



# Diffusion and Oxidation



# Diffusion

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17 **Driven by concentration gradients**

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17 **Uses thermal energy**

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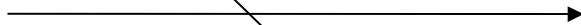
17 **Diffusion Constant is exponentially dependent**



# Diffusion

$C_0$

$J = \# \text{ of atoms/unit Area/Unit time}$



$C_1$

Fick's First Law:

$$J = -D \frac{\partial C(x)}{\partial x}$$

Diffusion Coefficient:  $D = D_0 \exp\left(\frac{-E_a}{kT}\right)$

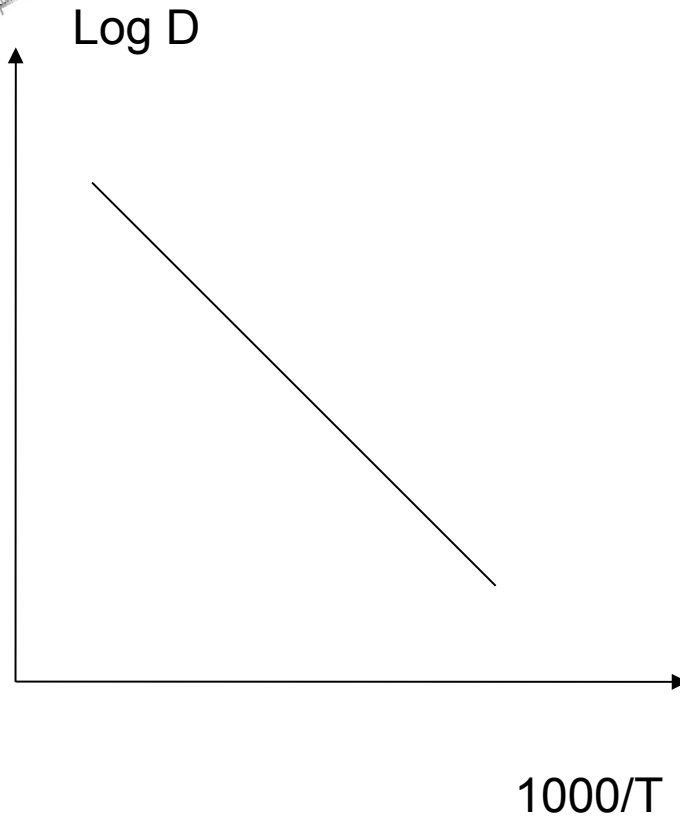
$E_a$  : Energy of Activation

Fick's Second Law:

$$\frac{\partial C(x, t)}{\partial t} = D \frac{\partial^2 C(x, t)}{\partial x^2}$$



# Arrhenius Plots



$$D = D_o \exp\left(\frac{-E_a}{kT}\right)$$
$$\ln D = \ln D_o - \frac{E_a}{k} \frac{1}{T}$$

Intercept

Slope

Smaller  $E_a$  means faster diffusion



# Predeposition Diffusion: Infinite Supply at Constant $C_s$

$$C(0, t) = C_s = \text{Constant}$$

$$\text{Concentration (\#/unit volume)} = C(x, t) = C(0, 0) \operatorname{erfc}\left(\frac{x}{2\sqrt{Dt}}\right)$$

$$\text{Dose (\#/unit area)} = Q_T = \int C(x, t) dx = \frac{2}{\sqrt{\pi}} C(0, t) \sqrt{Dt}$$

$$C(t, x_j) = C_B = \text{Bulk Concentration}$$

$$x_j = \text{junction depth} = 2\sqrt{Dt} \operatorname{erfc}^{-1}\left(\frac{C_B}{C_s}\right)$$



# Drive-in Diffusion: Finite Initial Supply

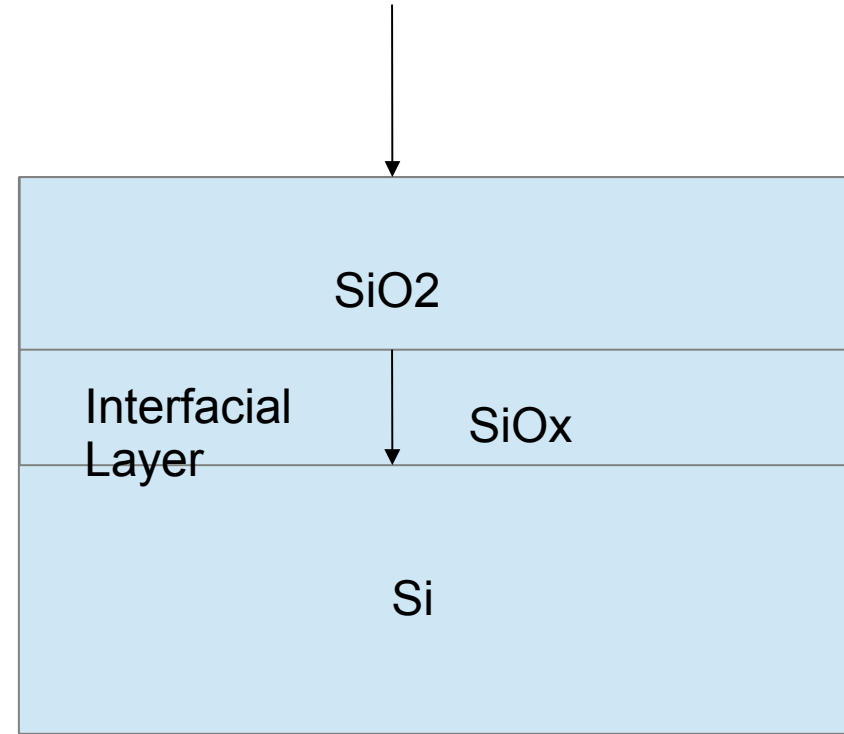
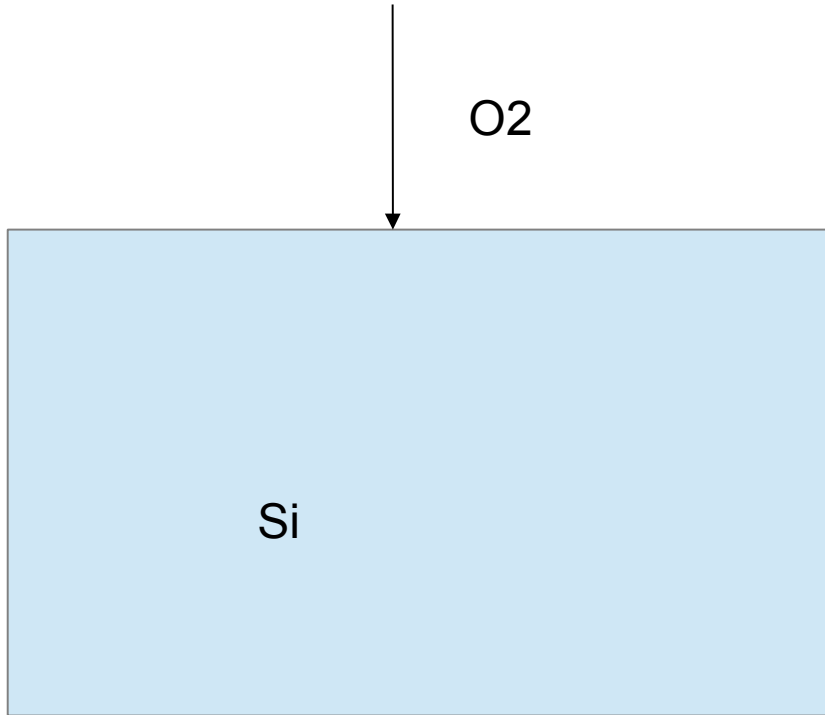
$$C(0,0) = C_s$$

$$\text{Dose (\#/unit area)} = Q_T = \text{constant} = \int C(x, t) dx$$

$$\text{Concentration (\#/unit volume)} = C(x, t) = \frac{Q_T}{\sqrt{\pi Dt}} \exp\left(\frac{-x^2}{4Dt}\right)$$

$$C(t, x_j) = C_B = \text{Bulk Concentration}$$

$$x_j = \text{junction depth} = \sqrt{4Dt \ln\left(\frac{Q_T}{C_B \sqrt{\pi Dt}}\right)}$$





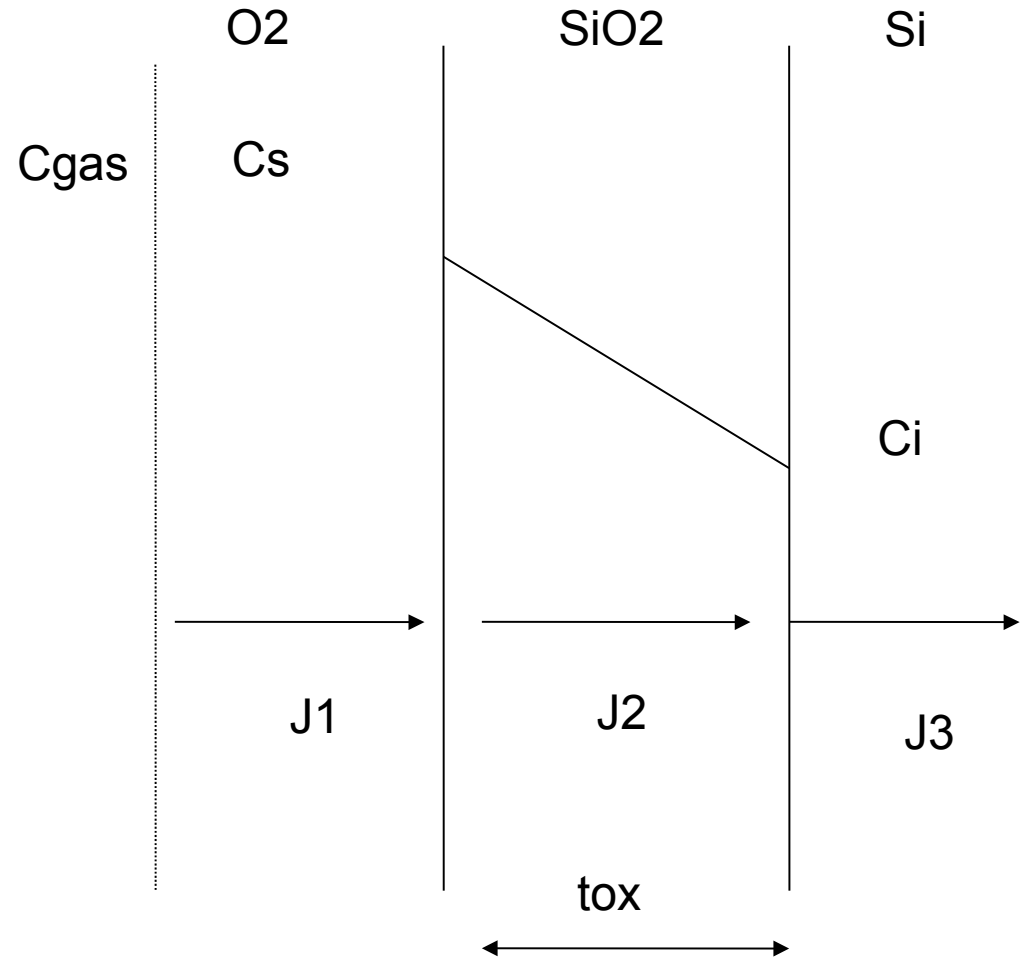
# Oxidation Kinetics

$$J_1 = J_2 = J_3$$

$$J_1 = h_G (C_G - C_s), C_G = \frac{P_G}{kT}$$

$$J_2 = D \frac{C_s - C_i}{tox}$$

$$J_3 = k_s C_i$$







# Oxide Thickness

General Equation

$$tox^2 + \frac{2D}{k} tox = 2 \frac{DC_o}{n} t$$

$n = \# \text{ of Oxygen atoms 'O' / unit volume}$

Initial Regime: small  $t$ ,  $tox^2 \ll tox$  : Linear Regime

$$tox = \frac{k C_o}{n} (t + \tau) = \frac{B}{A} (t + \tau)$$
$$\tau = \frac{tox_o^2 + A tox_o}{B}$$

Steady State Regime:  $tox^2 \gg tox$ : Parabolic Regime:

$$tox = \sqrt{\frac{2D C_o}{n} (t + \tau)} = \sqrt{B(t + \tau)}$$

In-between: use general equation



# B and B/A

B and B/A depend on D => both have Arrhenius dependence

