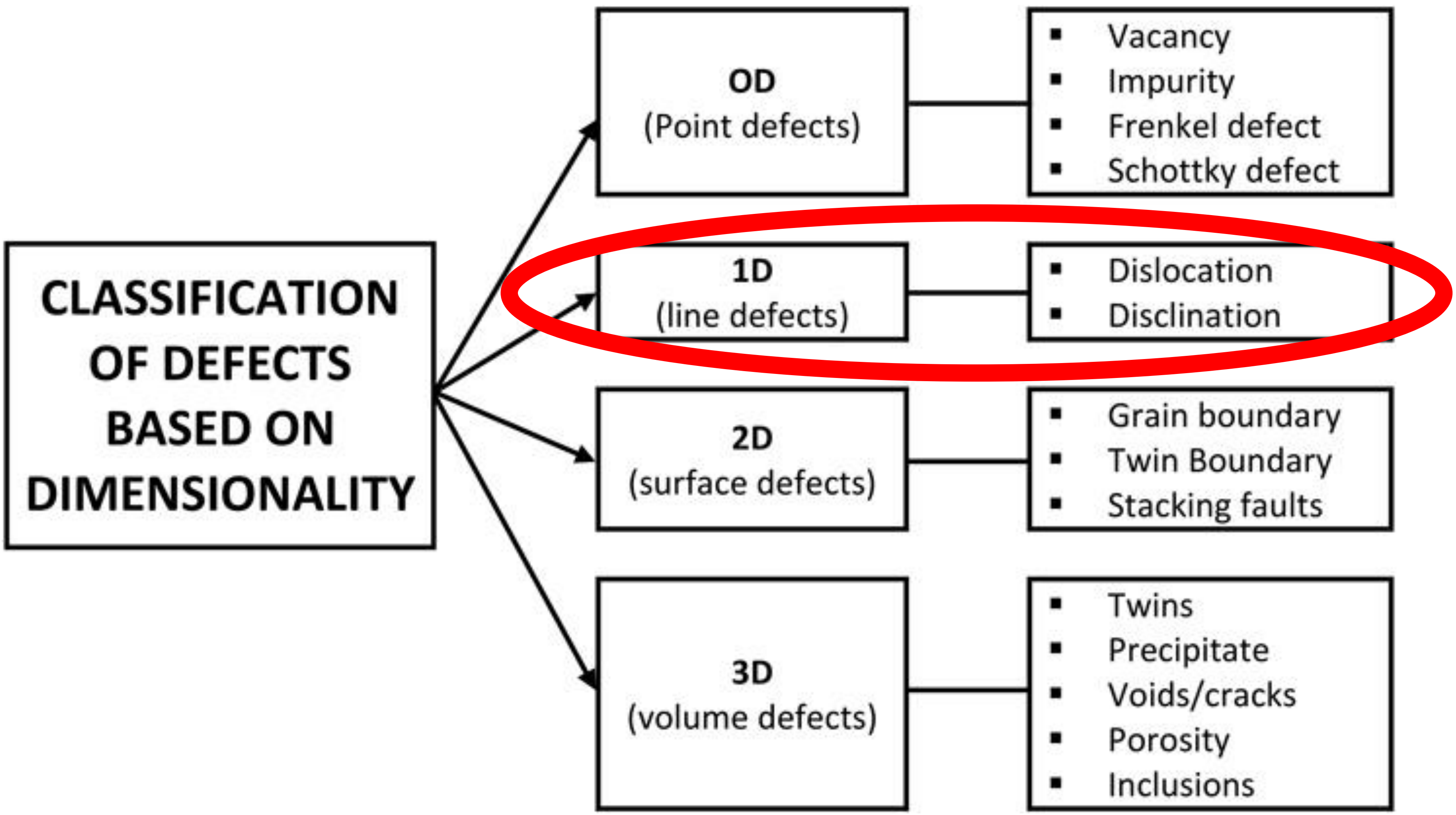
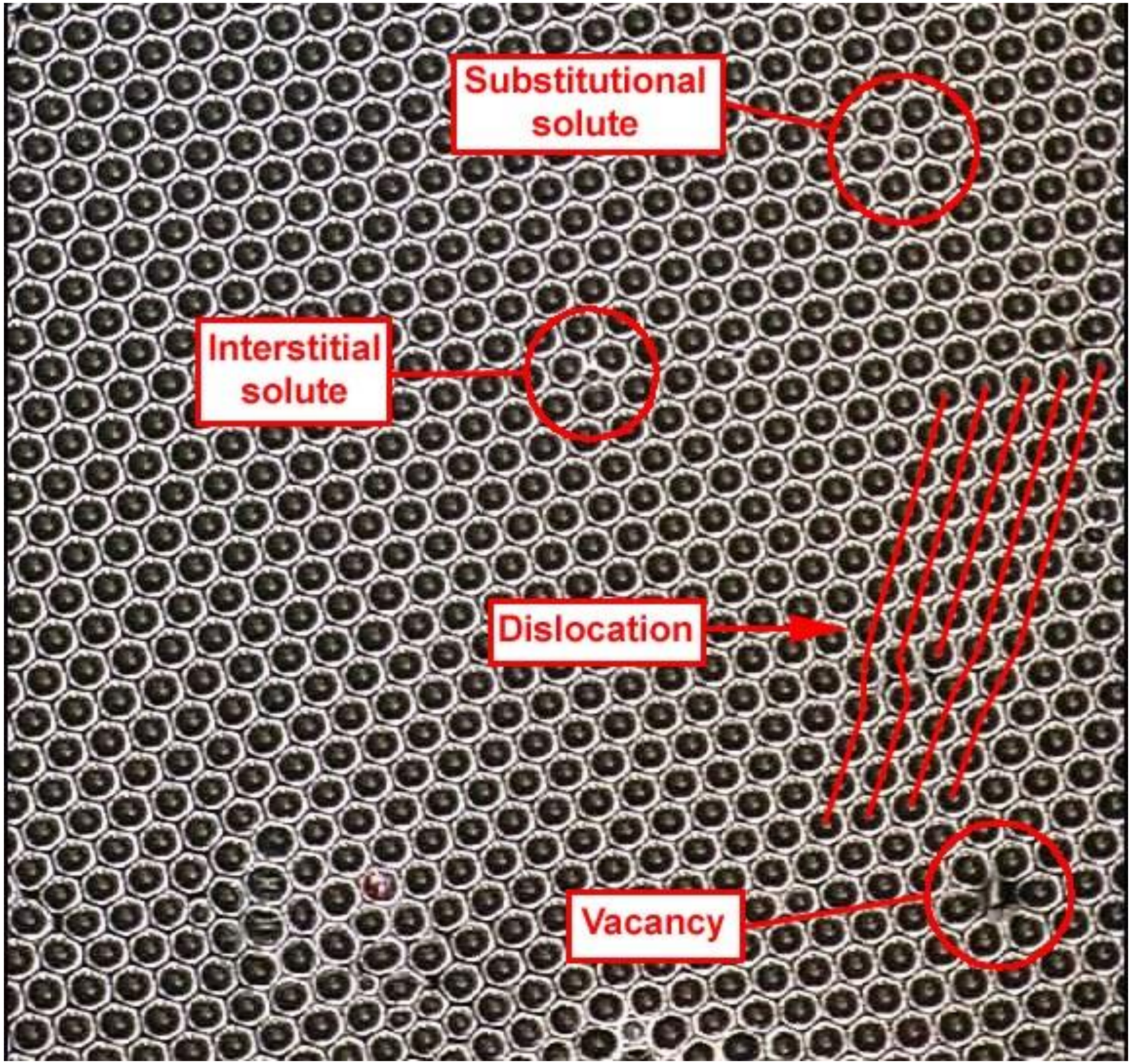
(1D) Line defects



1D, Linear defects: distorted atomic configurations are extended along a line and have microscopic dimensions in the directions perpendicular to the line

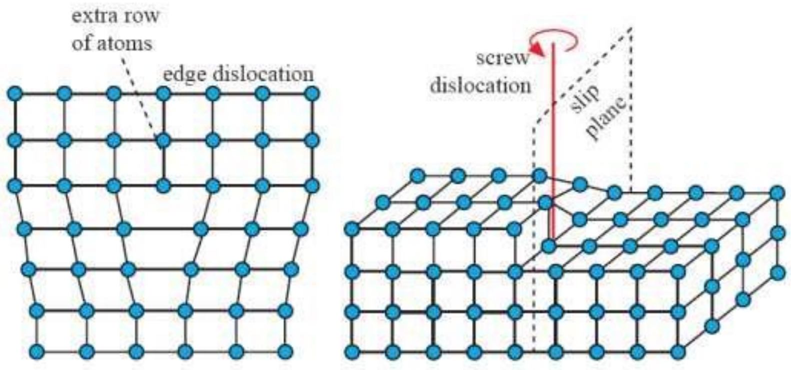


Dislocations are linear defects, around which the atoms of the crystal lattice are misaligned.

There are three basic **types of dislocations**:

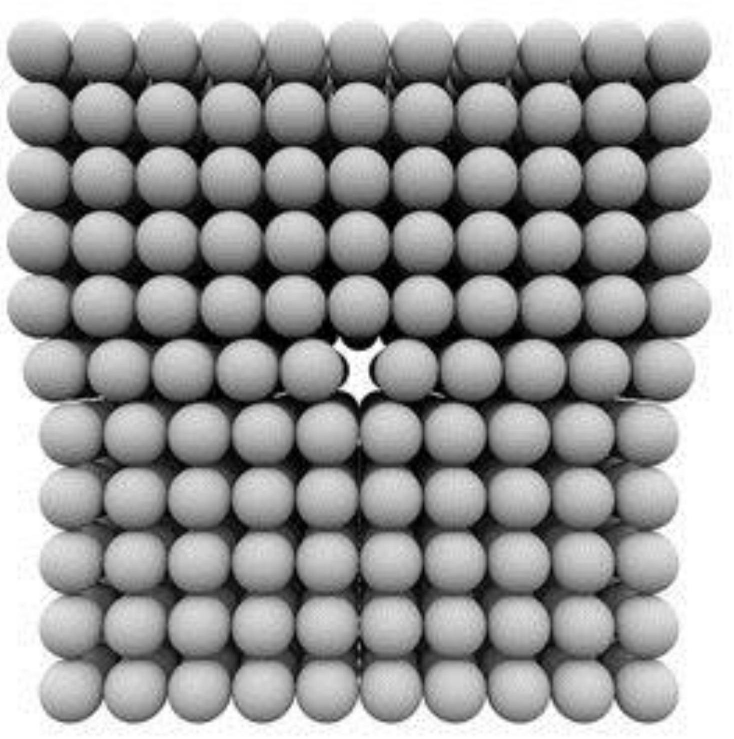
- edge dislocation
- screw dislocation
- “mixed" dislocations, combining aspects of both types

The concept of dislocation was firstly suggested by Tyler *et al.* in 1934.
In 1956, Hirsch *et al.* confirmed the existence of dislocation by the means of transmission electron microscopy.

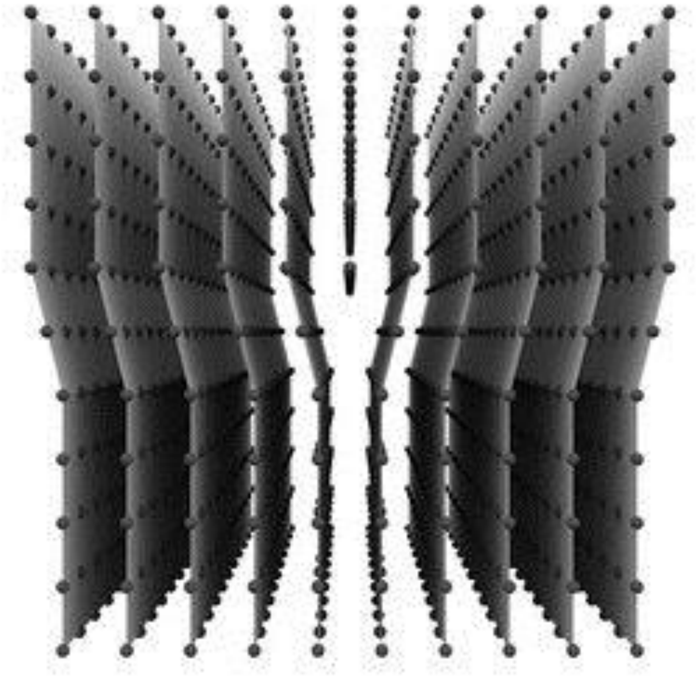


The mechanical properties of metal are affected to dislocations. When plastic deformation applied to metals, new dislocations are generated and the gliding of dislocations occurs. In addition, screw dislocations influence crystal growth and cause the helical structure that could be observed under a microscope.

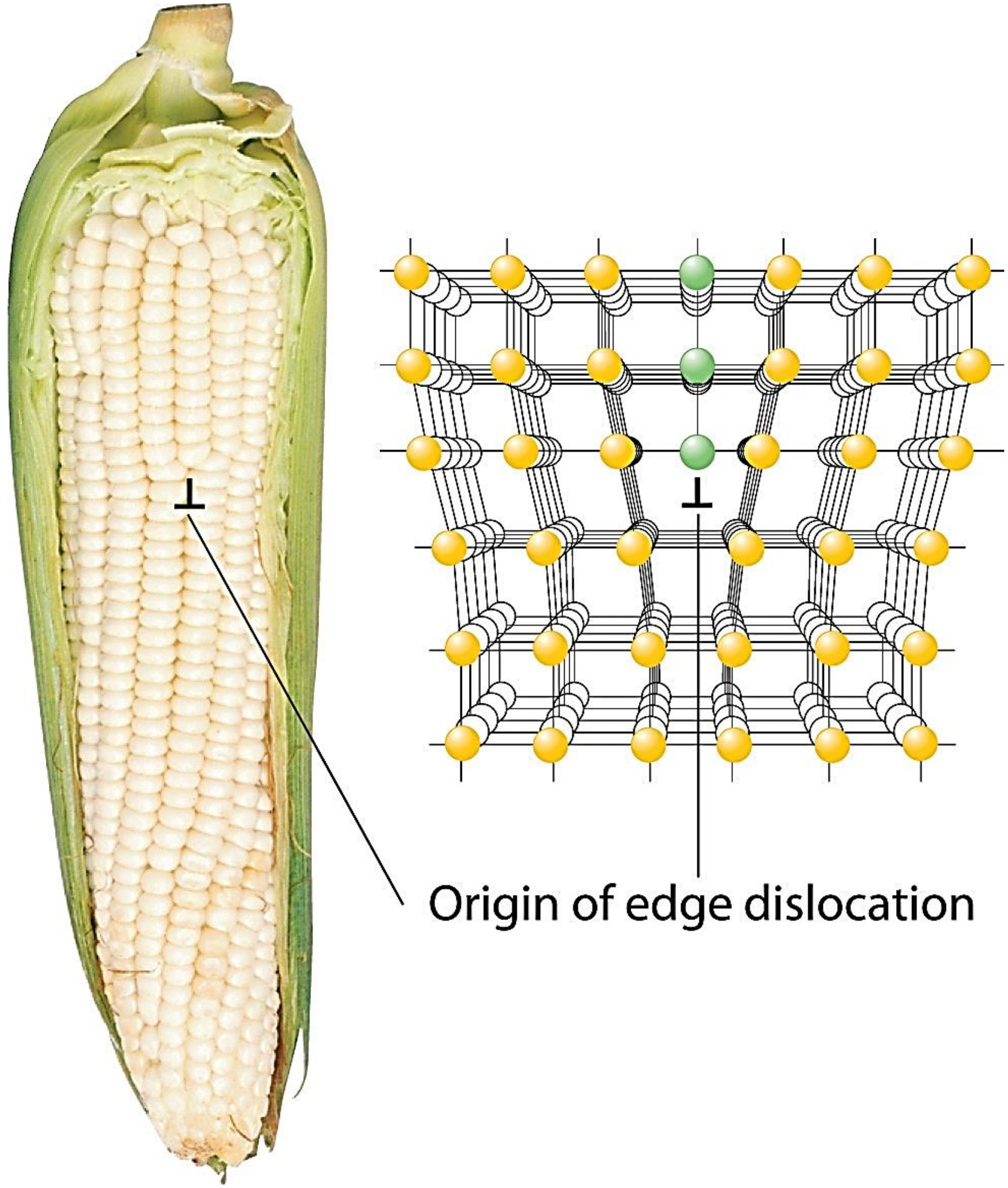
Edge dislocations are caused by the termination of a plane of atoms in the middle of a crystal. In such a case, the adjacent planes are not straight, but instead bend around the edge of the terminating plane so that the crystal structure is perfectly ordered on either side.



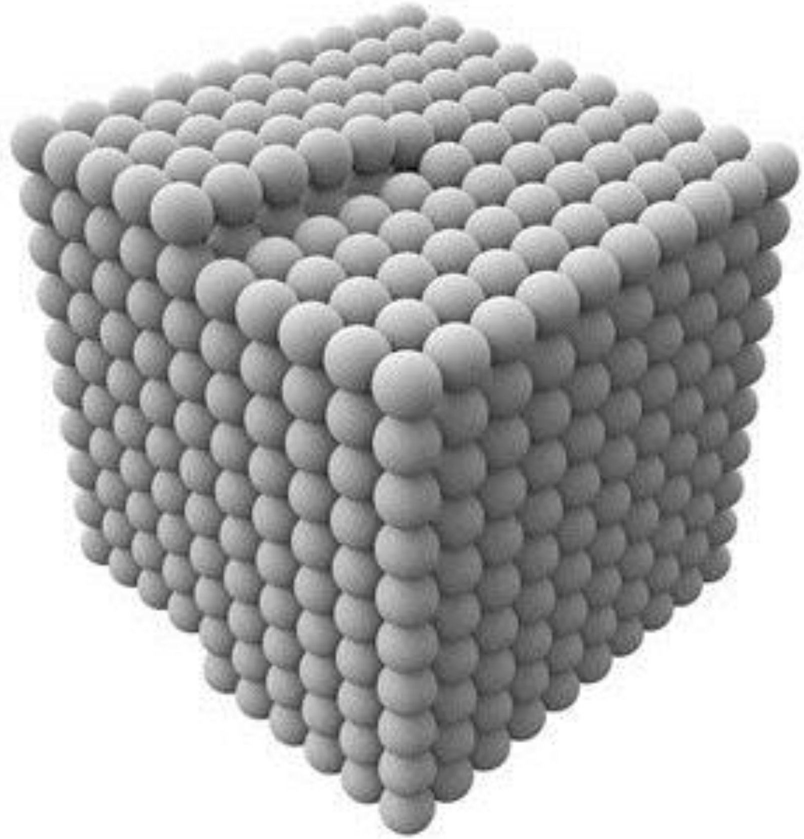
edge dislocation



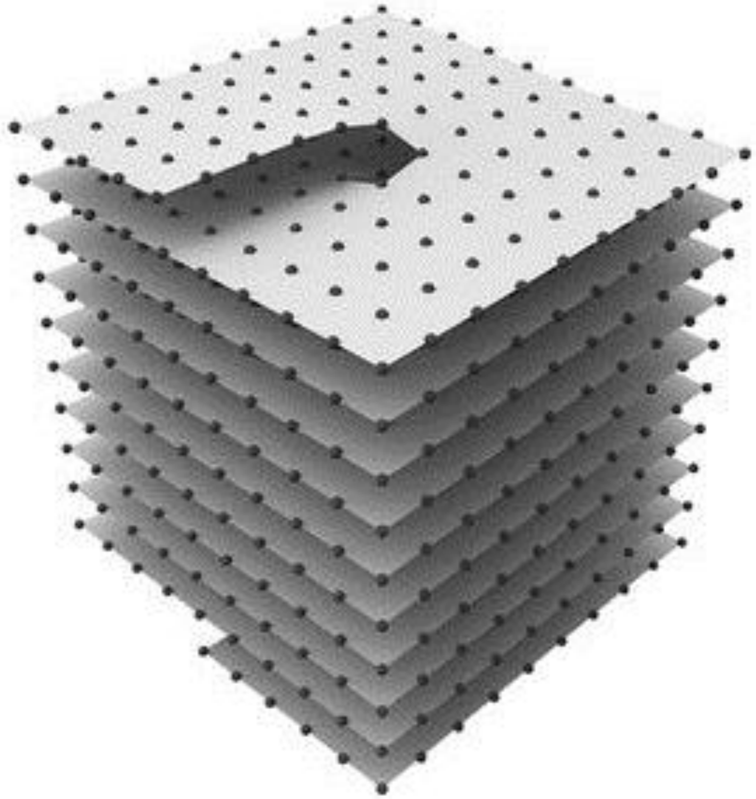
crystal plane schematic of edge dislocation


Origin of edge dislocation

The **screw dislocation** is more difficult to visualize, but basically comprises a structure in which a helical path is traced around the linear defect (dislocation line) by the atomic planes of atoms in the crystal lattice.



screw dislocation

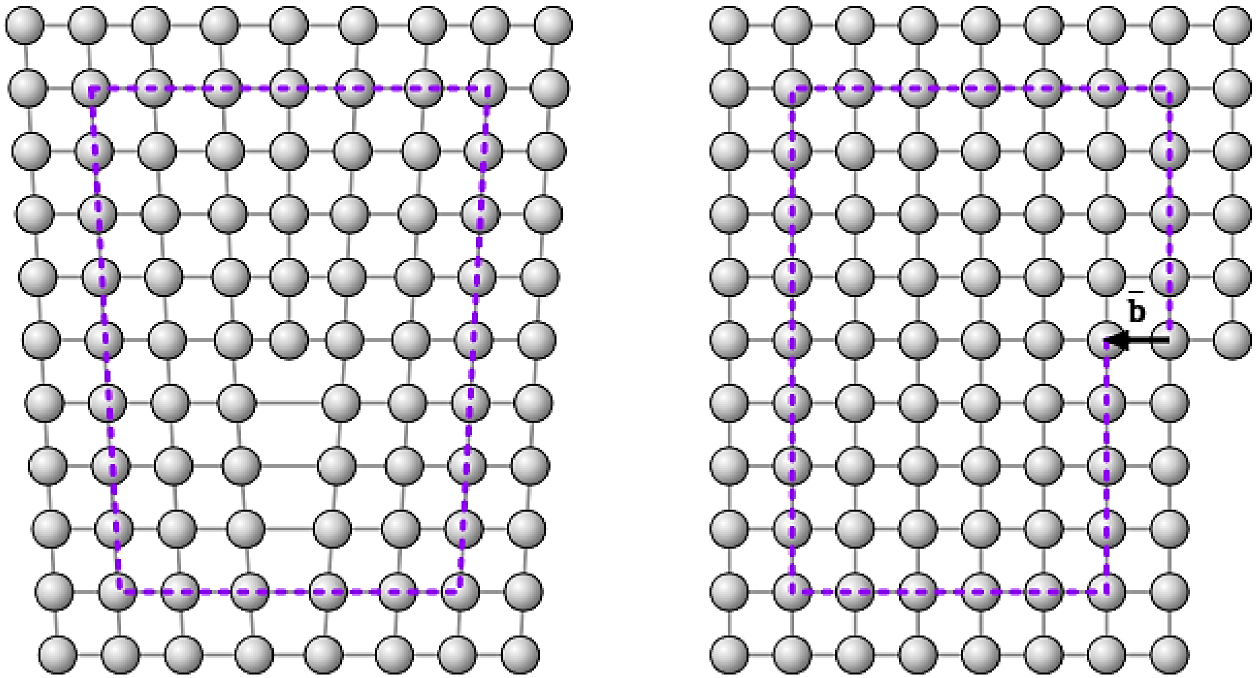


crystal plane schematic of screw dislocation

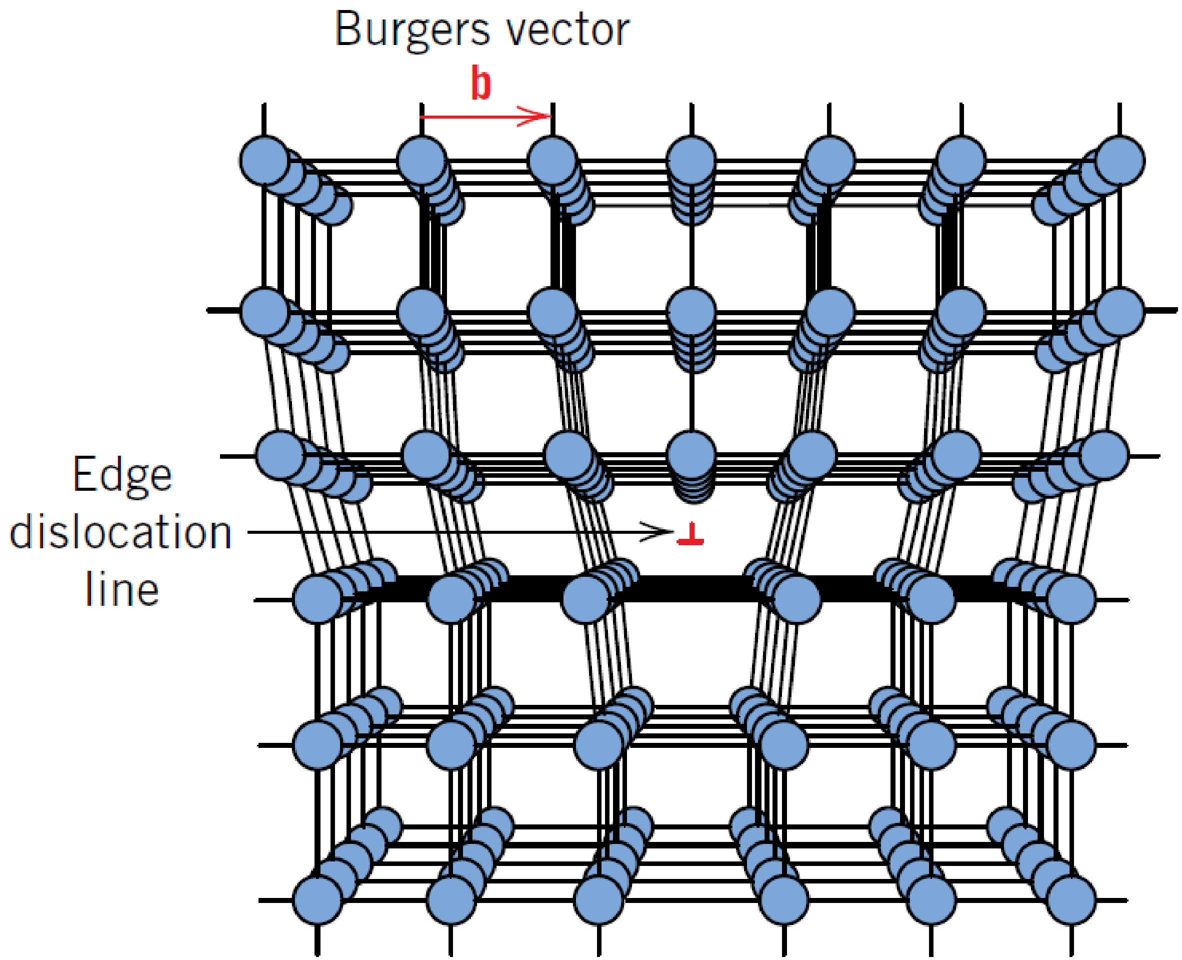
The presence of dislocation results in lattice strain (distortion).

The direction and magnitude of such distortion is expressed in terms of a **Burgers vector**.

For an edge type, **b** is perpendicular to the dislocation line, whereas in the cases of the screw type it is parallel. In metallic materials, **b** is aligned with close-packed crystallographic directions and its magnitude is equivalent to one interatomic spacing.



Burgers vector in a dislocation

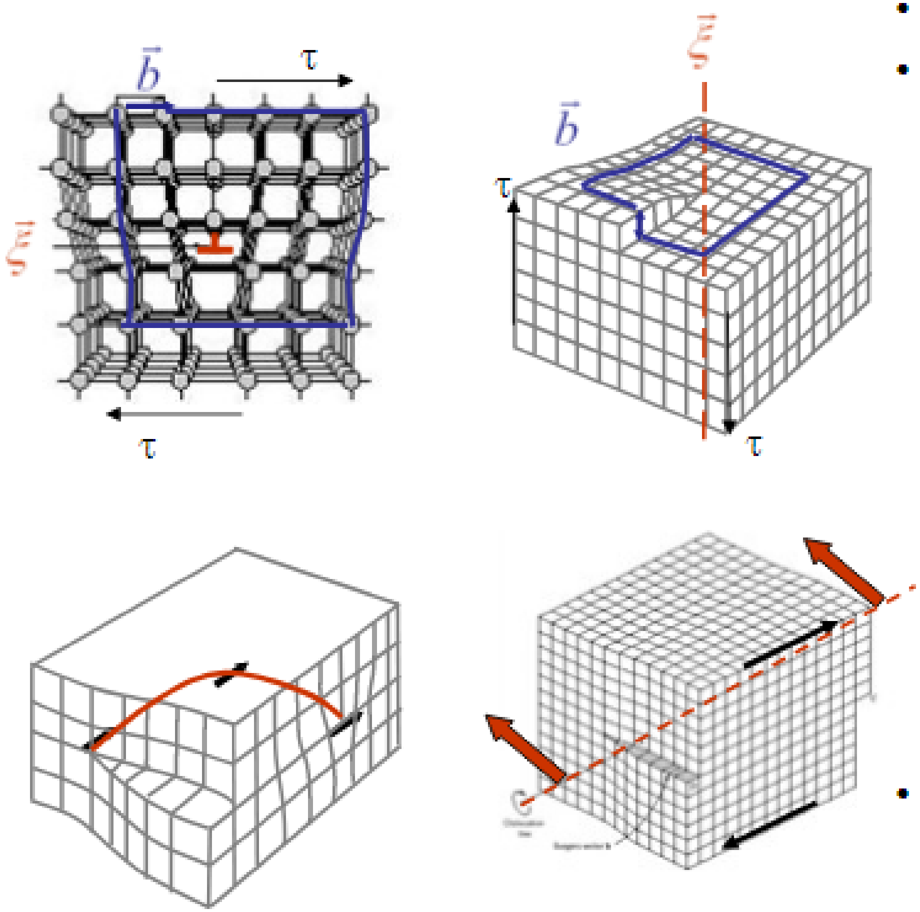


The atom positions around an edge dislocation; extra half-plane of atoms shown in perspective

Johannes (Jan) Martinus Burgers
(1895 – 1981)
(a Dutch physicist)

He is credited to be the father of Burgers' equation, the Burgers vector in dislocation theory and the Burgers material in viscoelasticity

Dislocations Types



From : Callister

- Edge, screw, mixed
- Burger's vector ($\vec{b}$)
  - Indicates magnitude and direction of motion
  - Constructing Burger's circuit
  - Edge dislocation
    - $\vec{b} \perp \vec{\xi}$
    - $\vec{\tau} \perp \vec{\xi}$
  - Screw dislocation
    - $\vec{b} \parallel \vec{\xi}$
    - $\tau \parallel \vec{\xi}$
- Mixed
  - Both edge and screw behavior
  - Burgers vector constant despite changing type

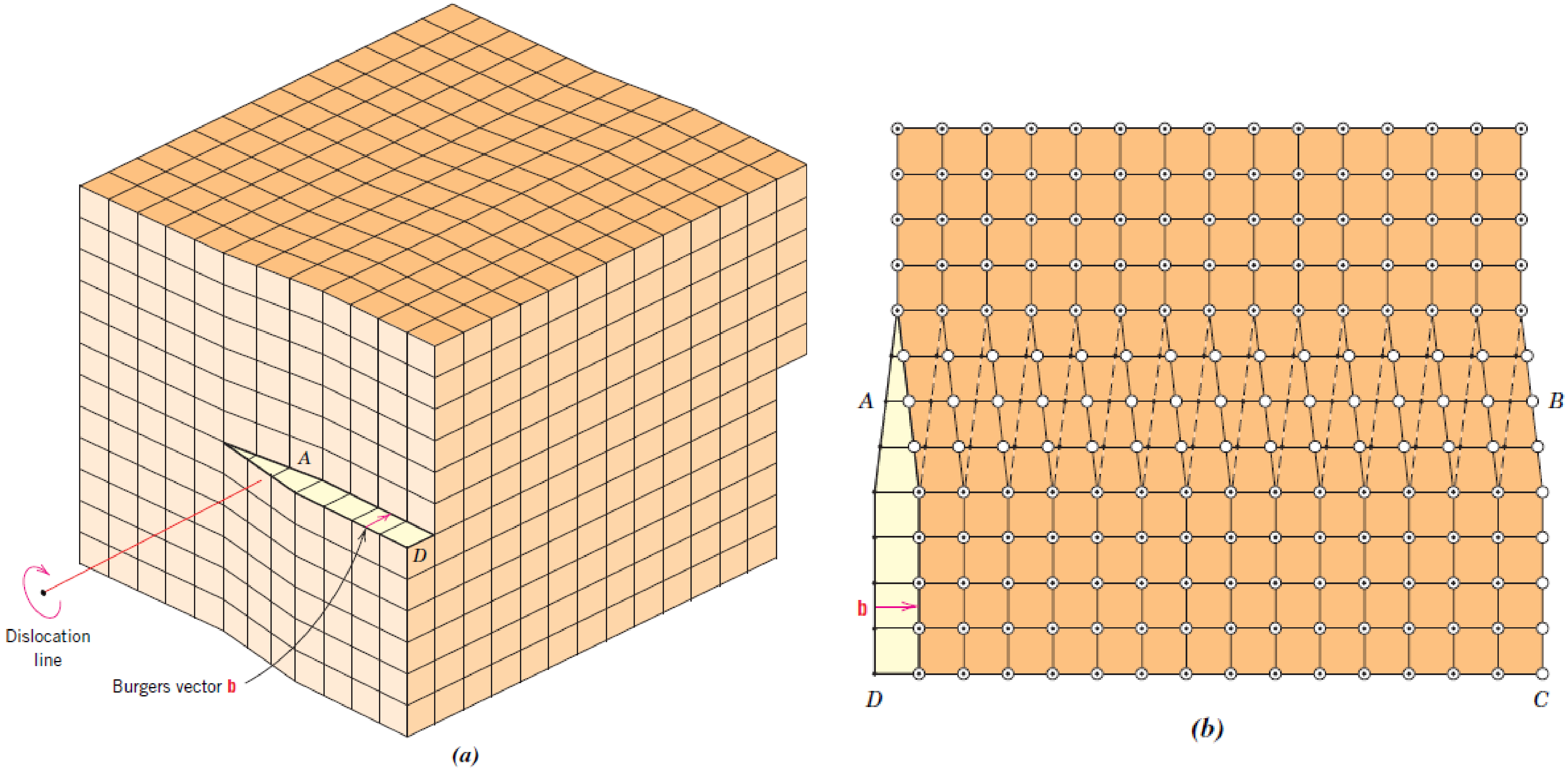


Figure 4.5 (*a*) A screw dislocation within a crystal.
(*b*) The screw dislocation in (*a*) as viewed from above. The dislocation line extends along line *AB*. Atom positions above the slip plane are designated by open circles, those below by solid circles.

mixed dislocation

Most dislocations found in crystalline materials are probably neither pure edge nor pure screw but exhibit components of both types; these are termed mixed dislocations. All three dislocation types are represented schematically in Figure 4.6; the lattice distortion that is produced away from the two faces is mixed, having varying degrees of screw and edge character.

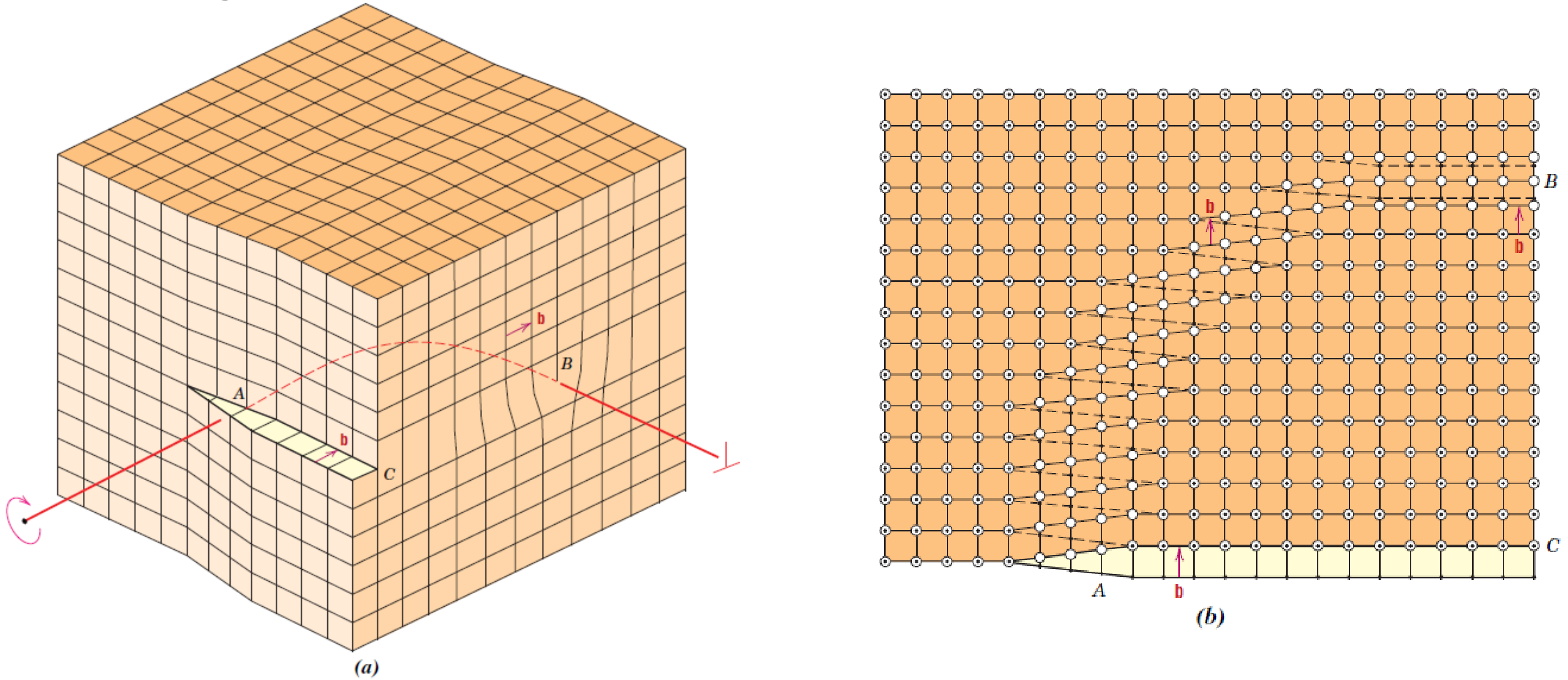


Figure 4.6 (a) Schematic representation of a dislocation that has edge, screw, and mixed character. (b) Top view, where open circles denote atom positions above the slip plane, and solid circles, atom positions below. At point A, the dislocation is pure screw, while at point B, it is pure edge. For regions in between where there is curvature in the dislocation line, the character is mixed edge and screw.

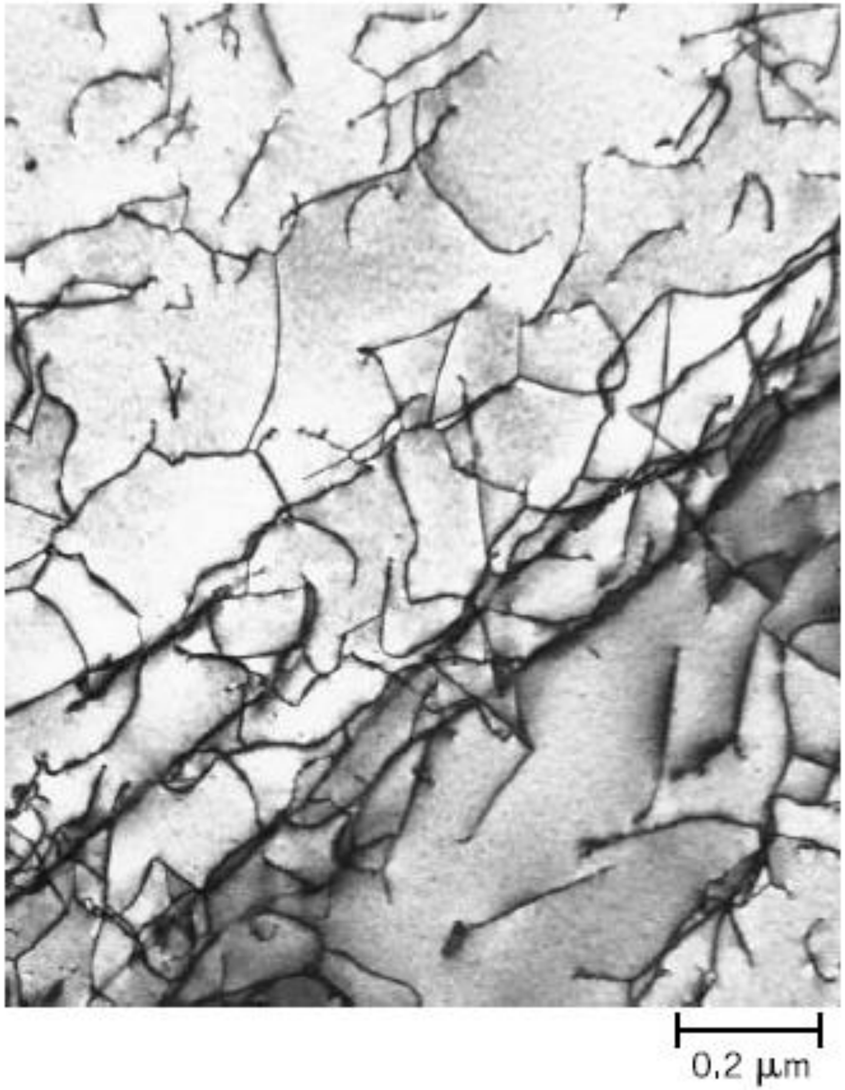
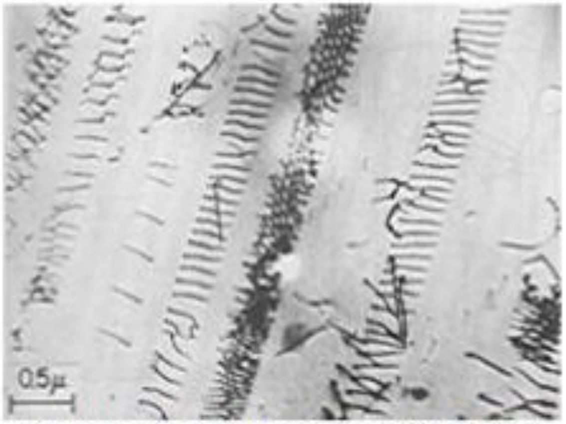
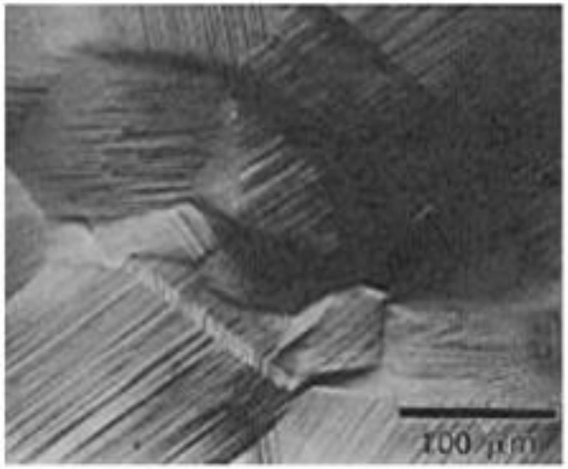


Fig. A transmission electron micrograph of a titanium alloy in which the dark lines are dislocations, 50,000.

Dislocations - microscopy



Dislocation pileup in 18Cr-8Ni stainless steel thin foil

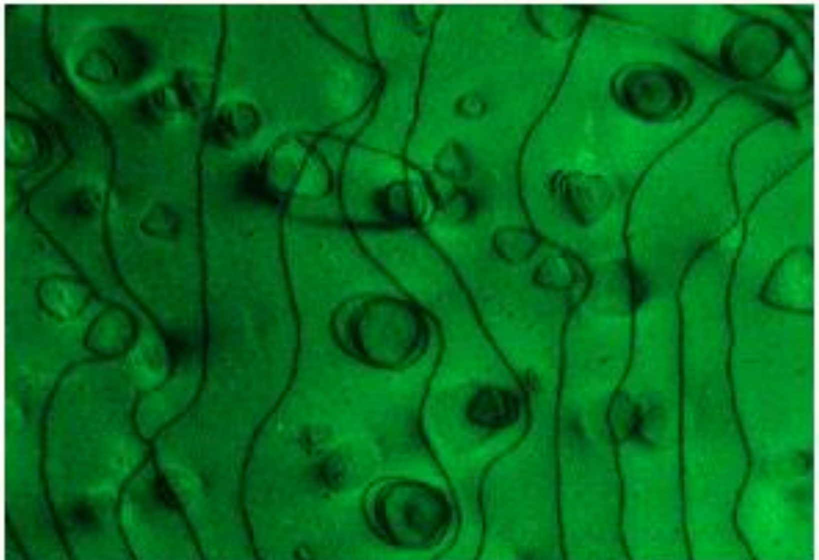


Macrograph of slip character in different grains

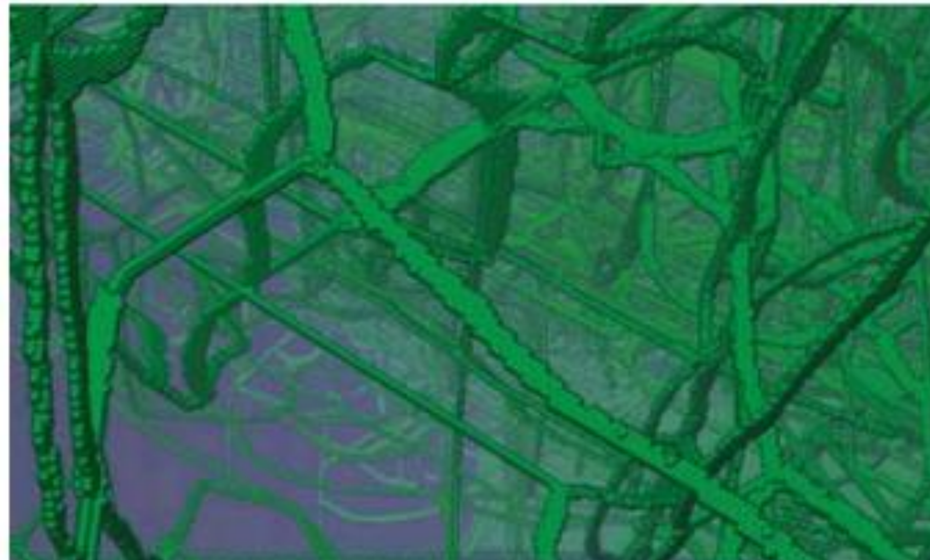
Frank-Reed source in Silicon crystal

- Introduced by
  - Solidification
  - Plastic deformation
  - Thermal processing

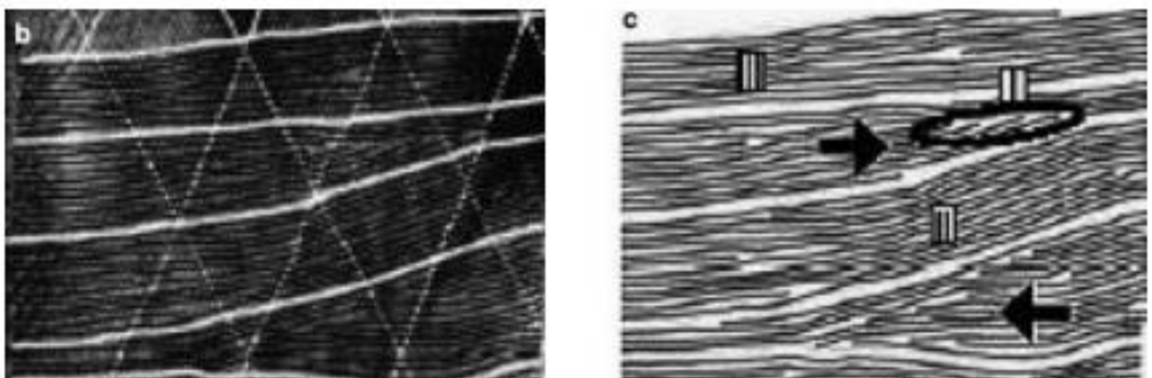
From : Hertzberg, p.71,78, 87.



TEM image of dislocations in Ni
Manchester Materials Science Center



atomistic simulation of work-hardening
IBM-LLNL collaboration



HRTEM image of a disclination dipole in Fe
[Murayama, Howe, Hidaka, Takaki, *Science* **295**, 2433, 2002]