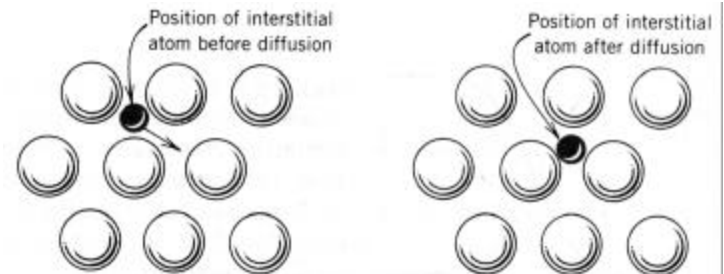
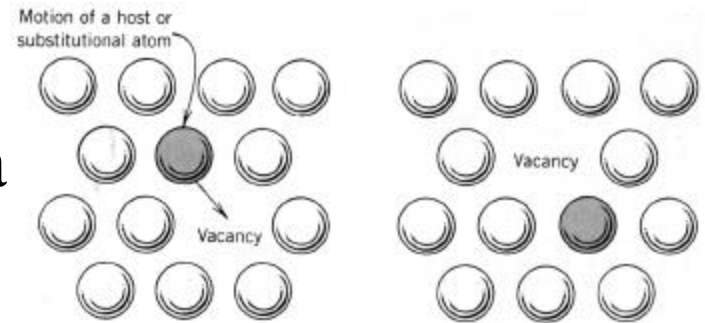


Diffusion

- The movement of atoms in a material from high concentrations to lower concentrations.
- Temperature has a large effect on diffusion, as temperature increases so does the rate at which the diffusion proceeds.

Diffusion Mechanisms

- **Vacancy Diffusion** - the movement of an atom from a normal lattice position to a vacancy
- **Interstitial Diffusion** - the movement of an interstitial atom from one interstitial site to another



Steady-State Diffusion

(Fick's First Law)

- Diffusion is a time dependent process and the rate of mass transfer is the *diffusion flux* (J).
- In a steady-state condition the concentration gradient is constant.

- Fick's First law:
$$J = -D \frac{\Delta c}{\Delta x}$$

Diffusion Coefficient

$$D = D_o \exp\left(\frac{-Q}{RT}\right)$$

D is the diffusion coefficient (cm²/s).

D_o = a temperature-independent pre-exponential (m²/s)

Q = the activation energy for diffusion (J/mol, cal/mol, or eV/atom)

R = the gas constant, 8.31 J/mol-K, 1.987 cal/mol-K, or 8.62X10⁻⁵ eV/atom-K)

T = absolute temperature (K)

Nonsteady-State Diffusion (Fick's Second Law)

- Most diffusion situations are nonsteady-state. The concentration gradient at some point will change with time.
- Fick's Second Law.

$$\frac{c_s - c_x}{c_s - c_o} = \operatorname{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

| $\frac{x}{2\sqrt{Dt}}$ | $\operatorname{erf} \frac{x}{2\sqrt{Dt}}$ |
|------------------------|---|
| 0 | 0 |
| 0.10 | 0.1125 |
| 0.20 | 0.2227 |
| 0.30 | 0.3286 |
| 0.40 | 0.4284 |
| 0.50 | 0.5205 |
| 0.60 | 0.6039 |
| 0.70 | 0.6778 |
| 0.80 | 0.7421 |
| 0.90 | 0.7970 |
| 1.00 | 0.8427 |
| 1.50 | 0.9661 |
| 2.00 | 0.9953 |

Error Function

| z | $erf(z)$ | z | $erf(z)$ | z | $erf(z)$ |
|-------|----------|------|----------|-----|----------|
| 0 | 0 | 0.55 | 0.5633 | 1.3 | 0.9340 |
| 0.025 | 0.0282 | 0.60 | 0.6039 | 1.4 | 0.9523 |
| 0.05 | 0.0564 | 0.65 | 0.6420 | 1.5 | 0.9661 |
| 0.10 | 0.1125 | 0.70 | 0.6778 | 1.6 | 0.9763 |
| 0.15 | 0.1680 | 0.75 | 0.7112 | 1.7 | 0.9838 |
| 0.20 | 0.2227 | 0.80 | 0.7421 | 1.8 | 0.9891 |
| 0.25 | 0.2763 | 0.85 | 0.7707 | 1.9 | 0.9928 |
| 0.30 | 0.3286 | 0.90 | 0.7970 | 2.0 | 0.9953 |
| 0.35 | 0.3794 | 0.95 | 0.8209 | 2.2 | 0.9981 |
| 0.40 | 0.4284 | 1.0 | 0.8427 | 2.4 | 0.9993 |
| 0.45 | 0.4755 | 1.1 | 0.8802 | 2.6 | 0.9998 |
| 0.50 | 0.5205 | 1.2 | 0.9103 | 2.8 | 0.9999 |

$$\frac{z - L_z}{U_z - L_z} = \frac{erf(z) - L_{erf(z)}}{U_{erf(z)} - L_{erf(z)}}$$

Where, $z = \left(\frac{x}{2\sqrt{Dt}} \right)$

Materials Processing

- **Grain Growth** - The movement of atoms across a grain boundary causing some grains to grow at the expense of others.
- **Diffusion Bonding** - The bonding of two materials by diffusion. Pressure and high temperatures are required.
- **Sintering** - The bonding of particles and the reduction of the voids between them.