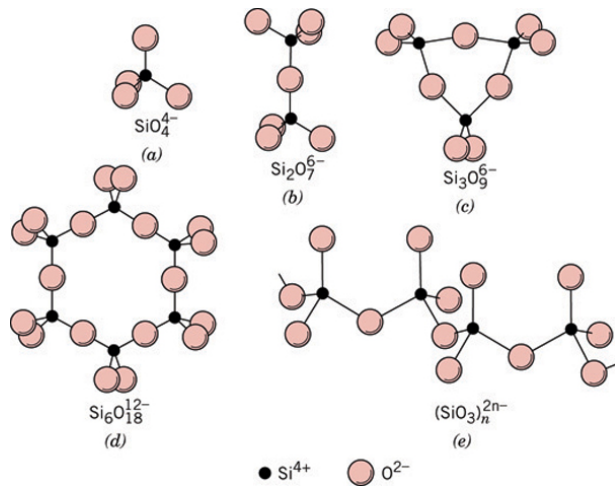
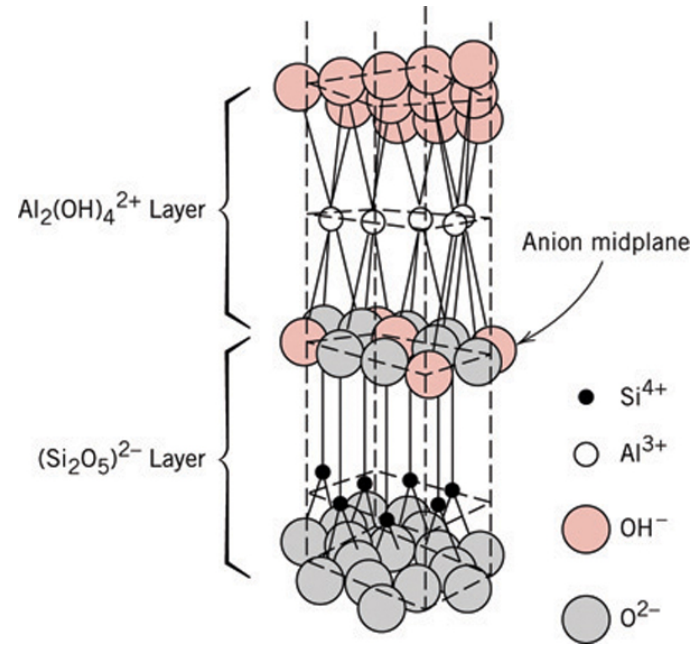


Silicate Ceramics

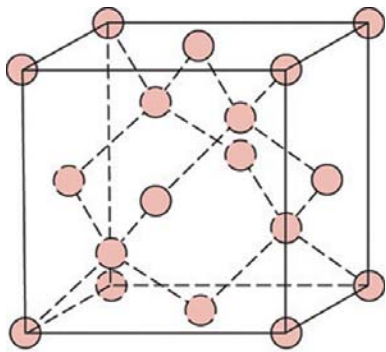


Some Si – O bonding patterns

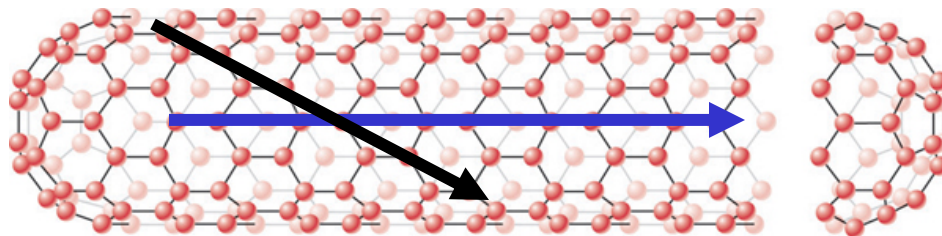
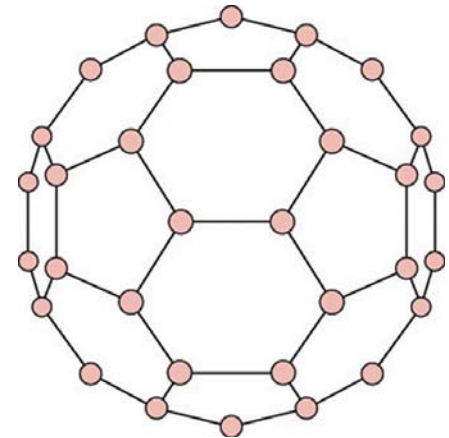
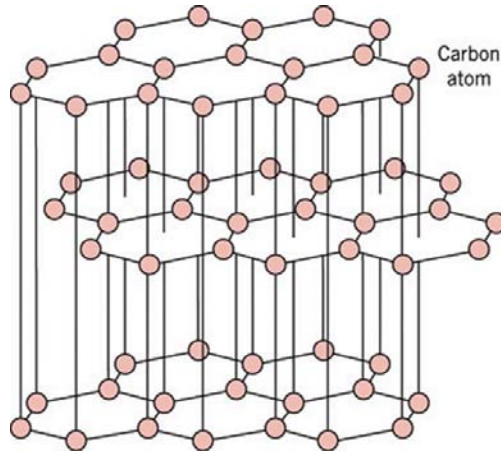


Kaolinite

Carbon polymorphs



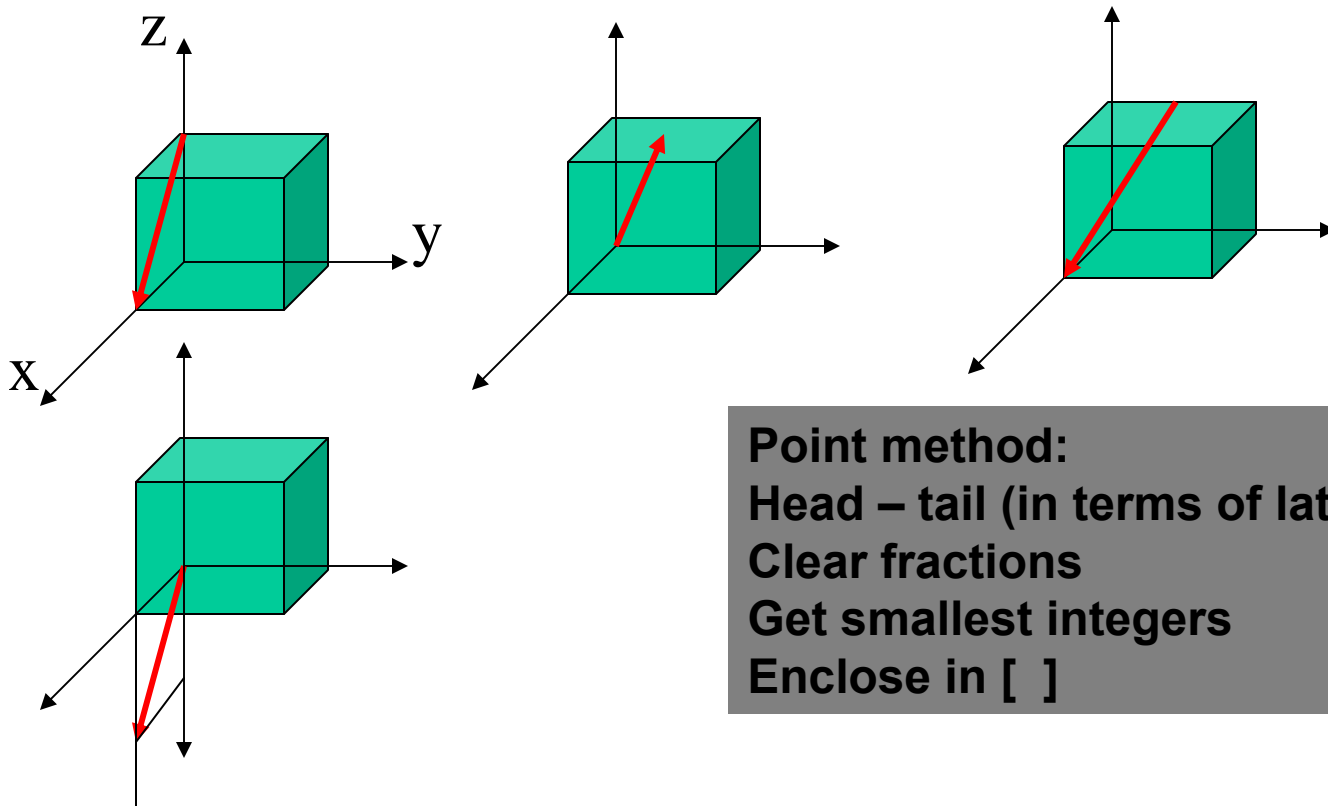
● c



Identification of planes and directions in crystals

Finding Crystallographic Directions

- When vector passes through the origin, project onto x y z axes
- Measure in terms of lattice constants a, b, c
- Clear fractions
- Multiply or divide to get smallest integers
- Enclose in []



Point method:
Head – tail (in terms of lattice constants)
Clear fractions
Get smallest integers
Enclose in []

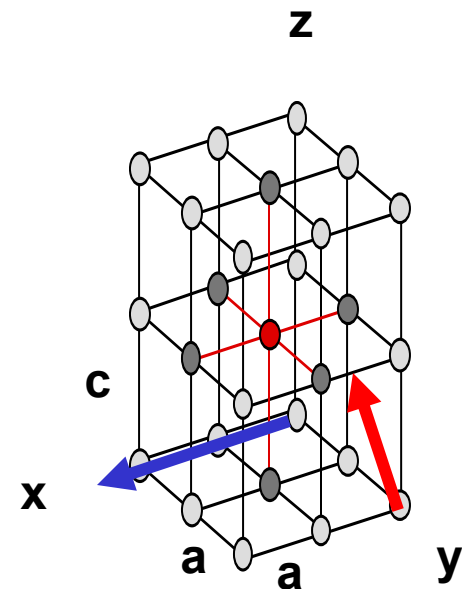
Finding Crystallographic Directions

- When vector passes through the origin, project onto x y z axes
- Measure in terms of lattice constants a, b, c
- Clear fractions
- Multiply or divide to get smallest integers
- Enclose in []

This method holds for all crystal systems regardless of angles.

Tetragonal cell, two lattice constants a and c

1. $1a, 0a, 0c = [1,0,0]$
2. $1/2a, 0a, 1c = [1,0,2]$



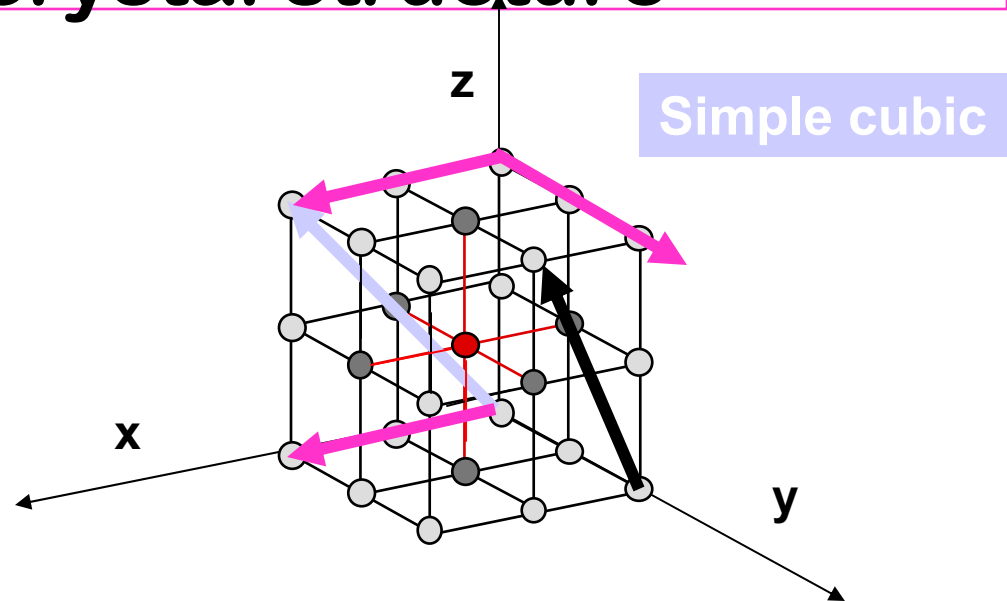
Crystallographic directions + crystal structure

- **Directions only** – not vectors – magnitude not important!
- Lattice points have equivalent surroundings, so can choose origin
- Many directions **crystallographically equivalent** (family of directions) $\langle 100 \rangle$
- Different directions have different atomic spacing (linear packing density- Fraction of unit cell length occupied by atom)
- **Direction + crystal structure needed to know atom location**

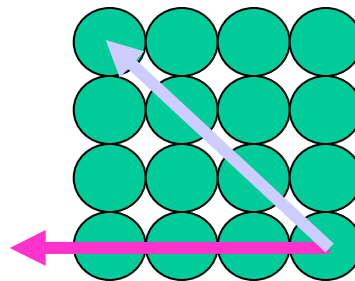
for Simple cubic:
Linear packing density

$$[100] \quad 1/a \text{ nm}^{-1}$$

$$[110] \quad 1/(a \sqrt{2}) \text{ nm}^{-1}$$

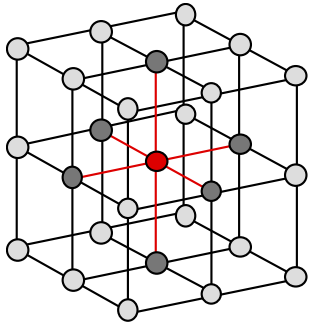


View of x-z plane



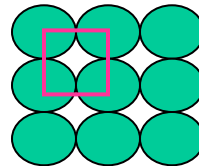
Crystallographic Planes – packing density

Atom positions for simple cubic planes

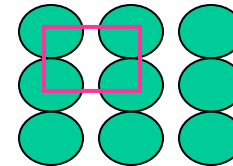


Po: $a = 0.33\text{nm}$

1 atom in each square



SC (100)
 $A = a \times a$



SC (110)
 $A = a \times (a \sqrt{2})$

Planar packing density

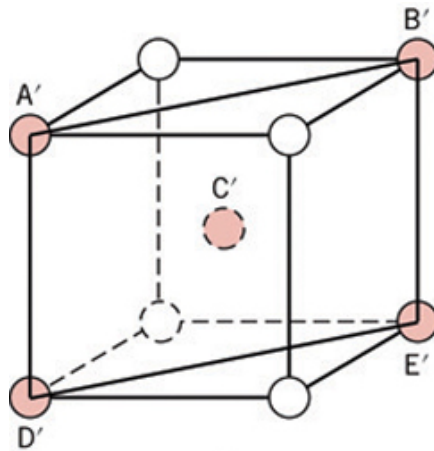
$$\frac{1}{(0.33)^2} \text{nm}^{-2}$$

$$\frac{1}{(0.33)^2 \sqrt{2}} \text{nm}^{-2}$$

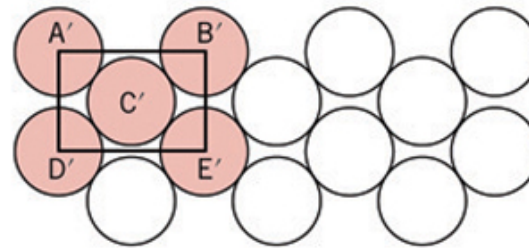
**Within a crystal structure:
Family of planes have
equivalent area packing density**

Crystallographic Planes – packing density

The same index may have different atomic packing for different crystal structures. Example: (011) on SC vs BCC



(a)



(b)

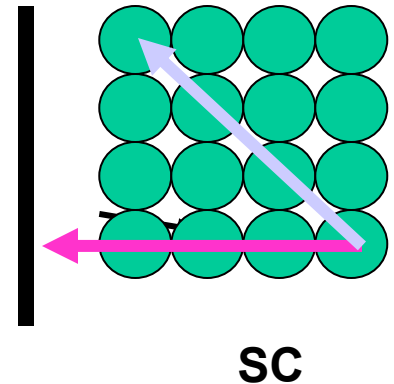
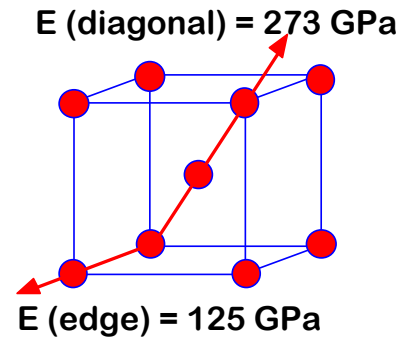
2 atom in each square

Planar packing density $\frac{2}{(a)^2\sqrt{2}} nm^{-2}$

SINGLE VS POLYCRYSTALS

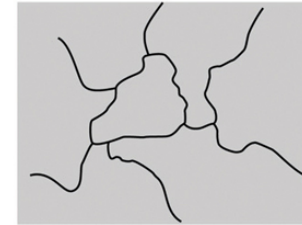
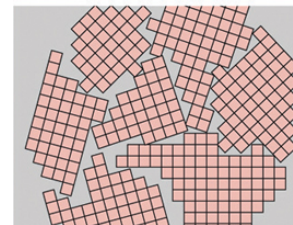
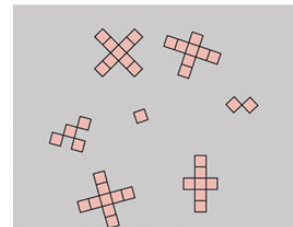
- **Single Crystals**

- Properties vary with direction: **anisotropic**.
- Example: the modulus of elasticity (E) in BCC iron:



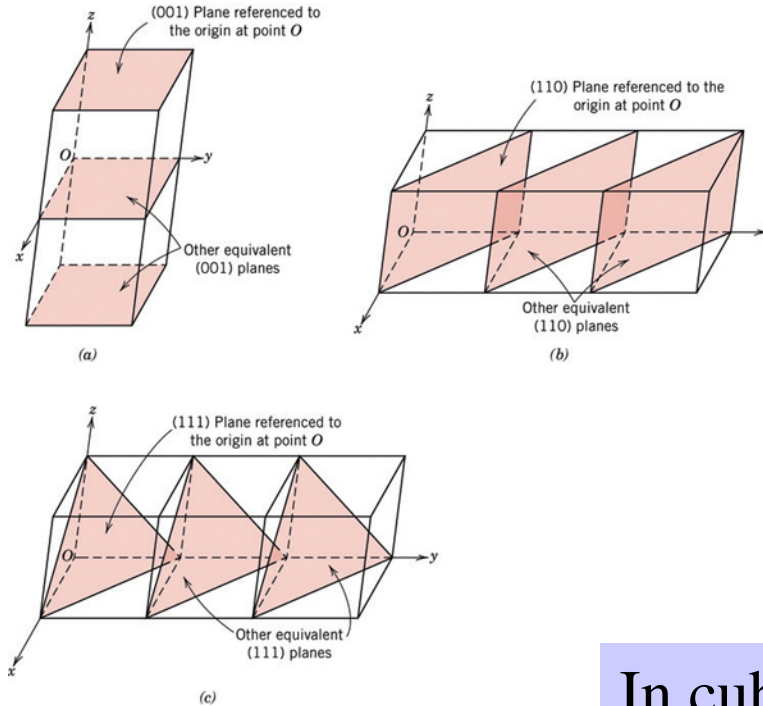
- **Polycrystals**

- Properties may/may not vary with direction.
- If grains are randomly oriented: **isotropic**. →
($E_{\text{poly iron}} = 210$ GPa)
- If grains are **textured**, anisotropic.



Crystallographic planes - repeating

Crystals have repeating unit cells so planes repeat



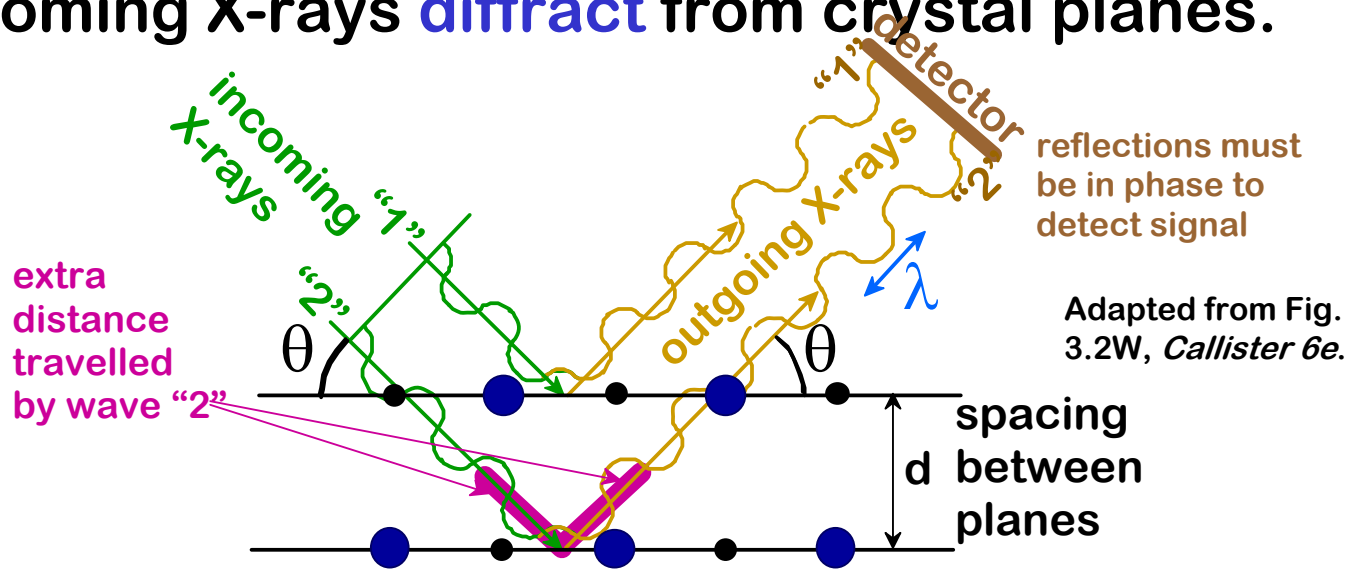
Distance between planes, measured perpendicular to the plane: “d-spacing”

In cubic system

$$d = \frac{a}{\sqrt{h^2 + k^2 + l^2}}$$

X-RAYS TO CONFIRM CRYSTAL STRUCTURE

- Incoming X-rays **diffract** from crystal planes.



- Measurement of:
Critical angles, θ_c ,
for X-rays provide
atomic spacing, d .

x-ray
intensity
(from
detector)

