- Edge versus screw dislocation (parallel / perpendicular) ✱
  re: normal vector perpendicular or parallel to Burger's

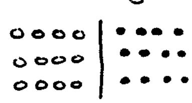
Pearlite { α - Fe (alpha ferrite)
Fe_3C (cementite)

equiaxed grains - grows equally in all directions
columnar grains - grows perpendicular to substrate
Grain boundaries restrict plastic flow.

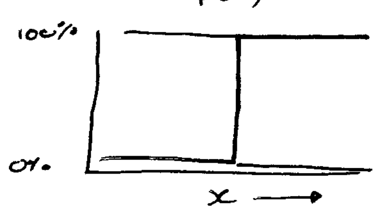
Grain boundaries {
less packing: higher diffusion of impurities, accumulation of impurities
higher energy than the grains: impurities get into grain boundaries, harden them by forming new structures along the grain.

Diffusion { interdiffusion : impurity diffusion to form substitutional solid sol'n
self-diffusion

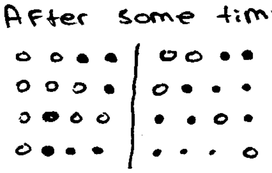
Initially:

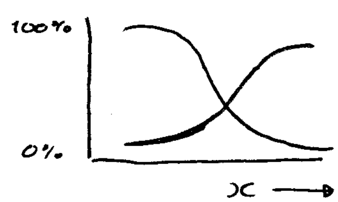


(diffusion couple)



After some time





Vacancy diffusion { self - diffusion
impurity diffusion in substitutional solid sol'n
Interstitial diffusion - impurity diffusion in interstitial solid solutions

If diffusion of atom is in this direction:
⟶

the motion of vacancy is in this direction:
⟵

Interstitial diffusion - For smaller atoms

interstitial vs. vacancy diffusion: (Rate comparison)

{ Smaller size of atoms (C vs. Fe)
  more interstitial sites than vacancy

(C atoms lock the planes from shearing) → diagrams with interstitial atoms
(resistant to cracking)

Rate of diffusion:

$$J = \frac{\text{moles (or mass) diffusing}}{(\text{area})\cdot(\text{time})}$$

$$\left(\frac{\text{mole}}{m^2 \cdot s} \; \Big\{ \; \frac{kg}{m^2 \cdot s} \; \Big\} \; \frac{\text{atom}}{cm^2 \; min} \right)$$

Steady state → 1^{ST} Fick's Law
Unsteady state → 2^{ND} Fick's Law

Fick's First Law : $J = -D\left(\frac{dC}{dx}\right)$

$\boxed{\text{Example :}}$

$\Delta x = 0.04 \text{ cm}$
$C_1 = 0.44 \text{ g/cm}^3$
$C_2 = 0.02 \text{ g/cm}^3$

Where: $D = 110 \times 10^{-8} \text{ cm}^2/s$

$$J = -(110 \times 10^{-8} \text{ cm}^2/s)\left(\frac{0.02 - 0.44 \text{ g/cm}^{\cancel{3}\,2}}{0.04 \text{ cm}}\right)$$

$$J = 1.16 \times 10^{-5} \text{ g/cm}^2/s$$

Oct. 24/18

Ficks First Law: Steady State Diffusion

$$D_1 = D_0 \exp\left[-\frac{Q_d}{RT_1}\right] \quad (1)$$

$$D_2 = D_0 \exp\left[-\frac{Q_d}{RT_2}\right] \quad (2)$$

$$\frac{D_1}{D_2} = \frac{D_0 \exp\left[-\frac{Q_d}{RT_1}\right]}{D_0 \exp\left[-\frac{Q_d}{RT_2}\right]} \Rightarrow \frac{(9.4\times10^{-6})}{(2.4\times10^{-4})} = \frac{\exp\left(-\frac{Q_d}{(8.31 J/mol K)(273 K)}\right)}{\exp\left(-\frac{Q_d}{8.31 J(mol K)(1273 K)}\right)}$$

$\hookrightarrow Q_d = 252{,}400$ J/mol

From (1): $D_0 = 2.2\times10^{-5}$ m²/s

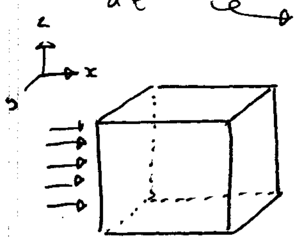
thus, $D_3 = (2.2\times10^{-5}\ m^2/s)\left[\frac{-(252400\ J/mol)}{(8.31\ J/mol K)(1373\ K)}\right] = 5.4\times10^{-15}\ m^2/s$

Ficks Second Law: Unsteady State Diffusion

accumulation = inlet rate − outlet rate

$$\frac{dm}{dt} = J_{left}\, dy\, dz - J_{right}\, dy\, dz$$

$$\hookrightarrow \frac{dm}{dt} = \frac{dc}{dt}\, dx\, dy\, dz$$



at $t = 0$ → $C = C_0$, $0 < x < \infty$

at $t > 0$: @ $x = 0$, $C = C_s$; @ $x = \infty$, $C = C_0$

$$c = f(x, t, T)$$

where erf − Gaussian error function

$$\frac{x}{\sqrt{Dt}} - \text{dimensionless} = \frac{m}{\sqrt{\frac{m^2}{s}s}} = 1$$

Design Example

$C_0 = 0.2$ wt %

$C_s = 1.00$ wt %

@ $x = 0.75$ mm $\quad C(x,t) = 0.6$ wt %

$900 < T < 1050 \quad$ γ − Fe (FCC) $\begin{cases} D_0 = 2.3\times10^{-5}\ m^2/s \\ Q_d = 148{,}300\ J/mol \end{cases}$

$$\frac{C_x - C_0}{C_s - C_0} = 1 - \text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

$$D = D_0 \exp\left(-\frac{Q_d}{RT}\right)$$

$$\frac{0.6-0.2}{1-0.2} = 1-\text{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

$$\text{erf}\left(\underbrace{\frac{x}{2\sqrt{Dt}}}_{z}\right) = \underbrace{0.5}_{\text{erf}(z)}$$

z	$\text{erf}(z)$
0.45	0.4755
?	0.5
0.5	0.5205

By interpolation:

$$y - 0.4755 = \frac{0.5205 - 0.4755}{0.5 - 0.45}(x - 0.45)$$

$$y = 0.9x + 0.0705$$

$$\text{erf}(z) = 0.9z + 0.0705$$

$$0.5 = 0.9z + 0.0705$$

$$z = 0.4772$$

$$\frac{x}{2\sqrt{Dt}} = 0.4772$$

$$\frac{(7.5\times10^{-4})}{(2\sqrt{Dt})} = 0.4772 \longrightarrow Dt = 6.18\times10^{-7}\ m^2$$

$$D_0 \exp\left(\frac{-Q_d}{RT}\right) t$$

$$6.18\times10^{-7}\ m^2 = 2.3\times10^{-5} \exp\left(-\frac{148000\ J/mol}{(8.31\ J/mol\,K)(T)}\right) t$$

$$t(s) = \frac{0.0269}{\exp\left(-\frac{17801}{T}\right)}$$

T (°)	time (s)
900	104819
950	56363
1000	31821
1050	18758

{drop 2, 12, 14 for Final}

Keep Ch. 3