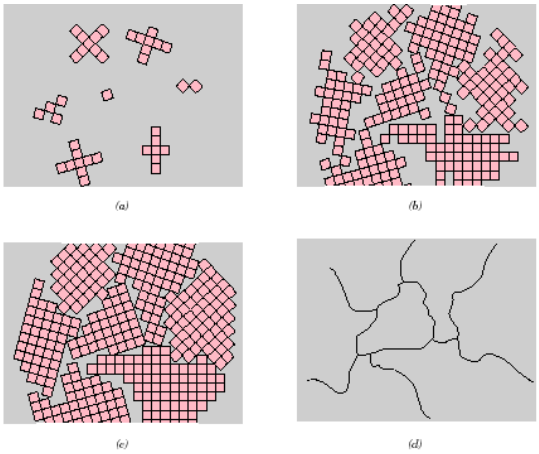
Single crystals

- **Periodic and repeated arrangement of atoms is perfect or extends through the entirety of the specimen**
- **Unit cells interlock in the same way and have the same orientation**
- **Can be produced naturally and artificially**

Single crystals of fluorite (CaF_2)

Polycrystalline materials

- A collection of many small crystals or grains
- Grain boundary: some atomic mismatch within the region where two grains meet



Anisotropy

- Anisotropy:
- Isotropic:

Table 3.3 Modulus of Elasticity Values for Several Metals at Various Crystallographic Orientations

	Modulus of Elasticity (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

Chapter 4: Imperfections in solids

Outline

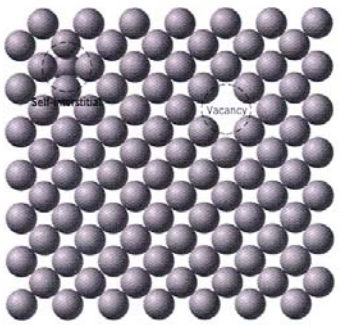
- Introduction
- Points defects
- Impurities in solids
- Dislocations-linear defects
- Interfacial defects
- Bulk or volume defects
- Microscopy

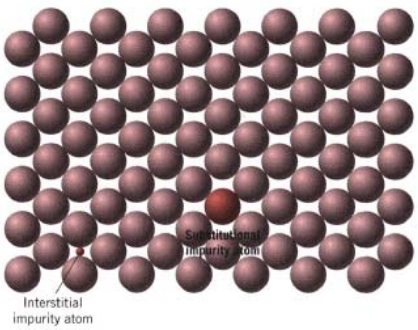
Types of imperfections

- Point defects
  - Vacancy atoms
  - Interstitial atoms
  - Substitutional atoms
- Dislocations (linear defects)
- Grain boundaries (planar defects)
- Volume

Point defects

- Vacancy:
- Self-interstitial:
- Substitutional



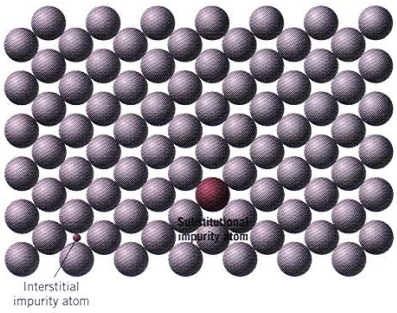


Point defects: equilibrium concentration

- Equilibrium concentration varies with temperature

Impurities in solids

- Fundamental concepts
  - alloy
  - solute
  - solvent
  - solid solution
- Solute solutions
  - substitution
    - **atomic size factor**
    - **crystal structure**
    - **electronegativity**
    - **valences**
  - interstitial



Impurities in solids (*continue*)

- Specification of composition
  - composition of an alloy in weight percent

$$C_1 = \frac{m_1}{m_1 + m_2} \times 100\%$$

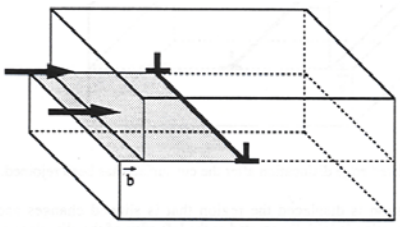
  - composition of an alloy in atom percent

$$C_1' = \frac{n_{m1}}{n_{m1} + n_{m2}} \times 100\%$$

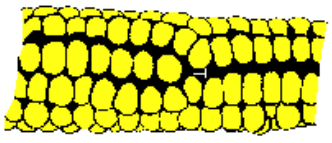
$$n_{m1} = \frac{m_1'}{A_1}$$

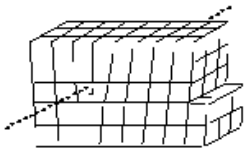
Dislocations-linear defects

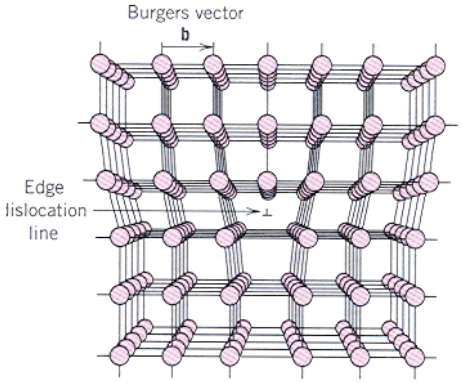
- Edge dislocation:
- Dislocation line:



Edge dislocation

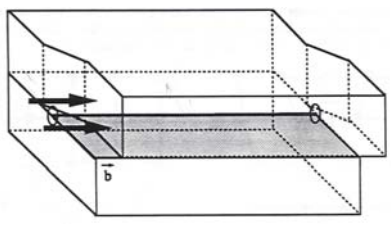


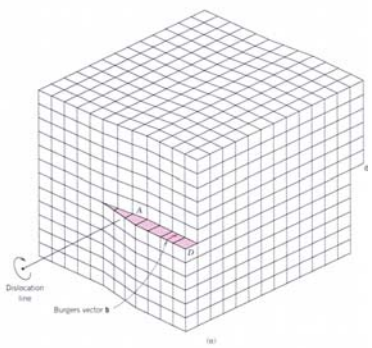




Dislocations-linear defects

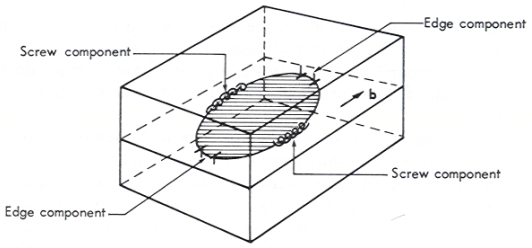
- Screw dislocation:
- Slip plane:
- Slip plane contains both Burgers Vectors and dislocation line

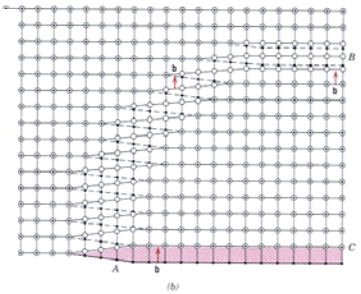




Dislocations-linear defects

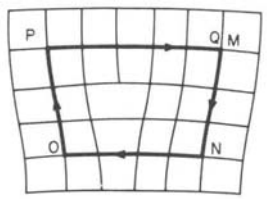
- Mixed dislocation



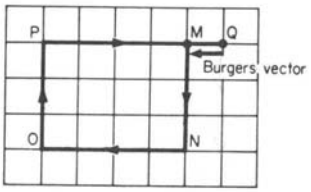


Burgers Circuit & Burgers Vector

- Burgers circuit: any close loop contain dislocations by an atom to atom path
- Burgers vectors: the vector required to complete the circuit in a perfect crystal; the direction of atom displacement



(a)



(b)

(a) Burgers circuit round an edge dislocation
(b) the same circuit in a perfect crystal

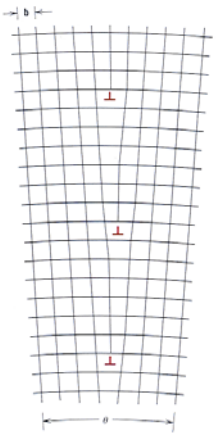
Dislocations-linear defects

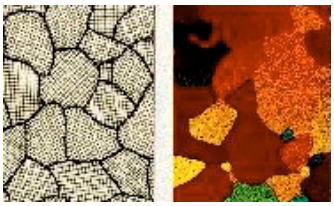
- What cause dislocations?
  - processing
  - plastic deformation
  - thermal stresses
- Observation of dislocations

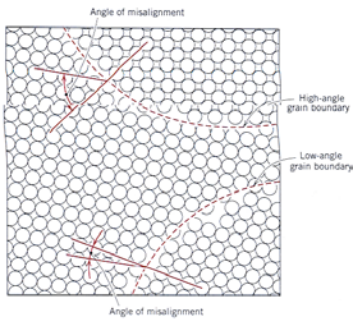
A TEM micrograph of a titanium alloy

Interfacial defects (two dimension)

- External surfaces
- Grain boundaries







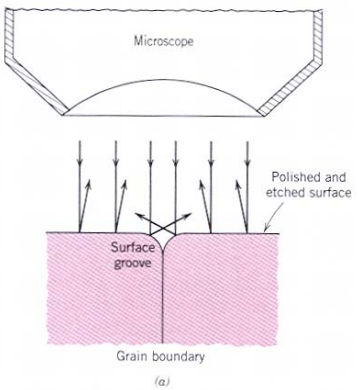
Bulk Defects (three dimension)

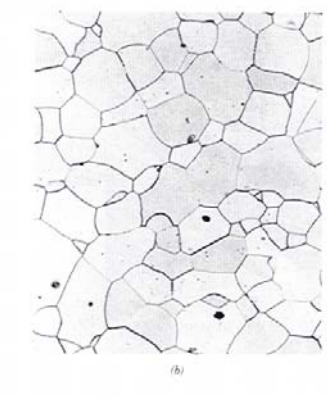
- Void
- Cracks
- Inclusions

TEM image of voids

Microscopic examination

- Optical microscopy





- Transmission electron microscopy
- Scanning electron microscopy
- Scanning probe microscopy