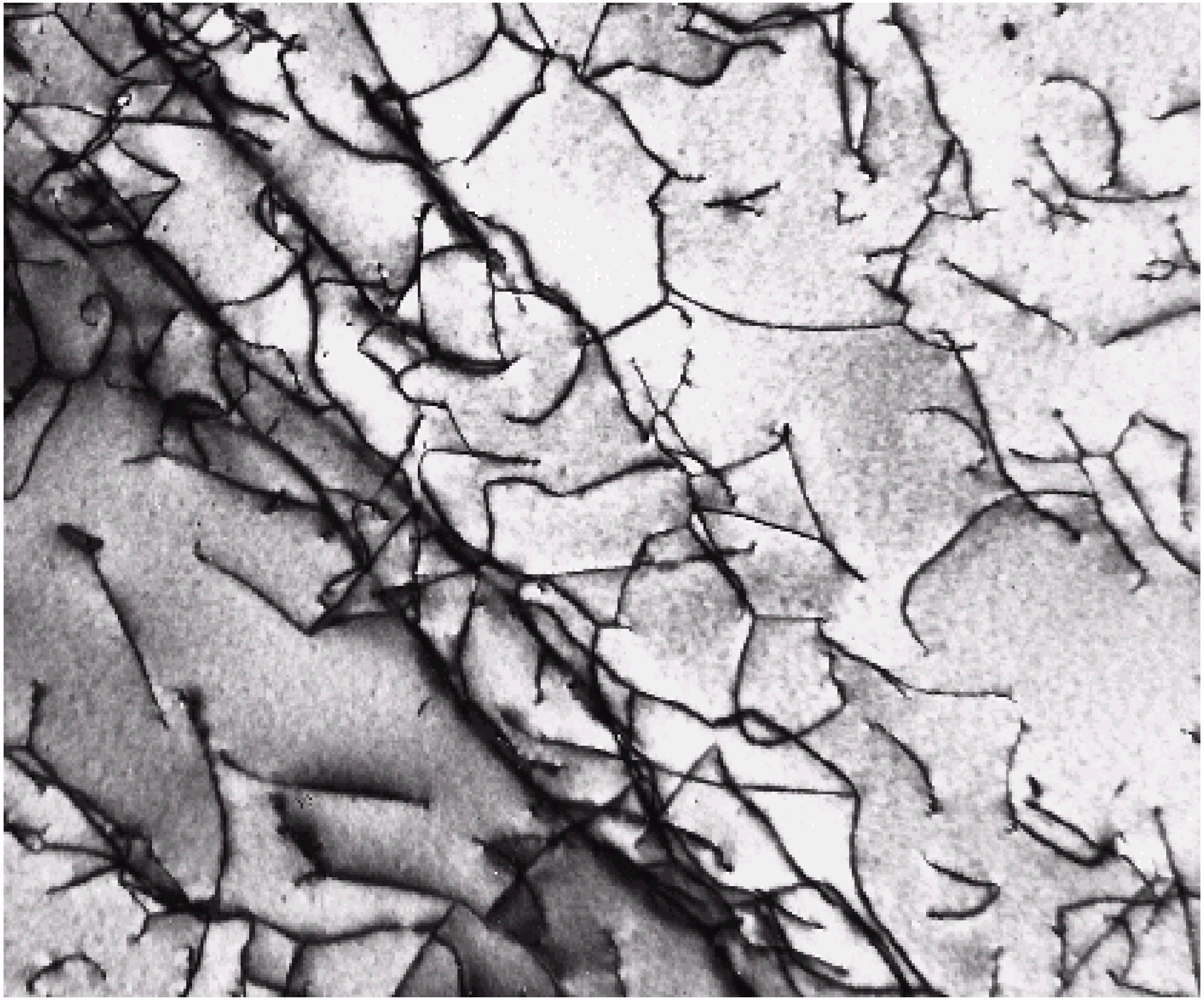
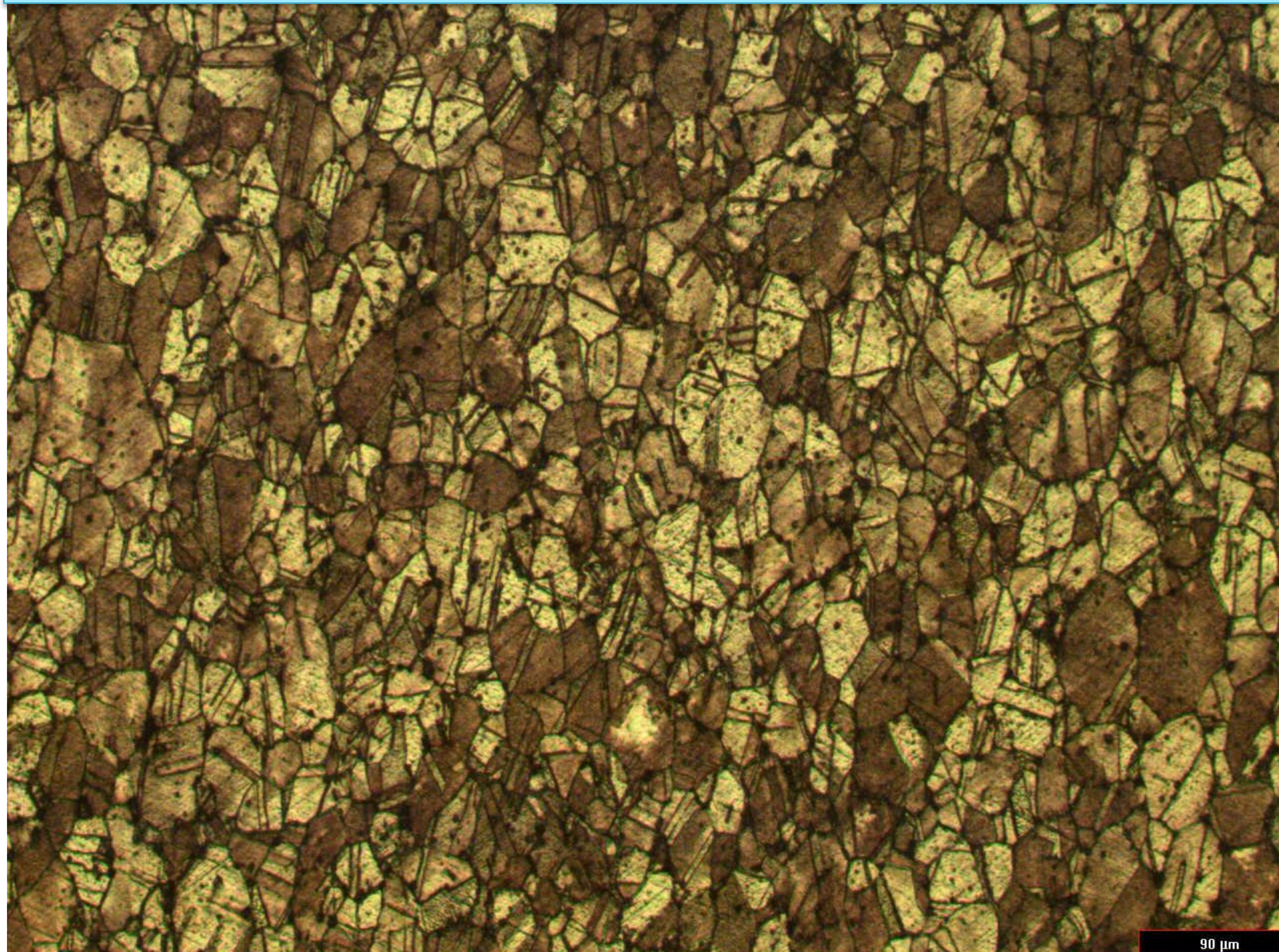
# Lattice Defects



# Brass (90 micron scale bar)



# Types of lattice defects

- Point defects

  (vacancy , interstitials, impurity, Frenkel defect and Schottky defect)
- Line defects (Dislocations):
- (Edge dislocations and screw dislocations)
- Surface defects (Grain boundaries)
- Volume defects

  (Porosity, Inclusions and Cracks)

# Point defects

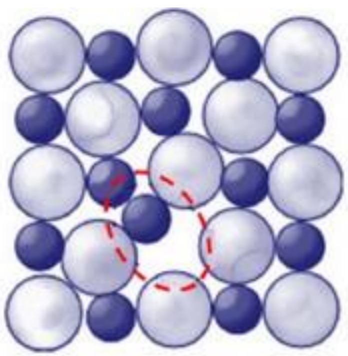
- **Vacancy – An atom missing from regular lattice position. Vacancies are present invariably in all materials.**
- **Interstitials – An atom trapped in the interstitial point (an intermediate point between regular lattice points) is called an interstitial.**
- **An impurity atom at the regular or interstitial position in the lattice is another type of point defect.**

# Point defects

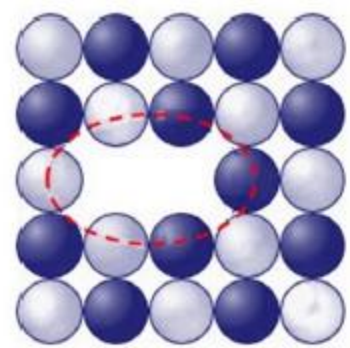
- **In ceramic materials point defects occur in pair to maintain the electro-neutrality.**

- **A cation-vacancy and a cation-interstitial pair is known as Frenkel defect.**

- **A cation vacancy-anion vacancy pair is known as a Schottky defect.**



Frenkel defect



Schottky defect

# Line defects

## Dislocation

- A dislocation is a crystallographic defect within a crystal structure.
- It comes under line defect.
- Motion of dislocations results in plastic deformation.
- Dislocations produces deformation via *incrementally* breaking bonds
- There are mainly three types of dislocations.

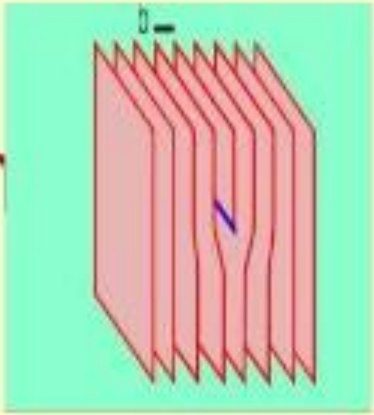
a) Edge dislocation

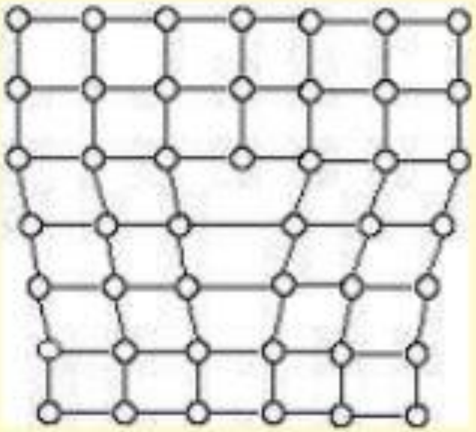
b) Screw dislocation and

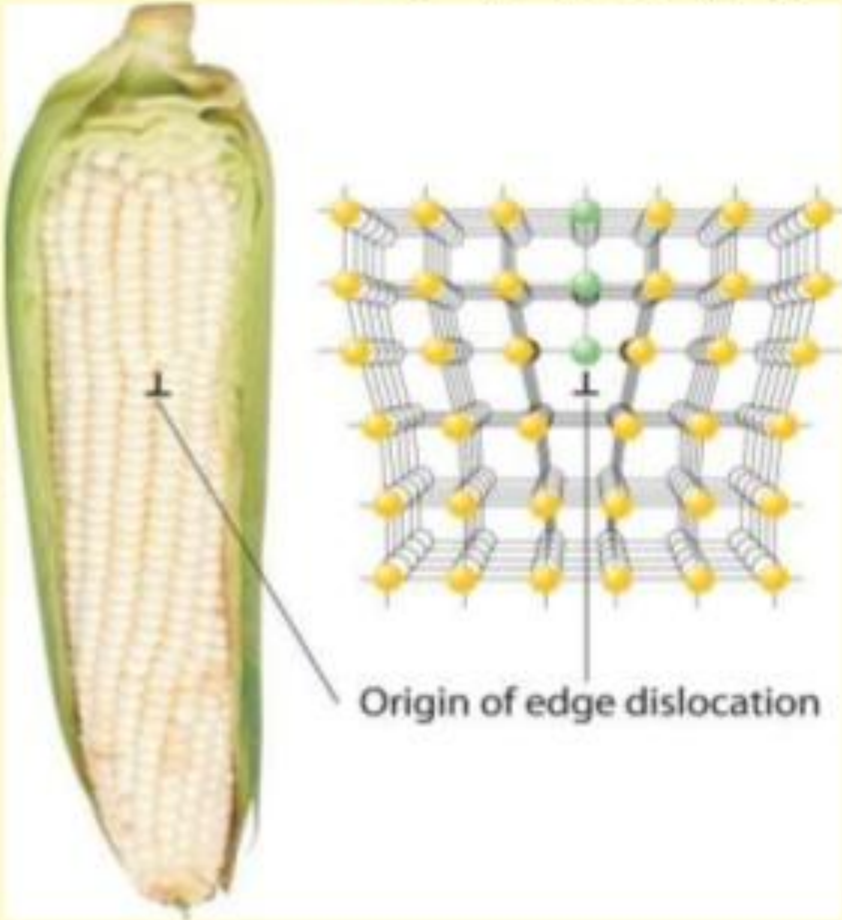
c) Mixed dislocation

# Edge dislocation

- An edge dislocation is a defect where an extra half-plane of atoms is introduced through the crystal, distorting nearby planes of atoms.
- Edge dislocations move in response to shear stress applied perpendicular to the dislocation line.

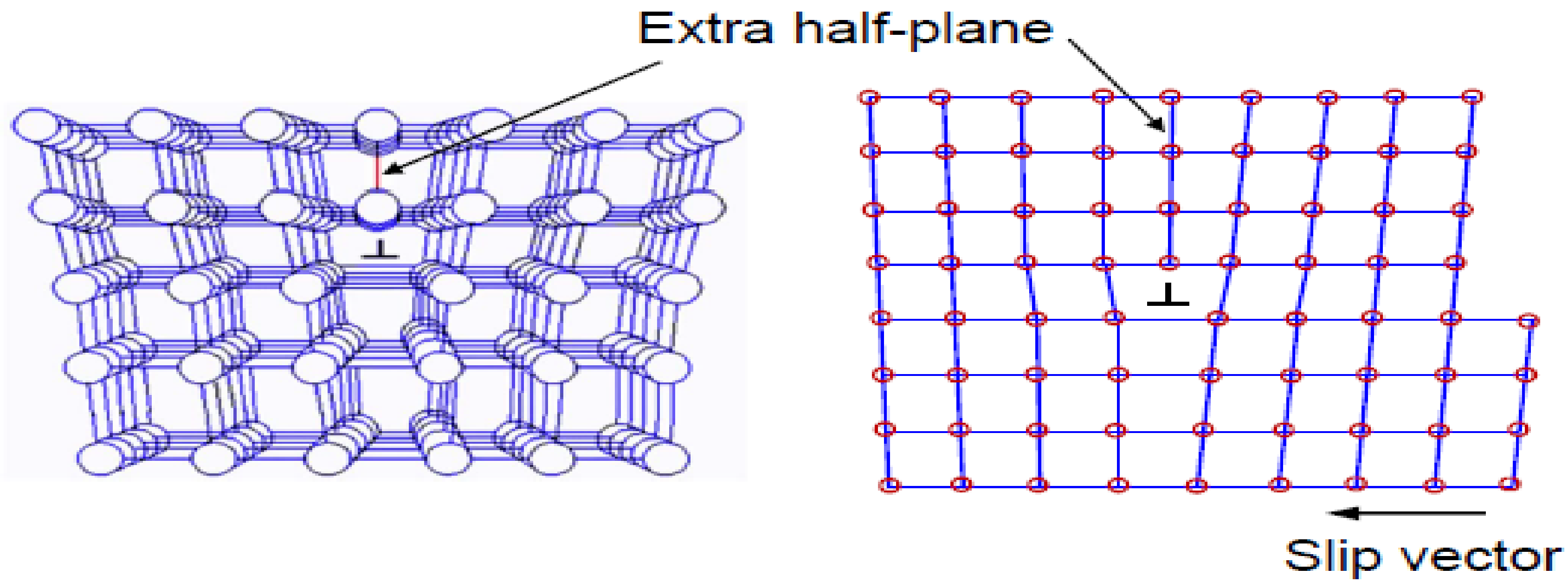




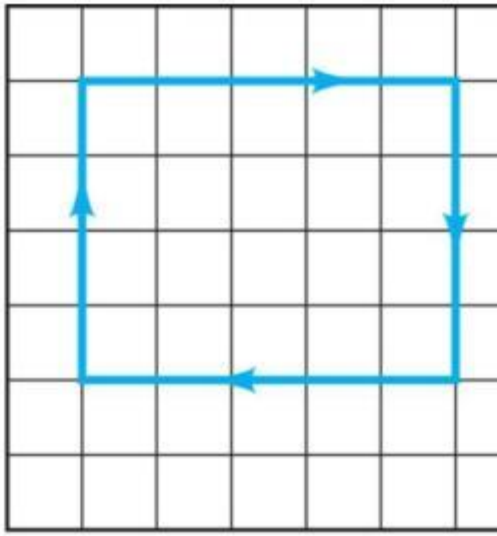


# Edge Dislocations

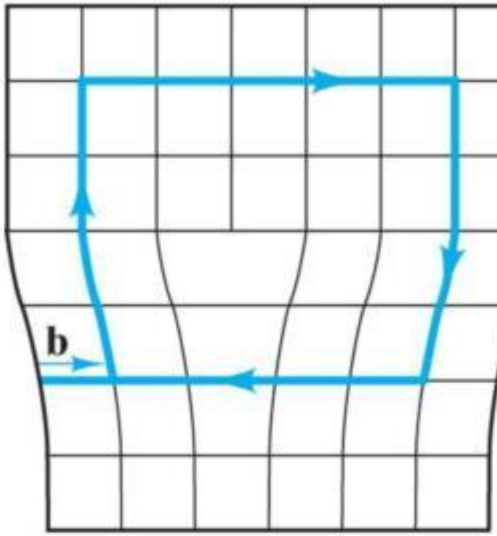
- In one type of dislocations, the Burger vector is perpendicular to the dislocation line and the distortion produces an extra half-plane above the slip plane.



*Definition of the Burgers vector,* **b**, *relative to an edge dislocation. (a) In the perfect crystal, an m× n atomic step loop closes at the starting point. (b) In the region of a dislocation, the same loop does not close, and the closure vector* **(b)** *represents the magnitude of the structural defect. For the edge dislocation, the Burgers vector is* perpendicular *to the dislocation line.*

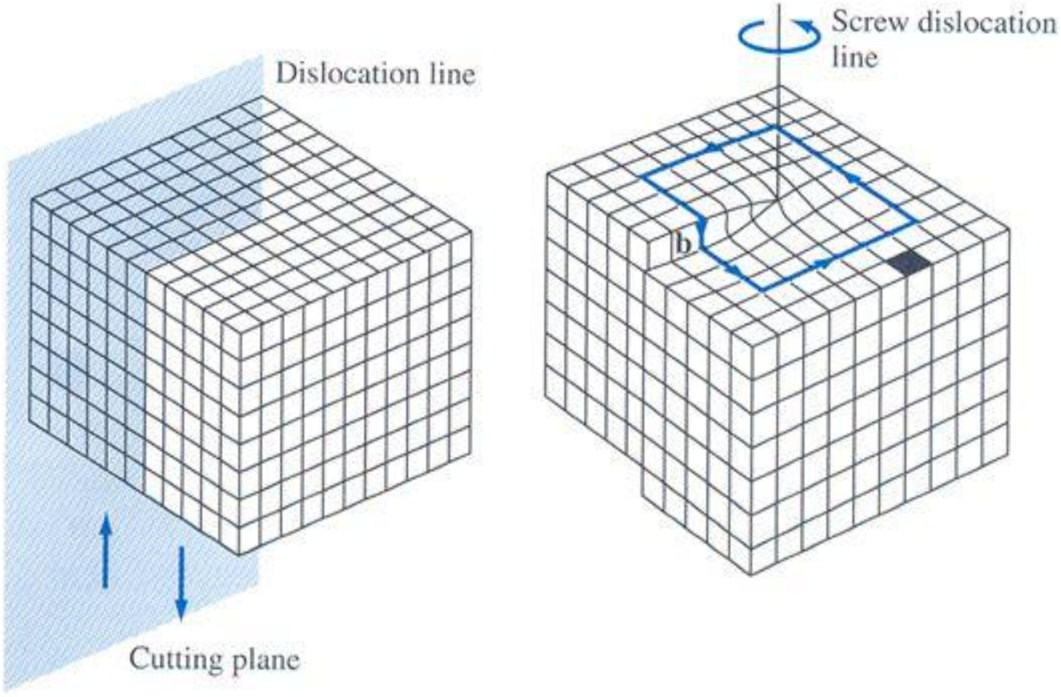


(a)

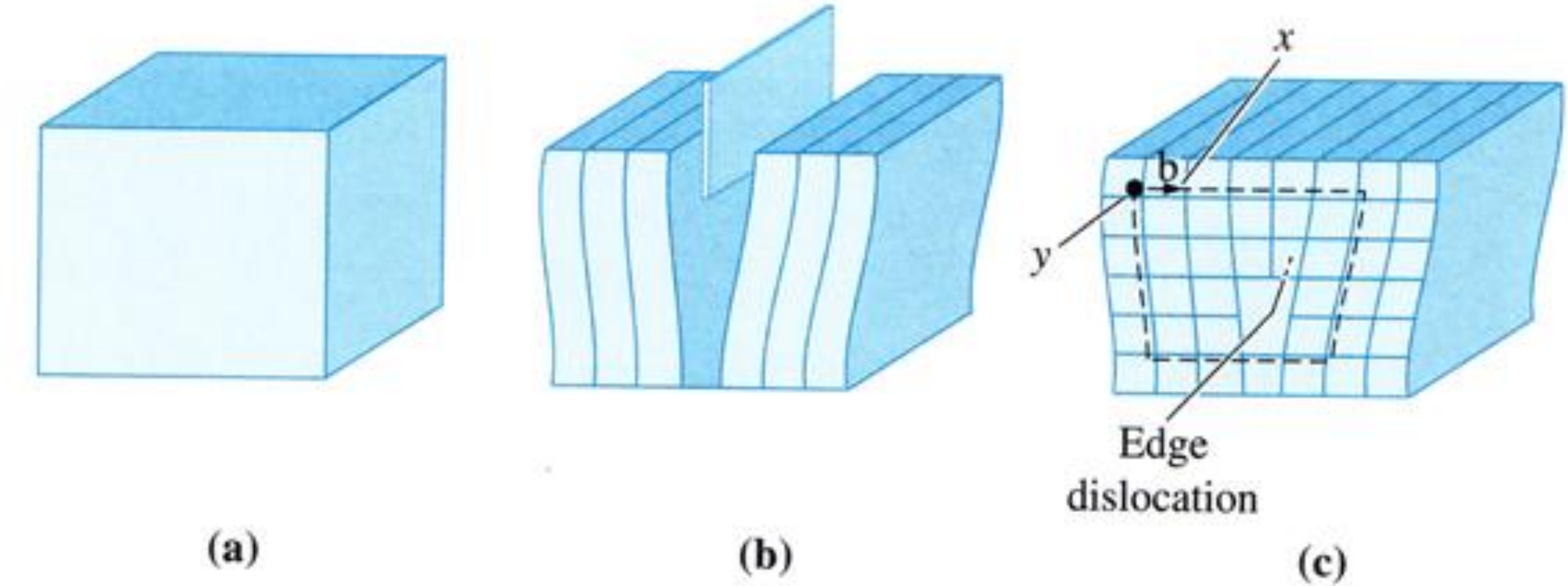


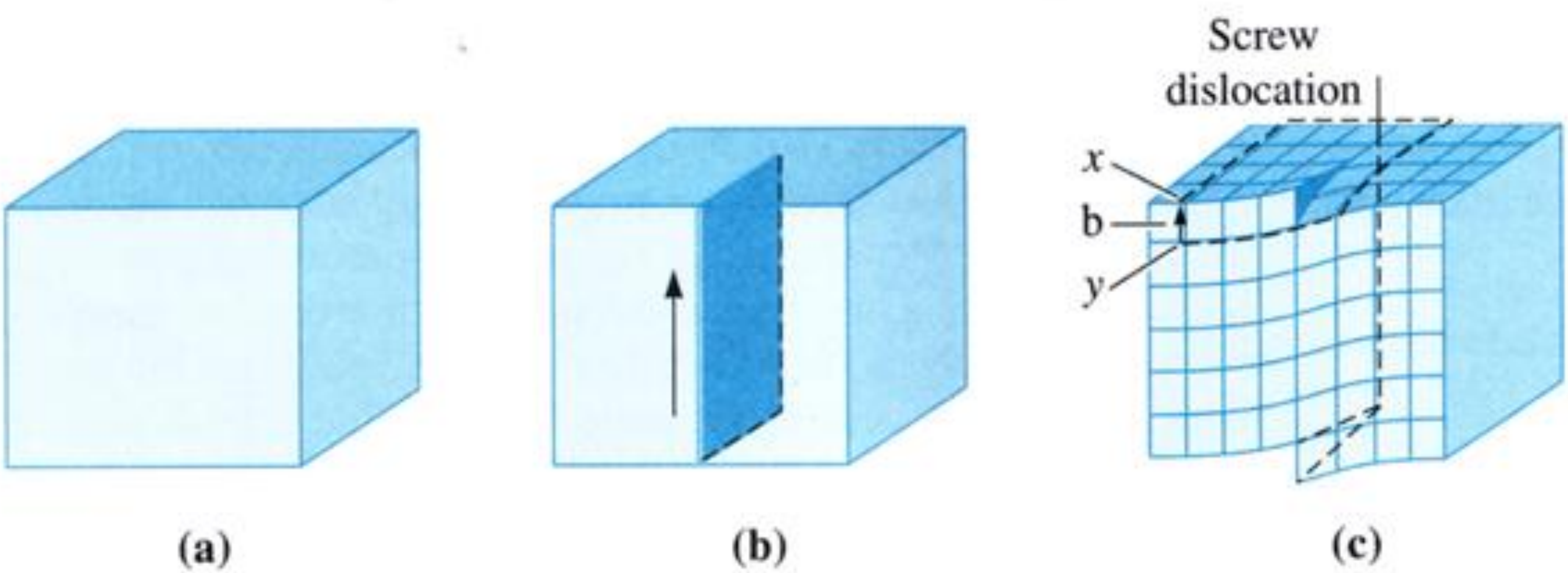
# Screw Dislocation

- **Created due to shear stresses applied to regions of a perfect crystal separated by cutting plane.**
- **Distortion of lattice in form of a spiral ramp.**
- **Burgers vector is parallel to dislocation line.**

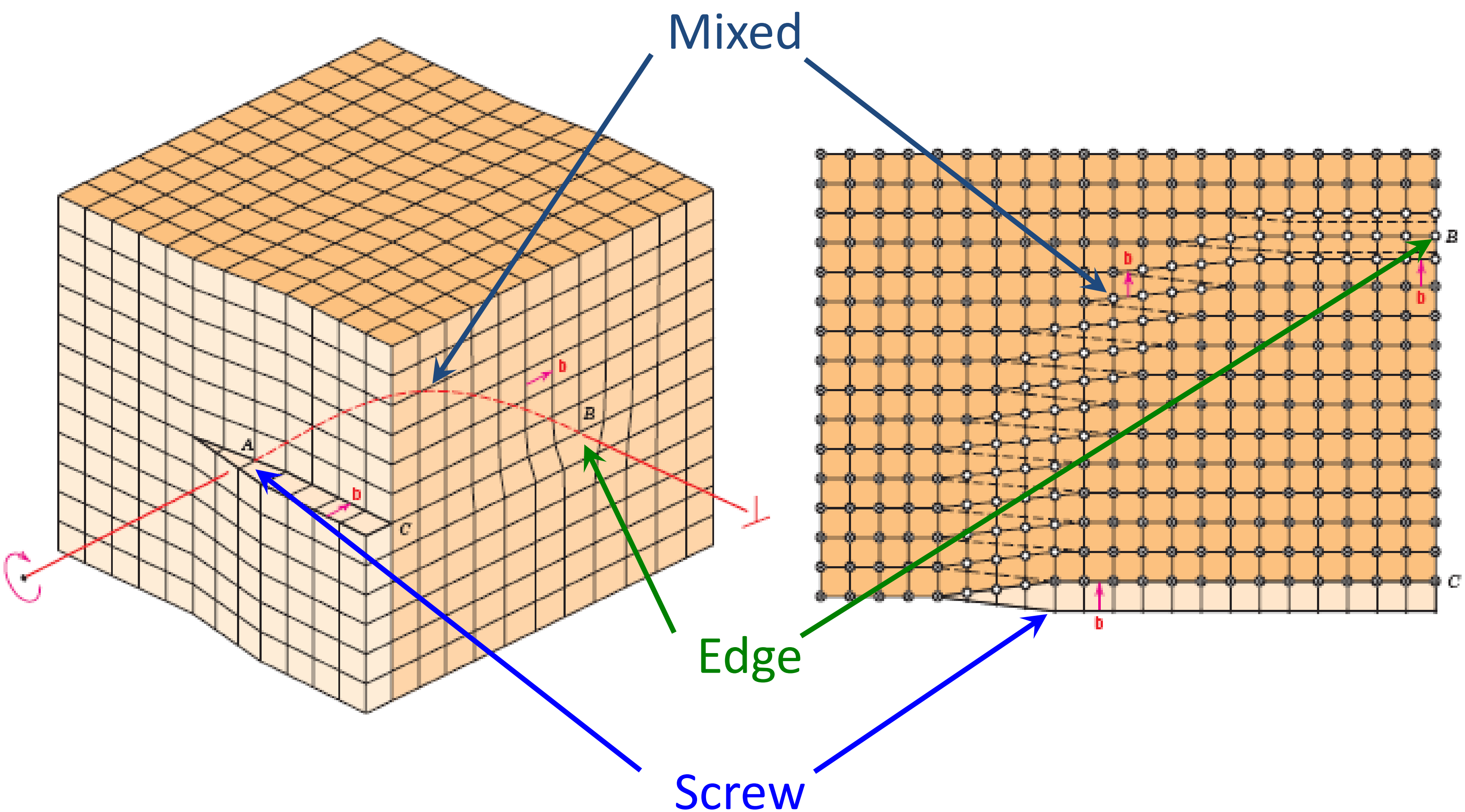



 After M. Eisenstadt, "Introduction to Mechanical Properties of Materials," Macmillan, 1971, p.118


x
b
y
Edge
dislocation
(a)
(b)
(c)


Screw
dislocation
x
b
y
(a)
(b)
(c)

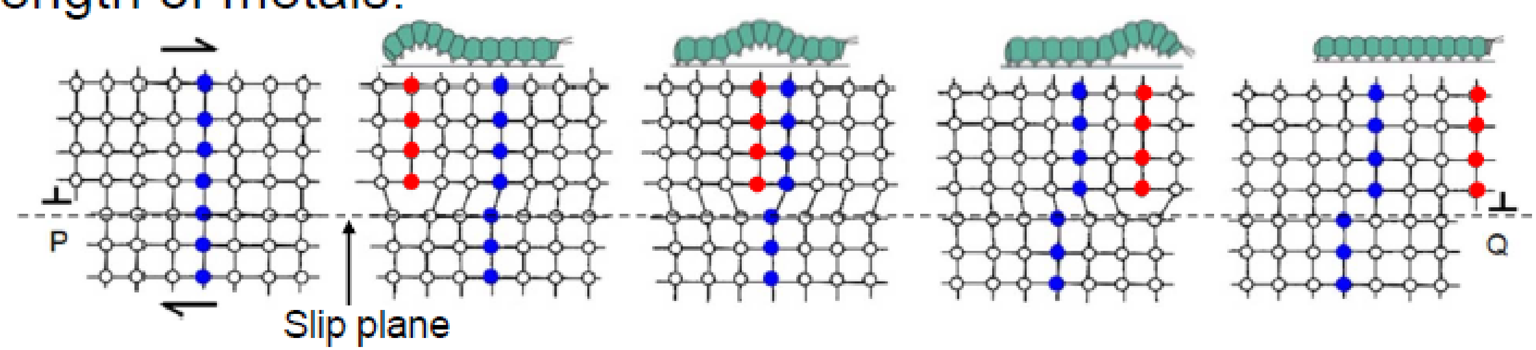
# Edge, Screw, and Mixed Dislocations

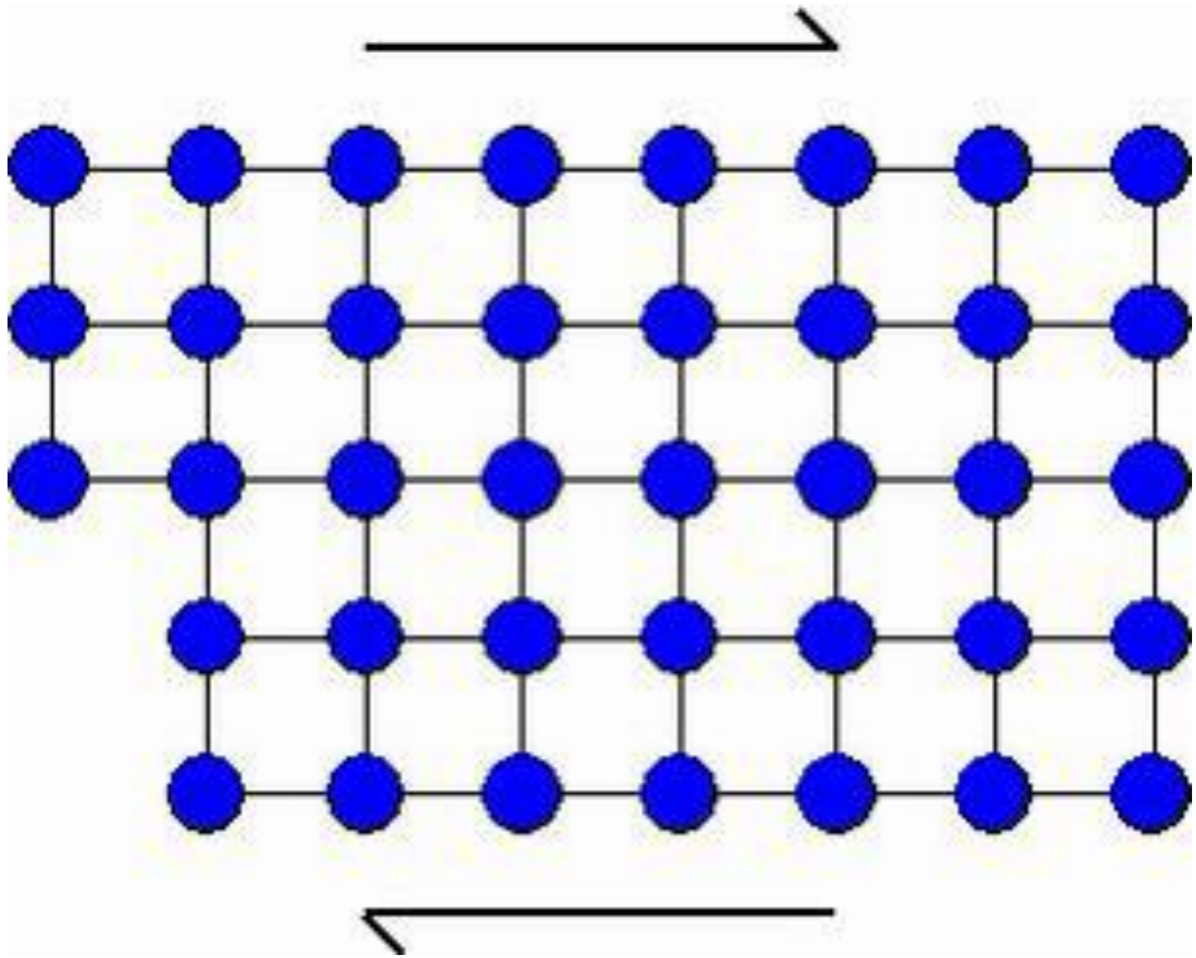



Adapted from Fig. 4.5, *Callister 7e.*

# Dislocation movement

- Dislocations move in steps. The edge dislocation at P moves to Q in steps as depicted by the red (half-plane) and blue atoms. This movement is analogous to movement of a caterpillar.
- When the half-plane reaches a free surface it produces a slip step.
- Edge dislocations can move only on the slip plane while screw dislocations do not have a fixed glide plane.
- Since plastic deformation takes place by movement of dislocations, any hindrance to their motion will increase the strength of metals.



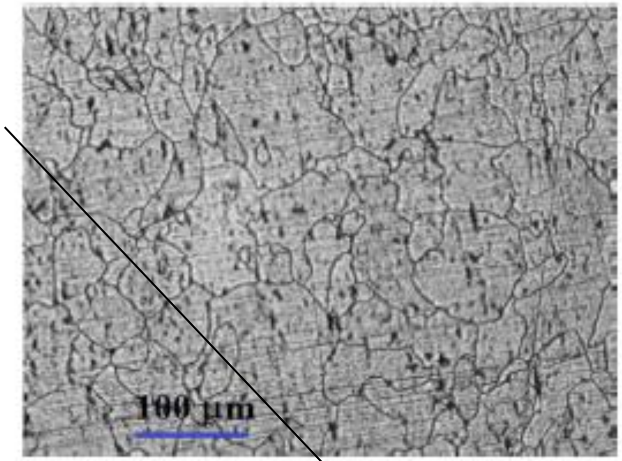


# Surface defects

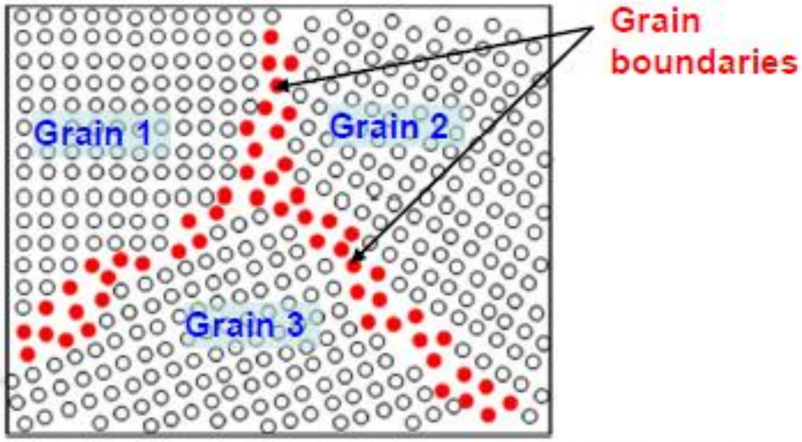
## Grain Boundaries

- Most crystalline solids are an aggregate of several crystals. Such materials are called polycrystalline.
- Each crystal is known as a grain. The boundary between the grains is the grain boundary (the irregular lines in Fig.a)
- A grain boundary is a region of atomic disorder in the lattice only a few atomic diameter wide.
- The orientation of the crystals changes across the grain boundary as shown schematically in Fig. b.
- Grain boundaries act as obstacles to dislocation motion. Hence, presence of more grain boundaries (finer grain size) will increase the strength.

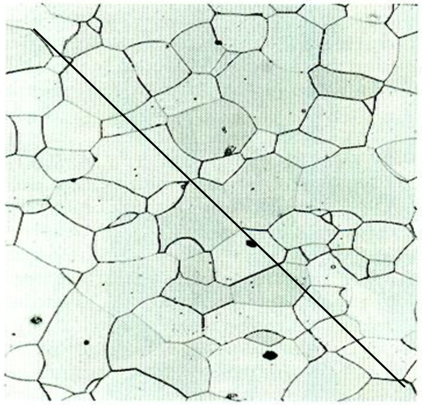
# Grain boundaries




(a) Optical micrograph of a polycrystalline material




(b) Schematic of orientation change across the grain boundary



(b)

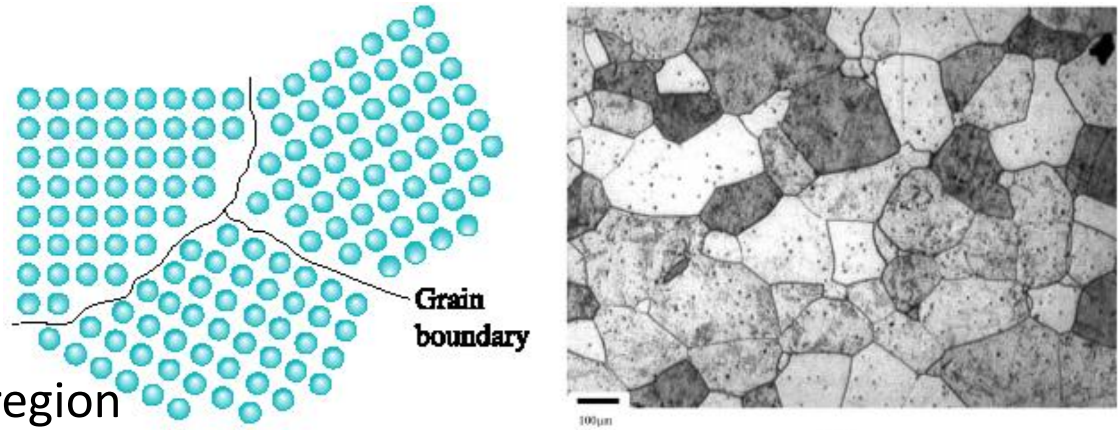
# Polycrystalline Materials

## Grain Boundaries

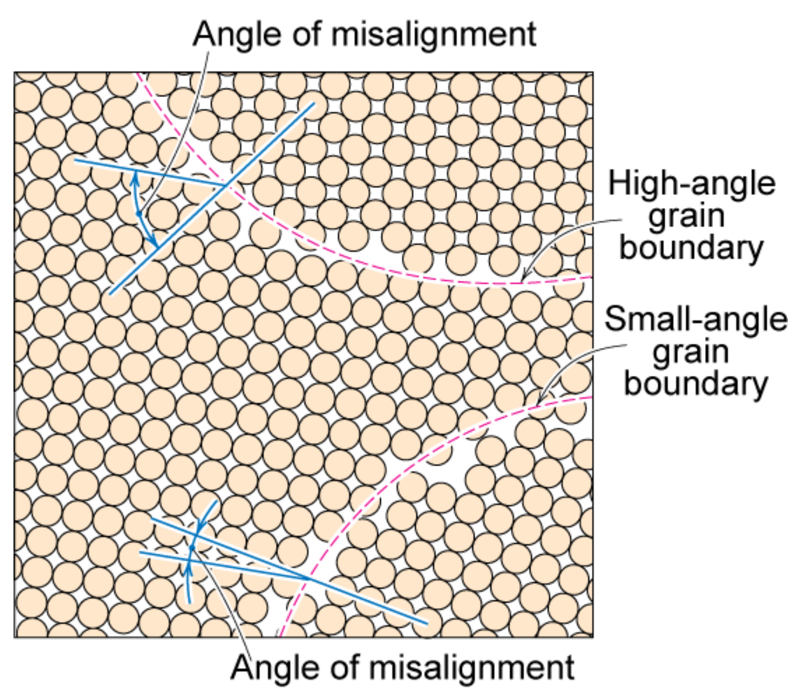
- regions between crystals
- transition from lattice of one region to another

(a) The atoms near the boundaries of the 3 grains do not have an equilibrium spacing or arrangement; slightly disordered.

(b) Grains and grain boundaries in a stainless steel sample. low density in grain boundaries




(a) (b)



# Bulk or volume defects

- Porosity
- Inclusions
- Cracks

- These defects form during manufacturing processes for various reasons and are harmful to the material.

# Bulk defects

Weld defect

Casting defect

Shrinkage cavity

- Casting blow holes, porosity – Gas entrapment during melting and pouring. Improper welding parameters/practice
- Shrinkage cavity due to improper risering
- Non-metallic inclusions – Slag, oxide particles or sand entrapment
- Cracks – Uneven heating/cooling, thermal mismatch, constrained expansion/contraction all leading to stress development

# Quiz

1.How many types of latiice defects exist?
2.What is an interstitialcy and how it is different from an impurity atom?
3. What is dislocation? What is Burger vector?
4. Draw the atomic arrangement around an edge dislocation and show the extra half-plane.
5. What is the fundamental difference between edge and screw dislocation?
6. What is Burger circuit?
7. Why the ideal strength of metals is less than the actual measured values?
8. Why is the movement of dislocations compared to caterpillar?
9. How does dislocation movement produce plastic deformation?

# Quiz

10. How do dislocations appear when observed an electron microscope?
11. From a dislocation mechanism point of view how can one increase the strength of metals?
12. What is meant by a polycrystalline material?
13. What is a grain?
14. Is the orientation of the crystal across a grain boundary same?
15. How do grain boundaries affect strength of a material?