



Ch1

- Processing → structure → hardness
- Heat-treatment = obtain softer materials
 - * Annealing (退火) : 有控制地降溫 (eg. $1000^{\circ}\text{C} \rightarrow 900^{\circ}\text{C} \rightarrow 800^{\circ}\text{C}$)
 - * Quench (淬火) = 急速降溫 (eg. $250^{\circ}\text{C} \rightarrow 25^{\circ}\text{C}$)
- Cold-Working : add strengths and hardness
 - * shaping
- Metal
 - * Strong, ductile, high-thermal and electrical conductivities
- Ceramics
 - * Hard, brittle, wear-resistance
 - low-thermal and electrical conductivities
- Polymers
 - * low-thermal and electrical conductivities
 - low strength, densities
- Mechanical Properties
 - * strength, Hardness, Ductility, Stiffness
- Deteriorative Properties
 - * rate of crack growth is diminished by heating rating

Ch 2

Quantum Number

n = principal (shell)

ℓ = azimuthal (subshell)

m_ℓ = magnetic (no. of orbitals)

m_s = spin

Designation/Values

K, L, M, N, O (1, 2, 3, 4, etc.)

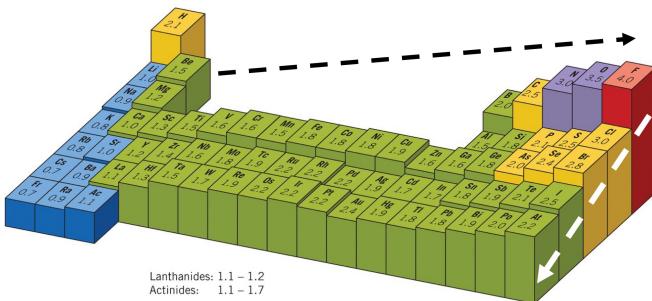
s, p, d, f (0, 1, 2, 3, ..., $n-1$)

1, 3, 5, 7 (- ℓ to + ℓ)

$\frac{1}{2}, -\frac{1}{2}$

- n = size & energy level
- ℓ = shape ($n-1$)
- M_ℓ = configuration of the orbitals
- S = $+\frac{1}{2}$ (clockwise)
 $-\frac{1}{2}$ (anti-clockwise)

ℓ	Orbital name	Shape
0	s	Ball
1	p	Dumbbells
2	d	Dual-dumbbells
3	f	Complicated



* electronegativity = tendency to obtain electron
 $0.7 \sim 4.0$

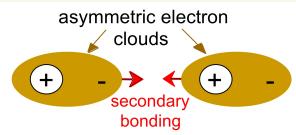
$$F_A = \frac{1}{4\pi\epsilon_0 r^2} (|Z_1|e) (|Z_2|e) \cdot 1.6 \times 10^{-19} C$$

↓
價電子數

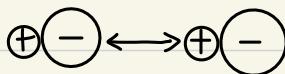
Attractive Energy $F_A = -F_R$

• Secondary bonding

* Fluctuating dipoles =
eg. $H_2 \leftrightarrow H_2$

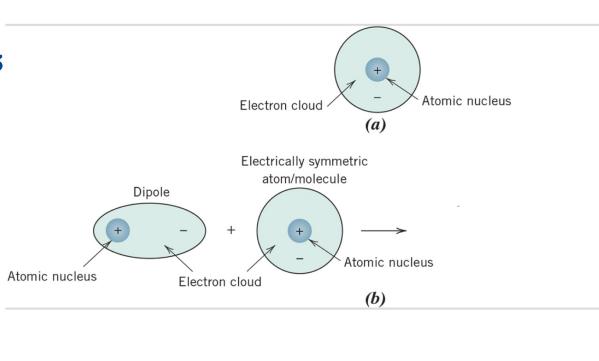


* Permanent dipoles =

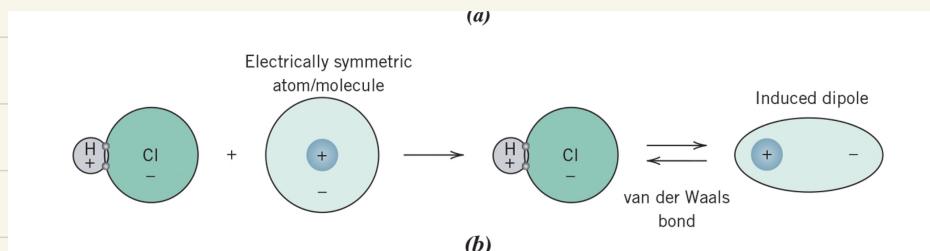


* Van Der Waals Bonding = Atomic or molecular dipoles

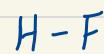
* Fluctuating induced dipole bonds



* Polar molecule - induced dipole bonds



* Permanent dipole bonds = (氫鍵)



* % ionic character

電負度

$$\% IC = \{1 - \exp[-(0.25)(\underline{X_A} - X_B)^2]\} \times 100$$

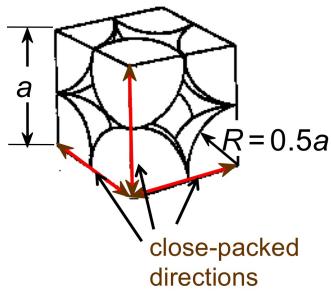
$$\% IC = \{1 - e^{[-\frac{1}{4}(X_A - X_B)^2]}\} \times 100$$

* Melting Temperature : The larger E_b → higher T_m
bond Energy

Ceramics (Ionic & covalent bonding):	Large bond energy high T _m large E _b small α _f
Metals (Metallic bonding):	Variable bond energy moderate T _m moderate E _b moderate α _f
Polymers (Covalent & Secondary):	Weak bond energy (between chains) Secondary bonding responsible for most physical properties low T _m small E _b large α _f

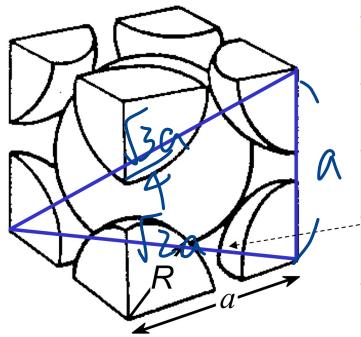


Ch 3



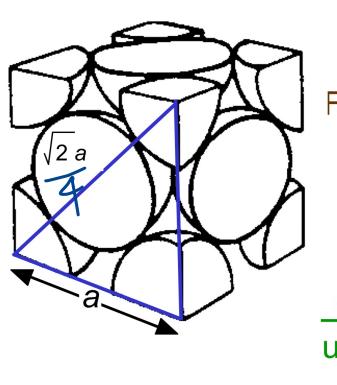
* Simple cubic

$$APF = \frac{1 \times \frac{4}{3}\pi (0.5a)^3}{a^3} = 0.52$$



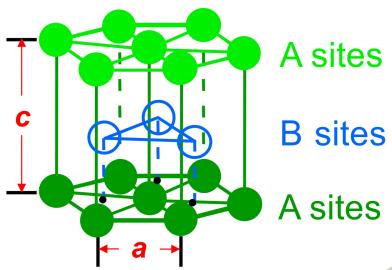
* BCC = $\frac{2 \times \frac{4}{3}\pi (\frac{\sqrt{2}}{4}a)^3}{a^3}$

$$= 0.68$$



* FCC = $\frac{4 \times \frac{4}{3}\pi (\sqrt{2}a/4)^3}{a^3}$

$$= 0.74$$



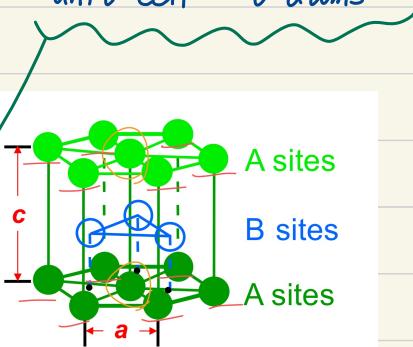
* HCP

$$\text{coordination} = 12$$

$$\text{APF} = 0.94$$

$$c/a = 1.633$$

$$\text{unit cell} = 6 \text{ atoms}$$



WILE

$$N = \underbrace{3}_{\text{B site}} + \underbrace{\frac{2}{2}}_{\text{B site}} + \underbrace{\frac{12}{6}}_{\text{A site}}$$

$$N = 6$$



* Theoretical Density of Metals, ρ

$$\rho = \frac{n A}{V_c N_A}$$

n : unit cell

A : atom weight

V_c : a^3 for cubic

$$N_A = 6.022 \times 10^{23} \text{ atoms/mol}$$

Number of formula units/unit cell

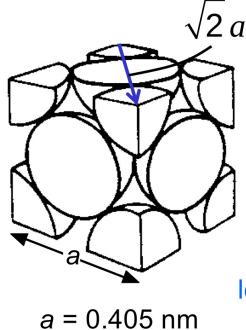
$$\rho = \frac{n'(\Sigma A_C + \Sigma A_A)}{V_C N_A}$$

Volume of unit cell

Avogadro's number
亞佛加羅

$$a^3 = (\text{陽 ion 直徑} + \text{陰 ion 直徑})^3$$

* Linear Density of Atoms (LD)



ex:

linear density of Al in [110] direction

(上下 12 個平面)

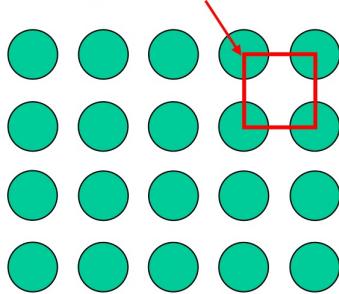
There are 2 half atoms and 1 full atom
= 2 atoms centered on vector

atoms

$$\text{LD} = \frac{2}{\sqrt{2}a} = \frac{2}{\sqrt{2}(0.405 \text{ nm})} = 3.5 \text{ nm}^{-1}$$

* PD (Planar Density)

2D repeat unit



Radius of iron,
 $R = 0.1241 \text{ nm}$

ex: planar

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

a

atoms

$$\text{PD} = \frac{\# \text{ atoms}}{\text{area}}$$

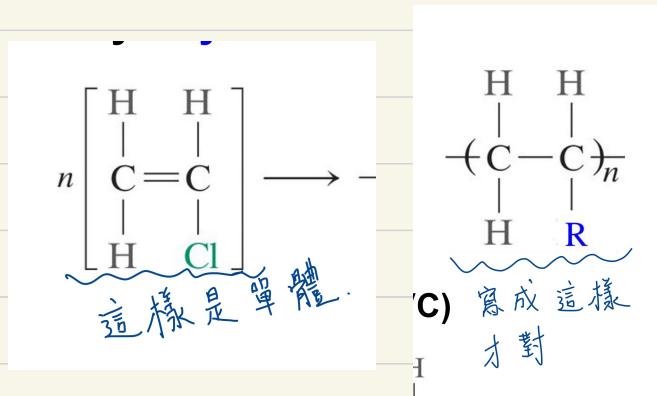
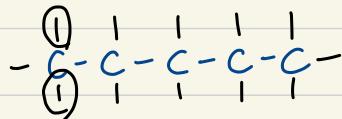
$$4r = \sqrt{3}a$$

$$\Rightarrow a = \frac{4}{\sqrt{3}} r$$

$$\text{PD} = \frac{1 \text{ atom}}{a^2}$$

Ch4

- Isomerism: 異構性
- Macro molecules: covalent bond, remain two valence electrons
- Free radical polymerization: 要有 3鍵 or 双鍵



- M_n : number - average $M_n = \frac{\text{total weight of polymer}}{\text{total # of molecules}}$
- M_w : weight - average
- DP (聚合度) = $\frac{\bar{M}_n}{m}$ m: repeat unit molecular weight
- \bar{M}_n range from 25k ~ 50k Da is suitable for condensation polymers
 $\bar{M}_n > 50\text{k Da} \Rightarrow$ addition polymer

weight range mass (lb)	mean weight W_i mass (lb)	number fraction x_i	weight fraction w_i
81-120	110	0.2	0.117
121-160	142	0.2	0.150
161-200	184	0.3	0.294
201-240	223	0.2	0.237
241-280	-	0	0.000
281-320	-	0	0.000
321-360	-	0	0.000
361-400	380	0.1	0.202

$$M_n = \sum x_i M_i = (0.2 \times 110 + 0.2 \times 142 + 0.3 \times 184 + 0.2 \times 223 + 0.1 \times 380) = 188 \text{ lb}$$

$$\begin{aligned} M_w = \sum w_i M_i &= (0.117 \times 110 + 0.150 \times 142 + 0.294 \times 184 \\ &\quad + 0.237 \times 223 + 0.202 \times 380) = 218 \text{ lb} \end{aligned}$$

WILEY

Using 40 lb ranges gives the following table:

weight range mass (lb)	number of students N_i	mean weight W_i mass (lb)
81-120	2	110
121-160	2	142
161-200	3	184
201-240	2	223
241-280	0	-
281-320	0	-
321-360	0	-
361-400	1	380

Calculate the number and weight fraction of students in each weight range as follows:

$$x_i = \frac{N_i}{\sum N_i}$$

$$w_i = \frac{N_i W_i}{\sum N_i W_i}$$

For example: for the 81-120 lb range

$$x_{81-120} = \frac{2}{10} = 0.2$$

$$w_{81-120} = \frac{2 \times 110}{1881} = 0.117$$

total number ΣN_i

10

$\Sigma N_i W_i$ ← total weight

1881

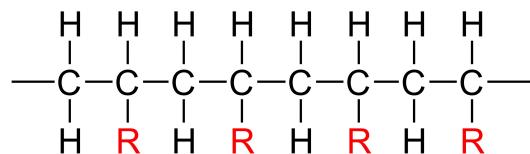
• Molecular configurations

* Stereoisomerism (立體異構物)

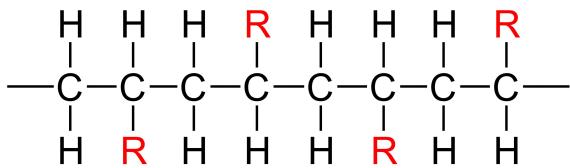
⇒ mirror images

* Tacticity: arrangement of R units

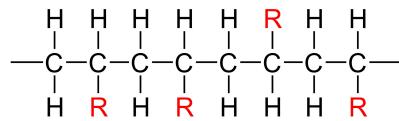
⇒ ①: isotactic (同排)



②: syndiotactic (對排)



③: atactic (雜排)



• Copolymers : two or more monomers

* random

* block

* alternating

* graft

→ Specimen density (要找的)

$$\bullet \% \text{ crystallinity} = \frac{\rho_c (\rho_s - \rho_a)}{\rho_s (\rho_c - \rho_a)} \times 100$$

↪ perfectly crystalline

$$\rho = \frac{n'(\sum A_c + \sum A_a)}{V_c N_A}$$

陰陽 ion
質量

• The glassy state $\xrightarrow{T_g}$ the rubbery state

Amorphous

slower and the chain

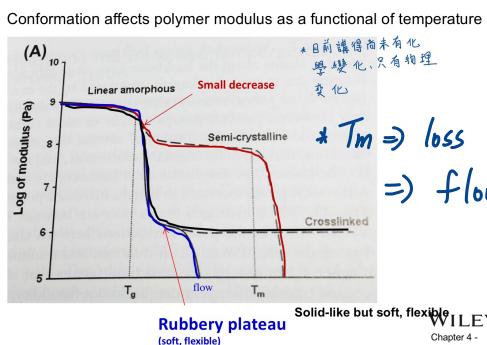
Soft, flexible, extensible
continuously rotate

stiffer

single bond rotation

cease \Rightarrow transition T_g

temperature



* $T_m \Rightarrow$ loss crystallinity
 \Rightarrow flow

$< T_g \Rightarrow$ hard, stiff

brittle

Ch 5

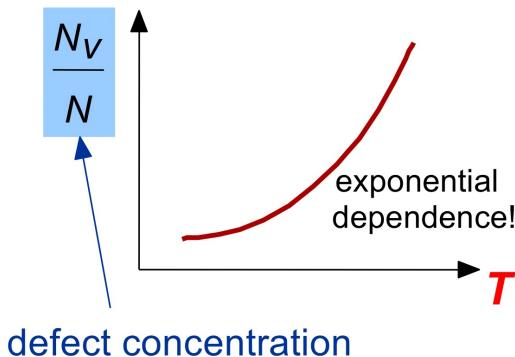
$$\frac{N_v}{N} = \exp\left(\frac{-Q_v}{kT}\right)$$

造成空位所需能量
Boltzmann 常数

$(1.38 \times 10^{-23} \text{ J/atom-K})$

$(8.62 \times 10^{-5} \text{ eV/atom-K})$

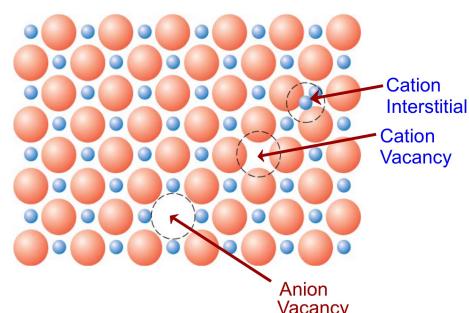
Defect density \approx plotted above



$$\Rightarrow T \uparrow \rightarrow N_v \uparrow$$

* Vacancies: both cation & anion

Interstitials: cation



* two types of solidification

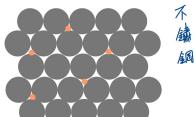
composed of host A atoms:

- Solid solution of B in A (i.e., random dist. of B atoms)



Substitutional solid soln.
(e.g., Cu in Ni)

OR



Interstitial solid soln.
(e.g., C in Fe)