TYPES OF IMPERFECTIONS

- Vacancy atoms
- Interstitial atoms
- Substitutional atoms

Point defects

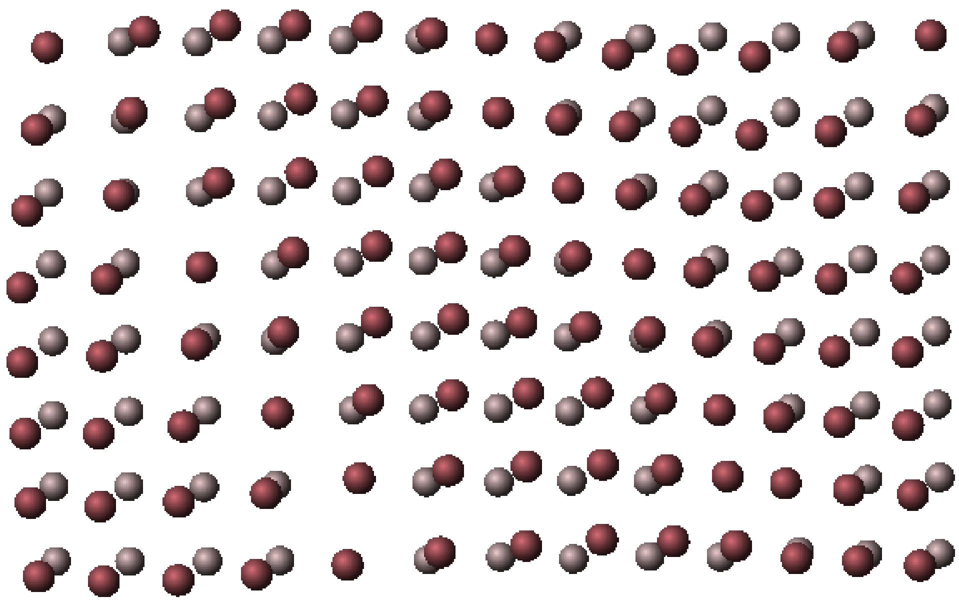
- Dislocations

Line defects

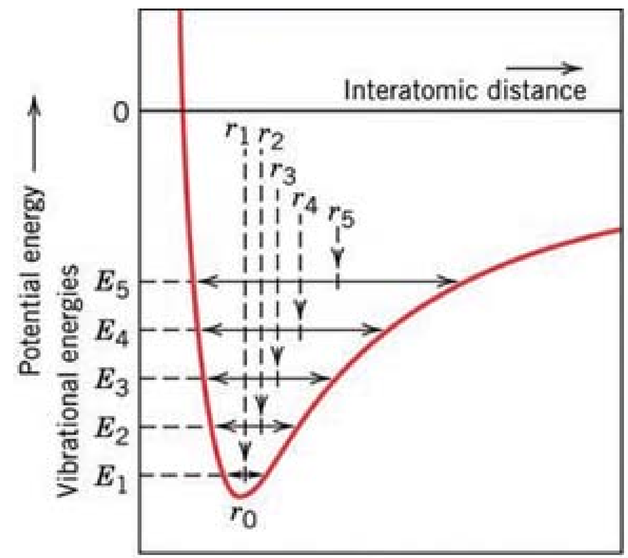
- Grain Boundaries
- Stacking faults

Area defects

No longer perfect: Thermal Energy



Lattice points
Atom positions

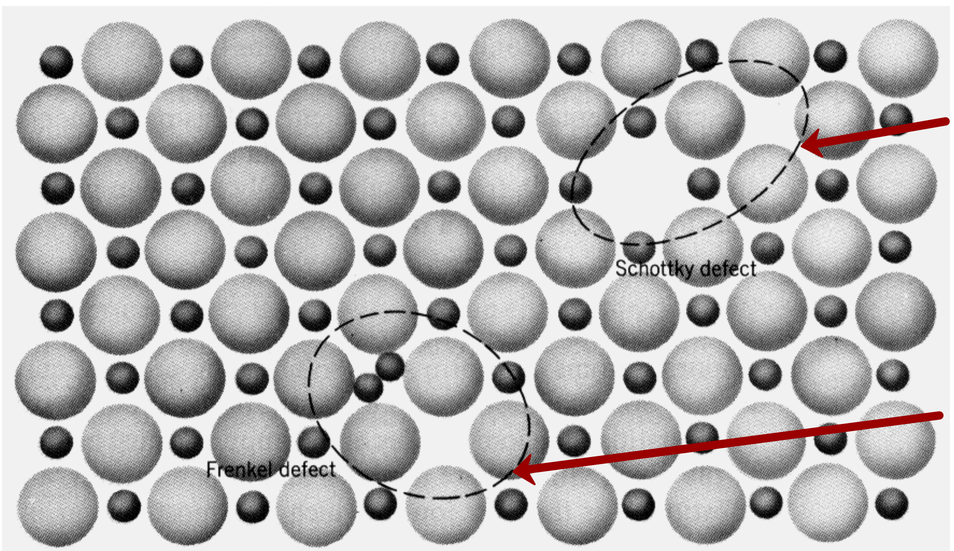


(a)

Chapter 17 on CD

DEFECTS IN CERAMIC STRUCTURES

- **Frenkel Defect**
  --a cation is out of place.
- **Shottky Defect**
  --a paired set of cation and anion vacancies.



Shottky Defect:

Frenkel Defect

Adapted from Fig. 13.20, *Callister 5e.* (Fig. 13.20 is from W.G. Moffatt, G.W. Pearsall, and J. Wulff, *The Structure and Properties of Materials*, Vol. 1, *Structure*, John Wiley and Sons, Inc., p. 78.) See Fig. 12.21, *Callister 6e*.

- **Equilibrium concentration of defects** $\sim e^{-Q_D/kT}$

EQUIL. CONCENTRATION: POINT DEFECTS

- Equilibrium concentration varies with temperature!

No. of defects

Activation energy

$$\frac{N_D}{N} = \exp\left(\frac{-Q_D}{kT}\right)$$

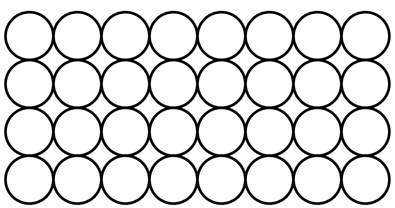
No. of potential defect sites.

Temperature

Boltzmann's constant

(1.38×10^{-23} J/atom K)

(8.62×10^{-5} eV/atom K)



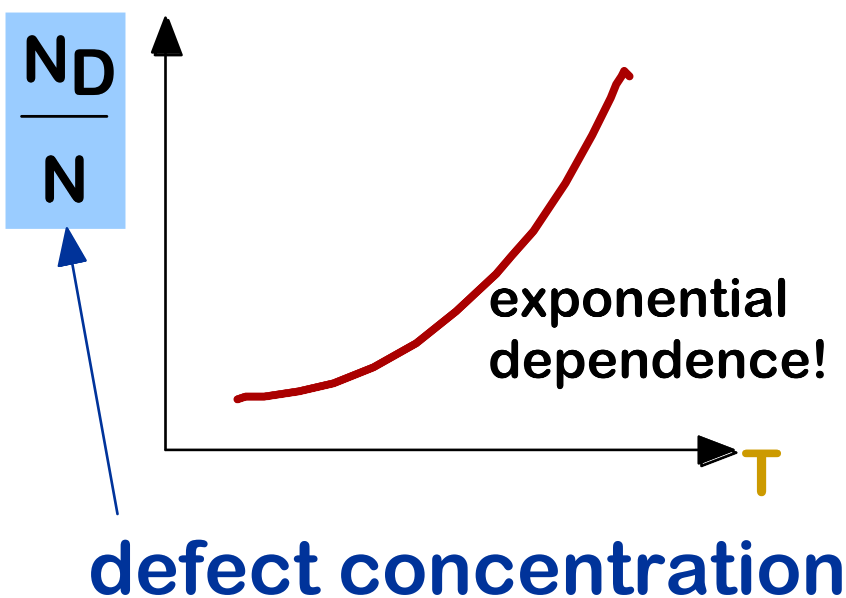
Each lattice site is a potential vacancy site

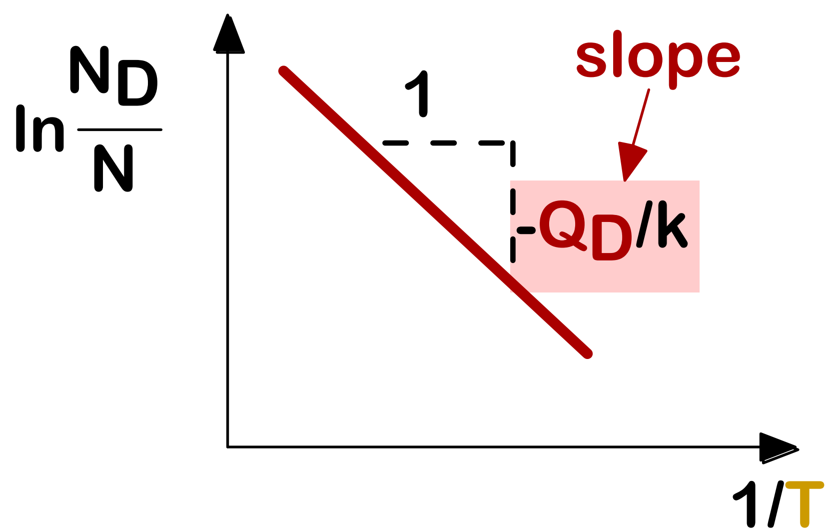
MEASURING ACTIVATION ENERGY

- We can get Q from an experiment.

$$\frac{N_D}{N} = \exp\left(\frac{-Q_D}{kT}\right)$$

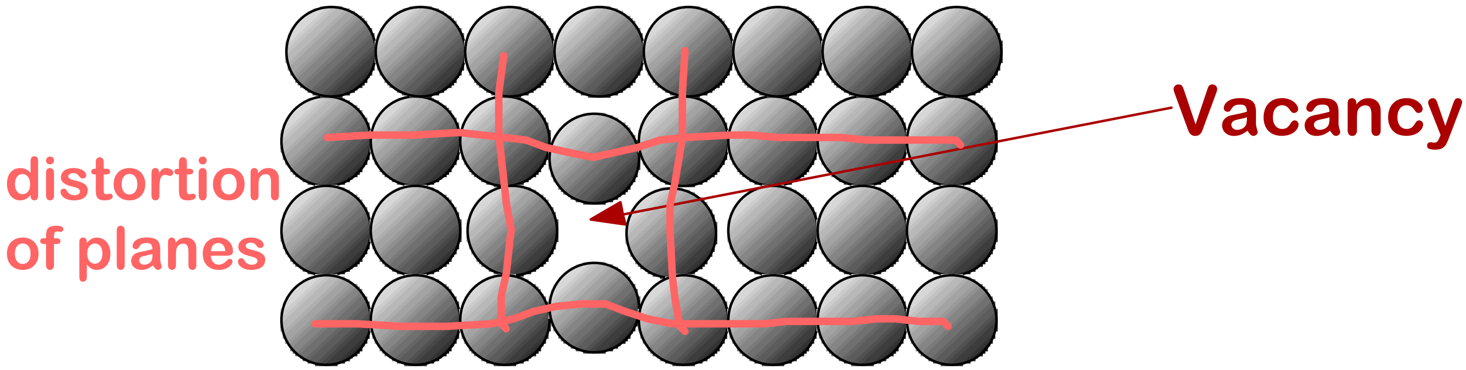
- Measure this...
- Replot it...



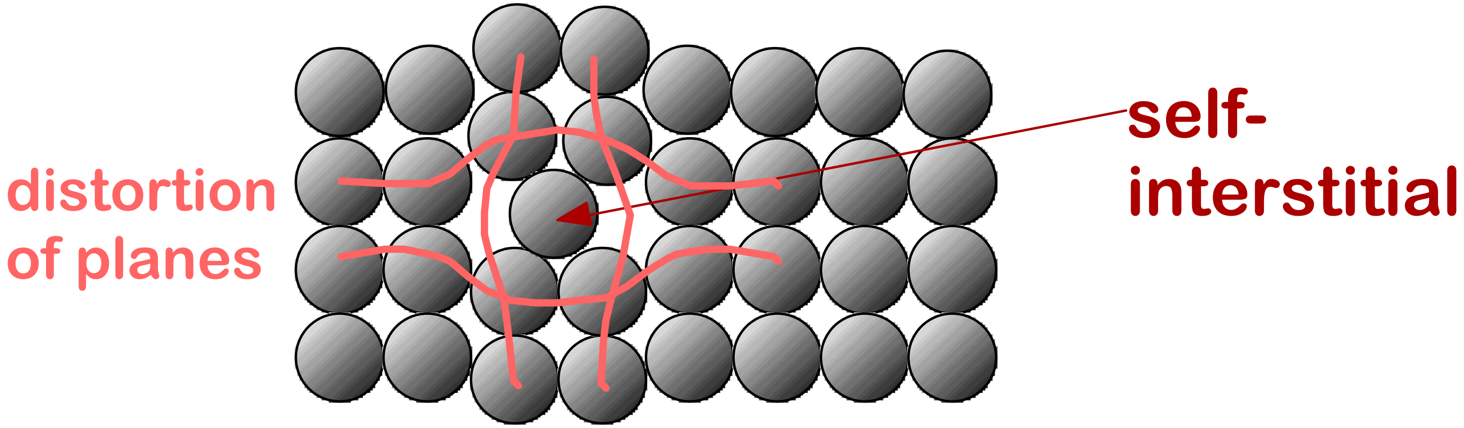


POINT DEFECTS

- **Vacancies**:
  -vacant atomic sites in a structure.



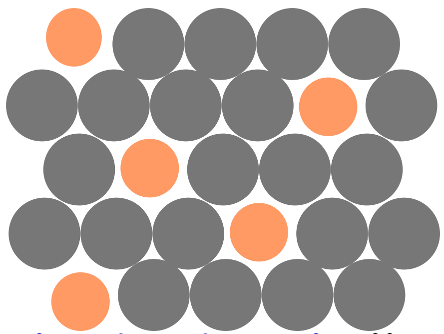
- **Self-Interstitials**:
  -"extra" atoms positioned between atomic sites.



POINT DEFECTS IN ALLOYS

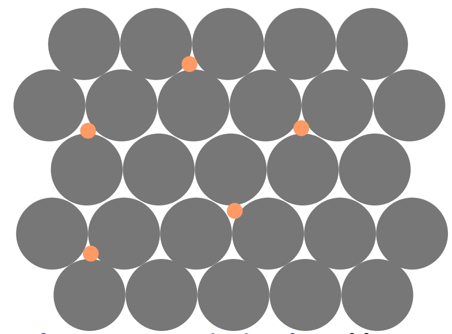
Two outcomes if impurity (B) added to host (A):

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



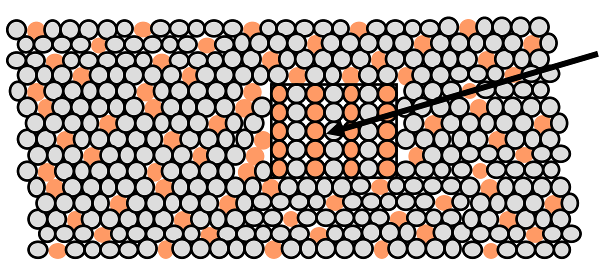
Substitutional alloy
(e.g., Cu in Ni)

OR



Interstitial alloy
(e.g., C in Fe)

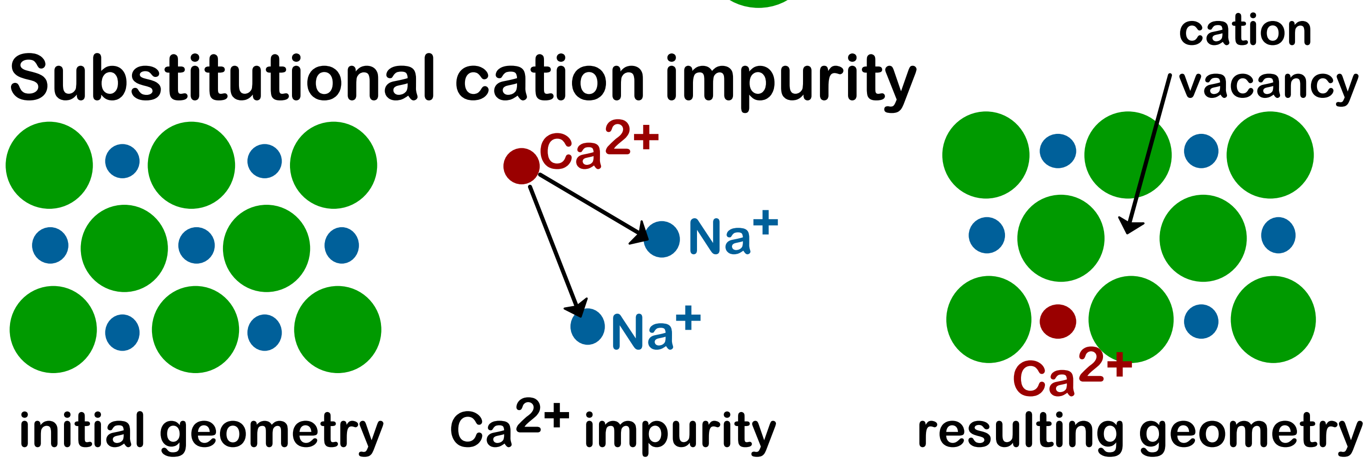
- Solid solution of B in A plus particles of a new phase (usually for a larger amount of B)



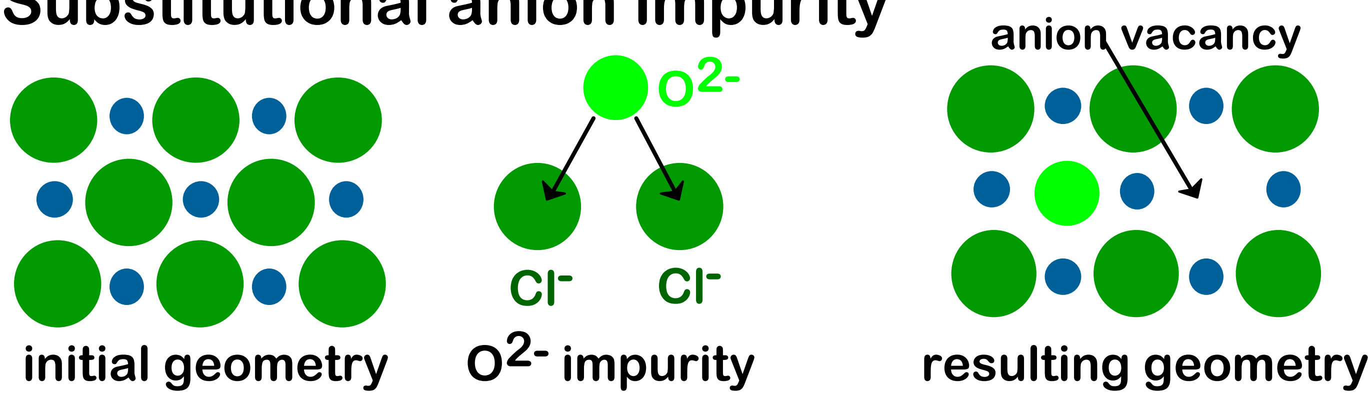
Second phase particle
--different composition
--often different structure.

IMPURITIES

- Impurities must also satisfy **charge balance**
- Ex: NaCl Na^{+} Cl^{-}
- Substitutional cation impurity



- Substitutional anion impurity



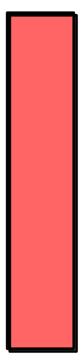
LINE DEFECTS

Dislocations:

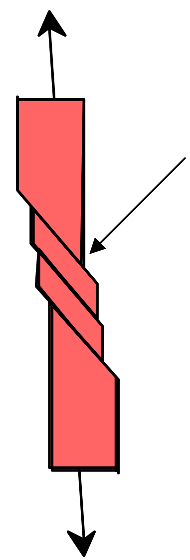
- are line defects,
- cause slip between crystal plane when they move,
- produce permanent (plastic) deformation.

Schematic of a Zinc (HCP):

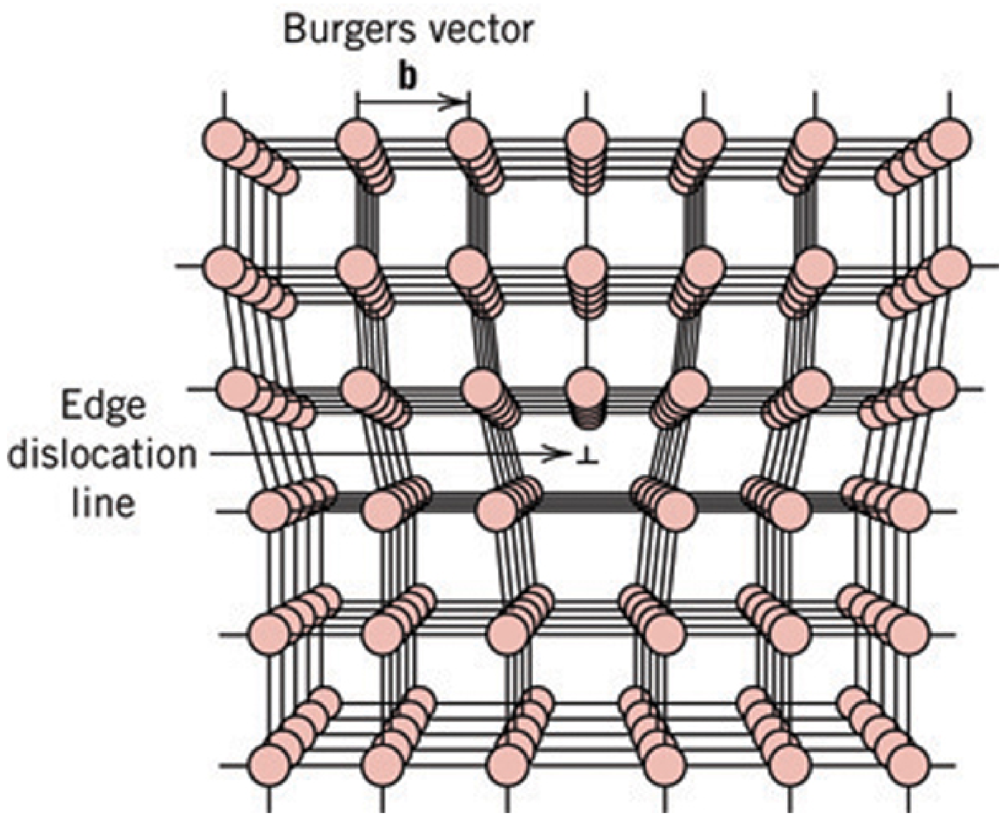
- before deformation



- after tensile elongation

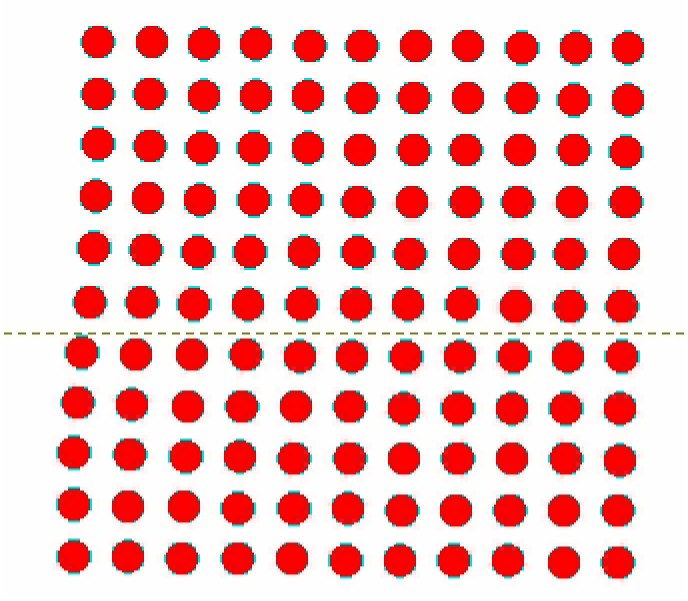


Edge dislocation



BOND BREAKING AND REMAKING

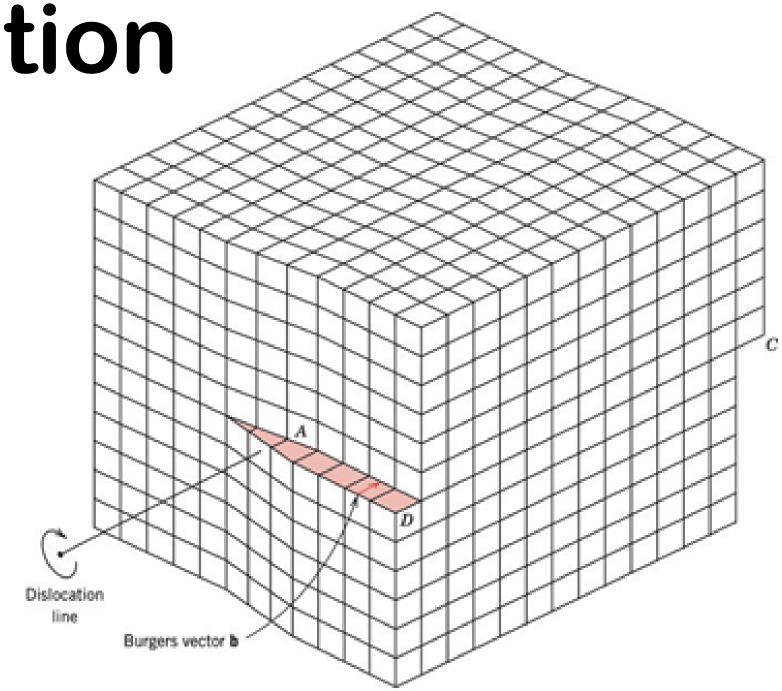
• Dislocations slip planes *incrementally*...
• The dislocation line separates slipped material on the left
from unslipped material on the right.
Dislocation motion requires the successive bumping of a half plane of atoms (from left to right here).
• Bonds across the slipping planes are broken and remade in succession.



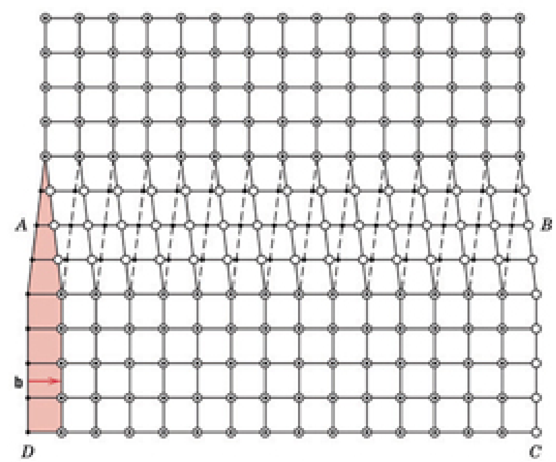
Atomic view of edge dislocation motion from left to right as a crystal is sheared.

(Courtesy P.M. Anderson)

Screw dislocation



(a)



(b)

Area Defects

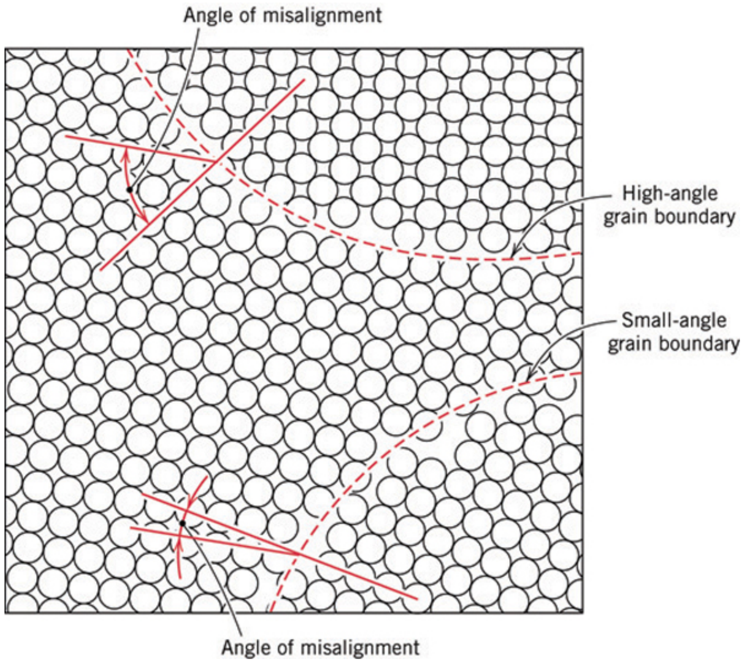
- Surface
- Grain boundary

AREA DEFECTS: GRAIN BOUNDARIES

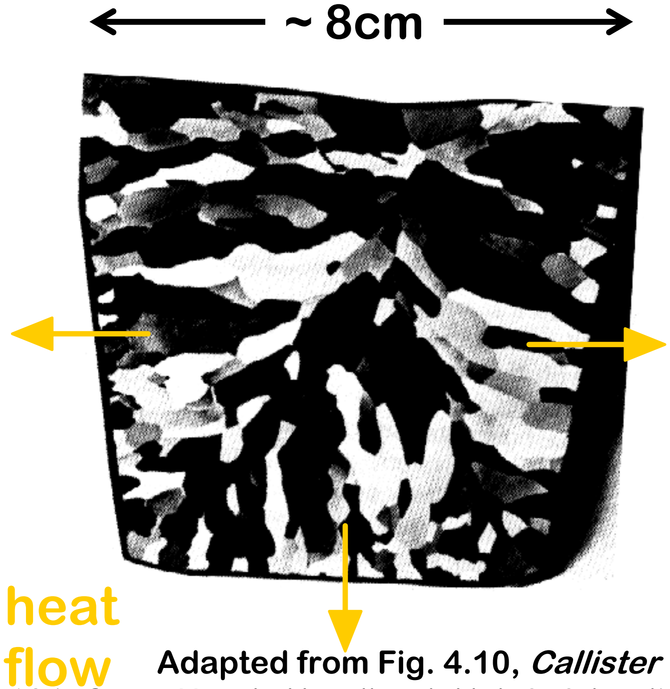
Grain boundaries:

- are boundaries between crystals.
- are produced by the solidification process, for example.
- have a change in crystal orientation across them.
- impede dislocation motion.

Schematic

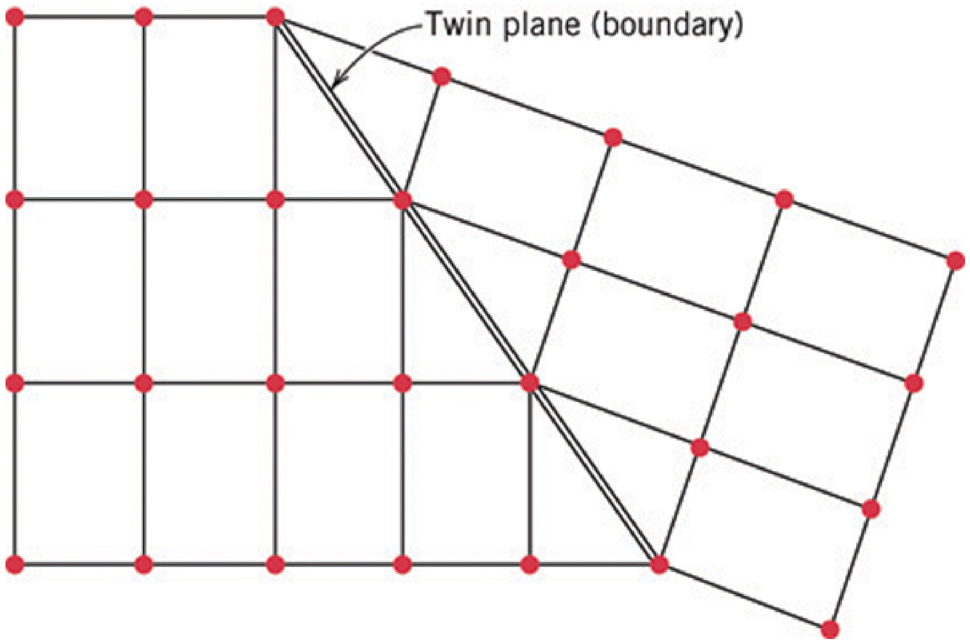


Metal Ingot



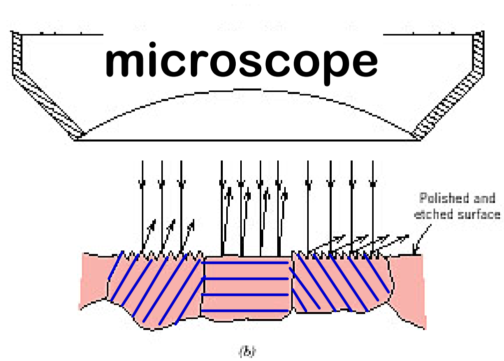
Adapted from Fig. 4.10, *Callister 6e.*
(Fig. 4.10 is from *Metals Handbook*, Vol. 9, 9th edition, *Metallography and Microstructures*, Am. Society for Metals, Metals Park, OH, 1985.)

Twin boundary



OPTICAL MICROSCOPY (1)

- Useful up to 2000X magnification.
- Polishing removes surface features (e.g., scratches)
- Etching changes reflectance, depending on crystal orientation.



close-packed planes

Adapted from Fig. 4.11(b) and (c), *Callister 6e.* (Fig. 4.11(c) is courtesy of J.E. Burke, General Electric Co.

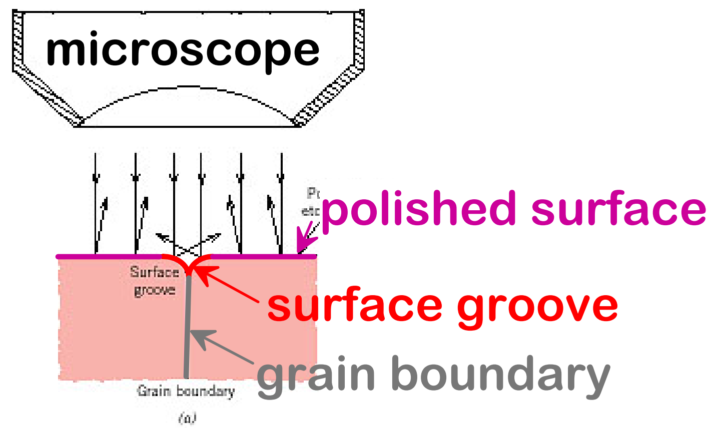
⟵ 0.75mm ⟶

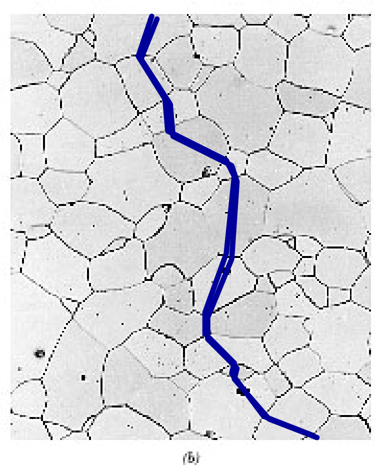
micrograph of Brass (Cu and Zn)

OPTICAL MICROSCOPY (2)

Grain boundaries...

- are imperfections,
- are more susceptible to etching,
- may be revealed as dark lines,
- change direction in a polycrystal.





Adapted from Fig. 4.12(a) and (b), *Callister 6e.* (Fig. 4.12(b) is courtesy of L.C. Smith and C. Brady, the National Bureau of Standards, Washington, DC [now the National Institute of Standards and Technology, Gaithersburg, MD].)

ASTM grain size number

$$N = 2^{n-1}$$

no. grains/in^2 at 100x magnification

SUMMARY

- Point, Line, and Area defects arise in solids.
- The number and type of defects can be varied and controlled (e.g., T controls vacancy conc.)
- Defects affect material properties (e.g., grain boundaries control crystal slip).
- Defects may be desirable or undesirable (e.g., dislocations may be good or bad, depending on whether plastic deformation is desirable or not.)