

Atomic bonding

Ionic: Anions gain electrons, cations lose electrons

Covalent: electrons shared between two atoms

Metallic: electrons shared between many atoms

Van der Waals: temporary or permanent dipole

Interacts with other objects

Crystal structures

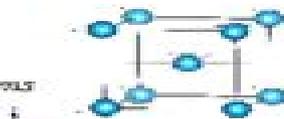
BODY CENTERED CUBIC

$$4R = \sqrt{a^2 + a^2 + a^2}$$

$$4R = a\sqrt{3}$$

1 center atom, 8 corner atoms

2 atoms per unit cell



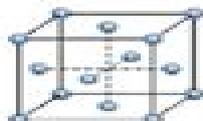
FACE CENTERED CUBIC

$$4R = \sqrt{a^2 + a^2}$$

$$4R = a\sqrt{2}$$

6 face atoms, 8 corner atoms

4 atoms per unit cell



Volume of a cubic = a^3

$$A = 10^{-10} \text{ m}$$

$$\text{Avogadro No} = 6.022 \times 10^{23} \left(\frac{\text{atoms}}{\text{mol}} \right)$$

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{\# \text{ of atoms} \times \text{atomic mass}}{\text{volume of unit cell} \times \text{Avogadro}}$$

Miller Indices

crystal	h	k	l
1. Intercepts	1	1	1
2. Reciprocals	1/1	1/1	1/1
3. Reduction	1	1	1
4. Miller indices	(111)		



crystal	h	k	l
1. Intercepts	1/2	1	1
2. Reciprocals	2/1/2	1/1	1/1
3. Reduction	2	1	2
4. Miller indices	(212)		



$$\text{Planar Density} = \frac{\text{atoms per face}}{\text{area of face}}$$

$$\text{Packing Factor} = \frac{\text{volume of atom} \times \text{number of atoms}}{\text{volume of the unit cell}}$$

Point Defects

$$n_v = n \cdot e^{-\frac{Q_v}{RT}}$$

$$n_v = \# \frac{\text{vacancies}}{\text{cm}^3}, n = \# \frac{\text{atoms}}{\text{cm}^3}$$

Q_v = energy for 1 mol of vacancies, T = Temp

$$R = \text{Gas constant} = 1.987 \frac{\text{cal}}{\text{mol} \cdot \text{K}} = 8.314 \frac{\text{joules}}{\text{mol} \cdot \text{K}}$$

Diffusion

$$D = D_0 \cdot e^{-\frac{Q}{RT}}$$

D_0 = constant based on material

Q = energy for 1 mol of vacancies, T = Temp

$$R = \text{Gas constant} = 1.987 \frac{\text{cal}}{\text{mol} \cdot \text{K}} = 8.314 \frac{\text{joules}}{\text{mol} \cdot \text{K}}$$

$$J = -D \cdot \frac{dc}{dx}, x = \text{thickness}, J = \text{Flux} \text{ - Fick's 1st law}$$

c = Compositions in atomic percent

Mechanical Properties

$$\text{Engineering stress } (S) = \frac{F}{A_0}$$

$$\text{Engineering Strain } (e) = \frac{\Delta l}{l}$$

$$\text{Young Modulus } (E) = \frac{S}{e}$$

F = Force, A_0 = Area

Δl = Change in length, l = Original length

$$K_f \text{ or } K_{fc} = f \sqrt{\pi a}$$

σ = Exposed stress, a = flaw size

f = geometry factor for the specimen and flaw

K_{fc} = fracture toughness

K_{Ic} = plain strain fracture toughness

$$\pm \sigma = 5.09 \cdot \frac{FL}{d^3}$$

F = Applied Load, L = Length of shaft

d = diameter of shaft

$$1 - K(V) = \exp \left[- \left(\frac{\sigma}{\sigma_0} \right)^m \right]$$

m = Weibull Modulus, σ_0 = Flexural Strength

F = Failure, σ_0 = Initial Flexural Strength

$$\text{Poissons Ratio } (\nu) = \frac{-\epsilon_{lateral}}{\epsilon_{longitudinal}}$$

$$\text{Modulus of resilience } (E_r) = \frac{1}{2} (\text{yield strength}) (\text{strain@yielding})$$

$$\text{Ductility \%Elongation} = \frac{l_f - l_0}{l_0} \cdot 100\%$$

$$\text{Ductility \%Reduction in area} = \frac{A_0 - A_f}{A_0} \cdot 100\%$$

$$\text{True Stress} = \frac{F}{A_f}$$

$$\text{True Strain} = \ln \left(\frac{l}{l_0} \right)$$

$$\sigma_t = K \epsilon_t^n$$

n = strain coefficient, K = Constant

ϵ_t = True strain, σ_t = True Stress

$$\sigma_m = 2\sigma_a \left(\frac{a}{r_c} \right)^{\frac{1}{2}}$$

σ_m = Stress @ Crack tip, σ_a = Applied stress

a = Crack Length, r_c = radius of curvature

$$\sigma_c = \left(\frac{2E\gamma_s}{\alpha\pi} \right)^{\frac{1}{2}}$$

σ_c = Critical Stress, E = elastic modulus

γ_s = specific surface energy

α = one half length of internal crack

Solidification and Nucleation

Material Science Final Exam Key

Scott C. Dulebohn



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