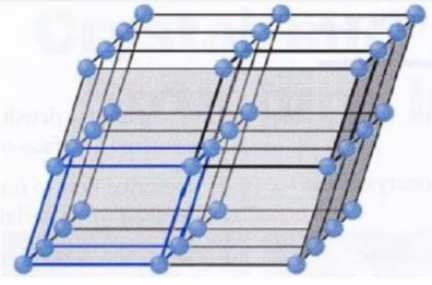
Types of Bonds

Primary		
Ionic	Electron *transfer*.	Non-directional
Covalent	Electron *sharing*.	Directional, strong, brittle, high melting temps, less conductive.
Metallic	"Sea of electrons."	Ductile, conductive.
Secondary	**(van der Waals)**	
	atom 1	*atom 2*
London	induced dipole	induced dipole
Debye	permanent dipole	neutral (non-polarized)
Keesom	permanent dipole	permanent dipole

Lattice



A collection of points arranged on a periodic pattern so that the surroundings of each lattice point are identical.

Atomic Radii and Crystal Structures for 16 Metals

Metal	Crystal Structure	Atomic Radius (nm)
Aluminum	FCC	0.1431
Cadmium	HCP	0.1490
Chromium	BCC	0.1249
Cobalt	HCP	0.1253
Copper	FCC	0.1278
Gold	FCC	0.1442
Iron	BCC	0.1241
Lead	FCC	0.1750
Molybdenum	BCC	0.1363
Nickel	FCC	0.1246
Platinum	FCC	0.1387
Silver	FCC	0.1445
Tantalum	BCC	0.1430
Titanium	HCP	0.1445
Tungsten	BCC	0.1371
Zinc	HCP	0.1332

[1, Tab 3.1]

E of Various Crystallographic Directions

	Young's Modulus (GPA)		
Metal	**[100]**	**[110]**	**[111]**
Aluminum	63.7	72.6	76.1
Copper	66.7	130.3	191.1
Iron	125.0	210.5	272.7
Tungsten	384.6	384.6	384.6

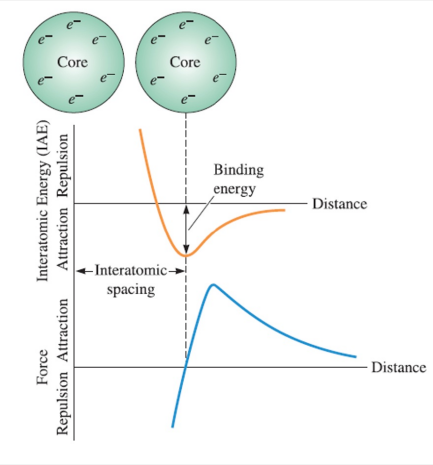
Plane From Miller Index

1. Look at the plane, determine where the plane intersects the various axes (X, Y, and Z intercepts).
2. Verify that the origin does not intersect with the plane.
3. Take reciprocals.
4. Clear fractions (if needed).
5. Any negative numbers? Use the overbar.
6. Enclose final result in parentheses.

Miller Index From Direction

1. Using a right-handed coordinate system, find the coordinates of TWO points that lie in the direction.
2. Subtract the “tail” point from the “head” point.
3. Clear fractions and/or reduce the results from step 2 to the lowest integers.
4. Enclose the numbers with brackets [ ]. *If a negative number is present, use a bar over the number.*

Equalibrium Distance



Equilibrium separation occurs when the total energy is minimized and also when the net force is zero.

Coefficient of Thermal Expansion

→CTE = α
→$\Delta L/L_o=\alpha(T_2+T_1)$
→Metal CTE is higher than ceramic CTE.
{{nl}→Heat = elongation
→Cooling = contraction

Sources

[1] W.D. Callister, *Fundamentals of Materials Science and Engineering*, 5th ed. New York, NY, USA: John Wiley & Sons, 2001, pp. 33

Common Crystal Structures

	FCC	BCC	HCP
C.N.	12	8	12
total atoms/unit cell	4	2	6
APF	0.74	0.68	0.74
a	$2R\sqrt{2}$	$4R/\sqrt{3}$	td

Atomic Packing Factor

$$APF = \frac{\text{total sphere volume}}{\text{total unit cell volume}} = \frac{V_S}{V_C}$$

$V_s = (4/3)(pi)(R^3)$
$V_c = a^3$

Theoretical Density of a Metallic Solid

$$\rho = \frac{nA}{\forall_c N_A}$$

n=# of atoms associated with each unit cell
A=atomic #.
$\forall_c$ = volume of the unit cell
N_A = Avogadro's number (6.023×10^{23} atoms/mol)

Direction From Miller Index

1. Look at the index values and if any are larger than one, take out a factor such that none of the integer values are greater than one.

2. For example, we have a Miller index of [2 1 1], we can take out a factor of 2 2* [1 1/2 1/2].

3. Essentially we have created a new point to plot with coordinates of x = 1, y = 1/2 and z = 1/2.

4. Set up your unit cube and it is fine to place the origin at the lower left hand corner as shown below.

5. Plot the new point (1, 1/2, 1/2) and connect the 'dots'.

Terms

Single crystal

Anisotropic

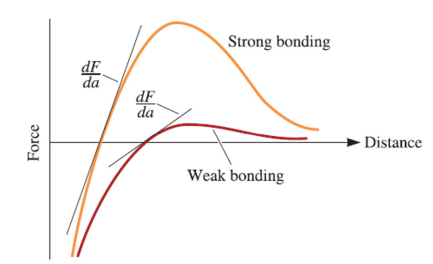
Polycrystal

Grain boundaries

Isotropic

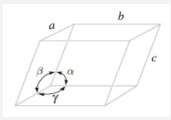
Polymorphism

Stiffness



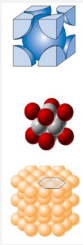
Stiffness of a material is related to the slope of the F vs atomic separation curve (r). The stiffness (dF/da) of the material is known as the **Young's modulus, E.**

Dimensions and Angles



Lattice parameters are the dimensions a,b and c of the unit cell.
Interaxial angles are α, β, and γ.

(top to bottom)BCC, FCC, & HCP



Miller Index From Plane

1. Draw the unit cube and right handed coordinate system & be sure that the plane does not pass thru the point you've selected to be the origin.

2. Take reciprocals

3. Plot the plane.

4. DO NOT CLEAR FRACTIONS.

Linear and Planar Density

Linear Density

> Number of atoms per unit cell whose centers are aligned in a specific direction.

LD=

> #atoms/unit length

Planar Density

> Number of atoms per unit area that are centered on the area of the plane.

PD=

> #atoms centered on plane/area of plane