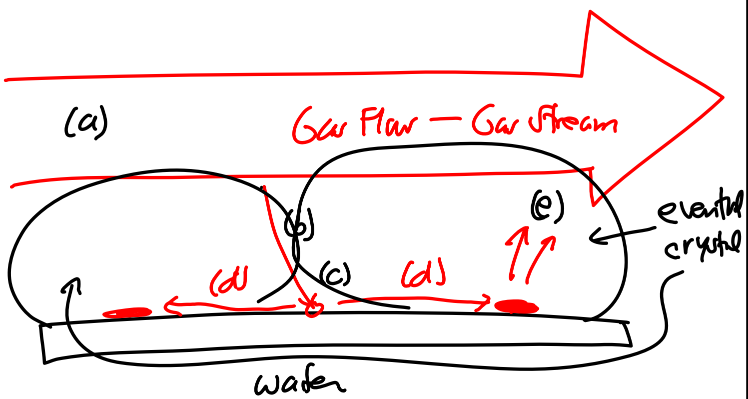
- Last Time:





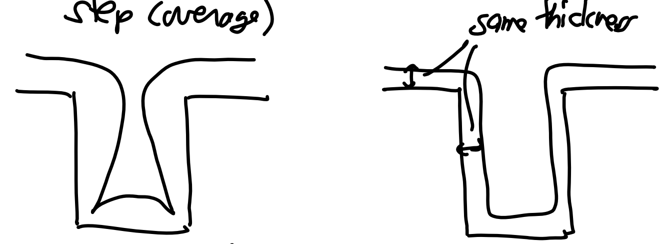
Step-by-Step:

(a) Reactant gases (+ inert diluting gases) are introduced into the reaction chamber.

(b) Gas species move to the substrate.

(c) Reactants adsorbed onto the substrate.

(d) Atoms migrate and react chemically to form films
↳ this determines to a large extent whether or not a film is conformal (i.e., better step coverage)



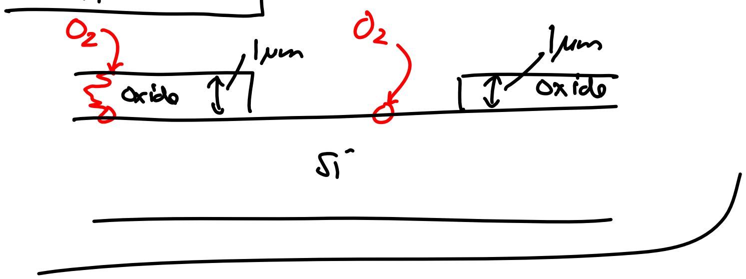
Not Conformal
↳ low T
↳ not enough adatom migration

Conformal
↳ high T
↳ plenty of adatom migration

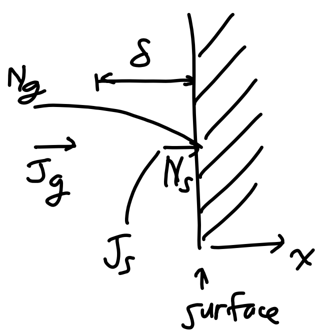
(e) Reaction by-products desorbed and removed from the reaction chamber

↳ Energy drives all of this
↳ supplied by several methods: thermal (heat)
photons
electrons (plasma)

Last HW Problem



Simplified Modeling



$N_g \triangleq$ conc. of reactant molecule in gas stream

$N_s \triangleq$ " " " " at the surface

$J_g \triangleq$ flux of molecules diffusing from the gas stream

$J_s \triangleq$ " " " at the surface

Governing Equations:

$J_s = k_s N_s$ [$k_s \triangleq$ surface reaction rate const.]

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

D_g: effective diffusion const. for the gas molecule

h_g: vapor phase mass-transfer coefficient

$[J_s = J_g = J]$, $\left[N_s = \frac{J_s}{k_s}\right]$

($J_s = J_g = J$:) otherwise, reactants will build up somewhere

$$J = h_g\left(N_g - \frac{J}{k_s}\right) = h_g N_g - \frac{h_g J}{k_s}$$

$$J\left(1 + \frac{h_g}{k_s}\right) = h_g N_g \rightarrow J = \frac{k_s h_g}{k_s + h_g} N_g$$

$$\boxed{J = (k_s \| h_g) N_g}$$

$$\text{growth rate} = \frac{\text{flux}}{\text{\# molecules incorporated/unit volume}} = \frac{J}{N} = \boxed{(k_s \| h_g)\frac{N_g}{N} = \text{growth rate}}$$

Case: $k_s \gg h_g \rightarrow$ surface reaction rate $\gg$ mass Xfer rate

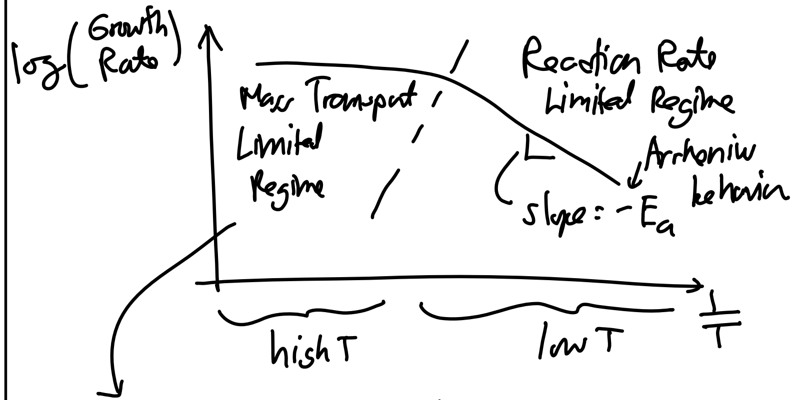
$$\boxed{\text{growth rate} = h_g \frac{N_g}{N}}$$ (mass transfer limited)

Case: $h_g \gg k_s \rightarrow$ mass Xfer rate $\gg$ surface reaction rate

$$\boxed{\text{growth rate} = k_s \frac{N_g}{N}}$$ surface reaction limited

$k_s \sim R_0 e^{-E_a/kT}$ (Arrhenius character)

Temperature Dependence of Growth Rate



dep. rate less dependent on T, here
↳ for better thickness control, better to operate @ higher T

- Go through slides 16-28 from Lecture Module 3