Defects in Solids

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Any deviations from the perfect periodic arrangement in a crystal is said to be imperfections or defects.

Examples

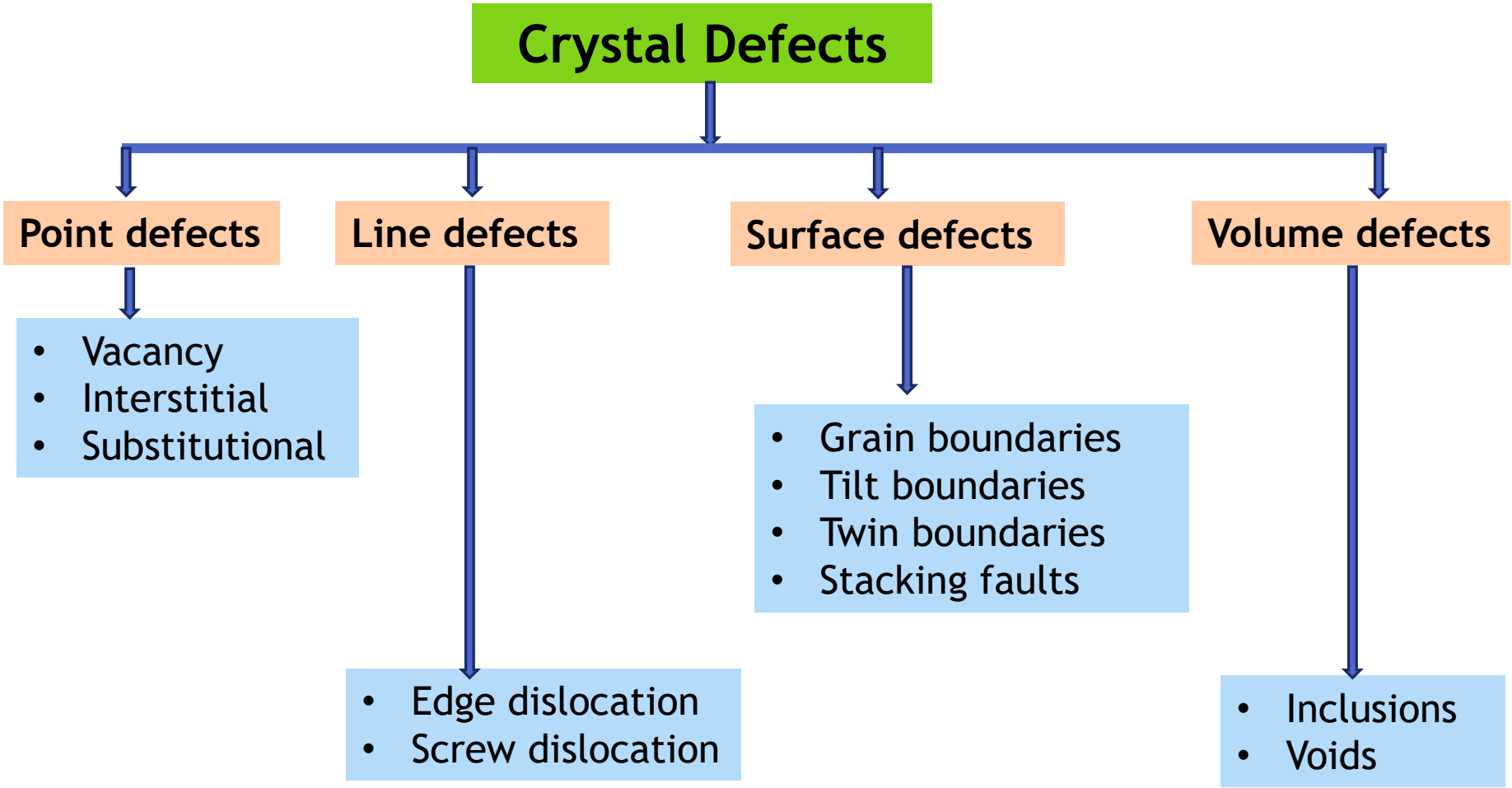
- Doping impurity into intrinsic semiconductor,
- Adding alloying elements into metal, etc.

Crystal defects influence many properties of crystals

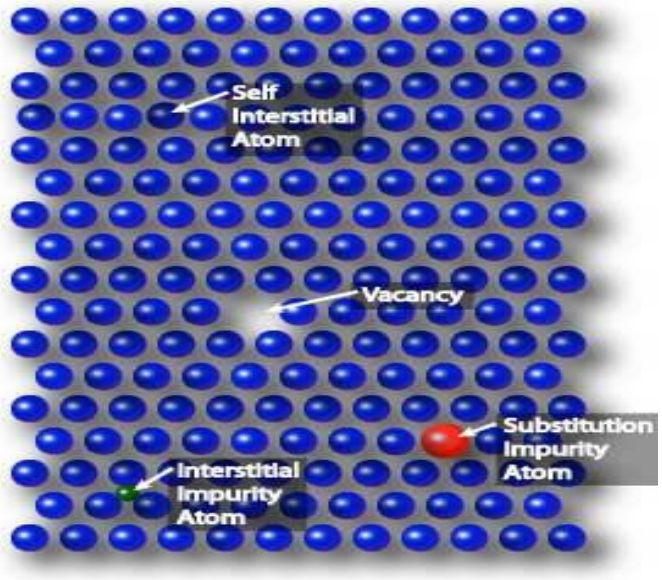
- Mechanical and plastic properties (E.g.- mechanical strength, rigidity, ductility, etc.).
- Electrical conductivity, hysteresis loss of ferromagnets.
- Color, luminescence of many crystals arise from impurities and imperfections.
- Optical transmittance, absorbance, refractive index, band gap, etc.
- Atomic diffusion may be accelerated enormously by impurities or imperfections.

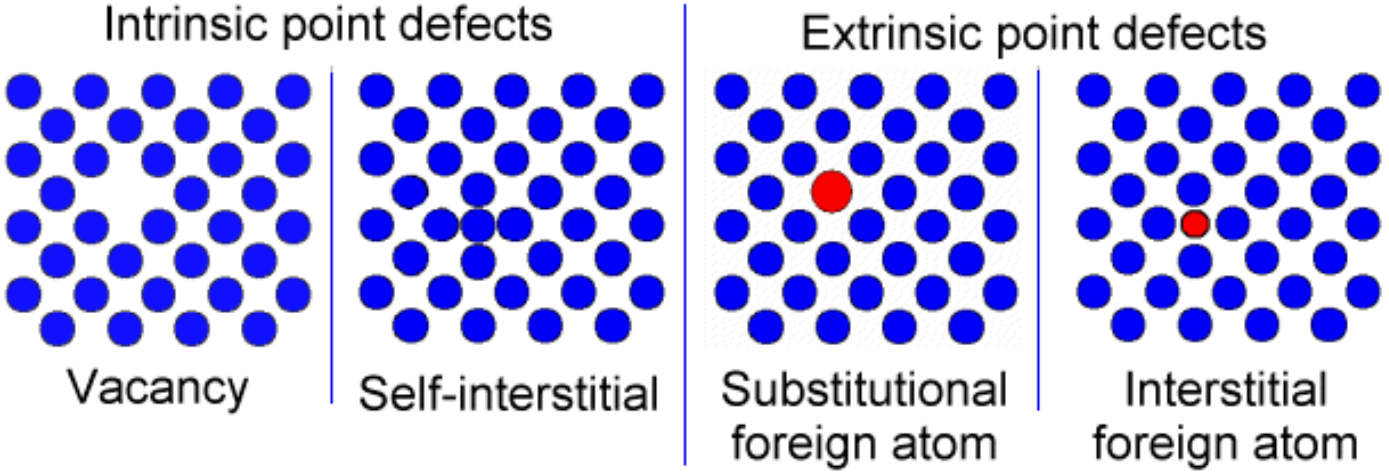
Classification of Imperfections in crystalline solids in terms of their dimension

1. Point imperfections (Zero dimensional defects)
2. Line imperfections (One dimensional defects)
3. Plane or surface imperfections (Two dimensional defects)
4. Volume imperfections (Three dimensional defects)


Crystal Defects
Point defects
Line defects
Surface defects
Volume defects
• Vacancy
• Interstitial
• Substitutional
• Edge dislocation
• Screw dislocation
• Grain boundaries
• Tilt boundaries
• Twin boundaries
• Stacking faults
• Inclusions
• Voids

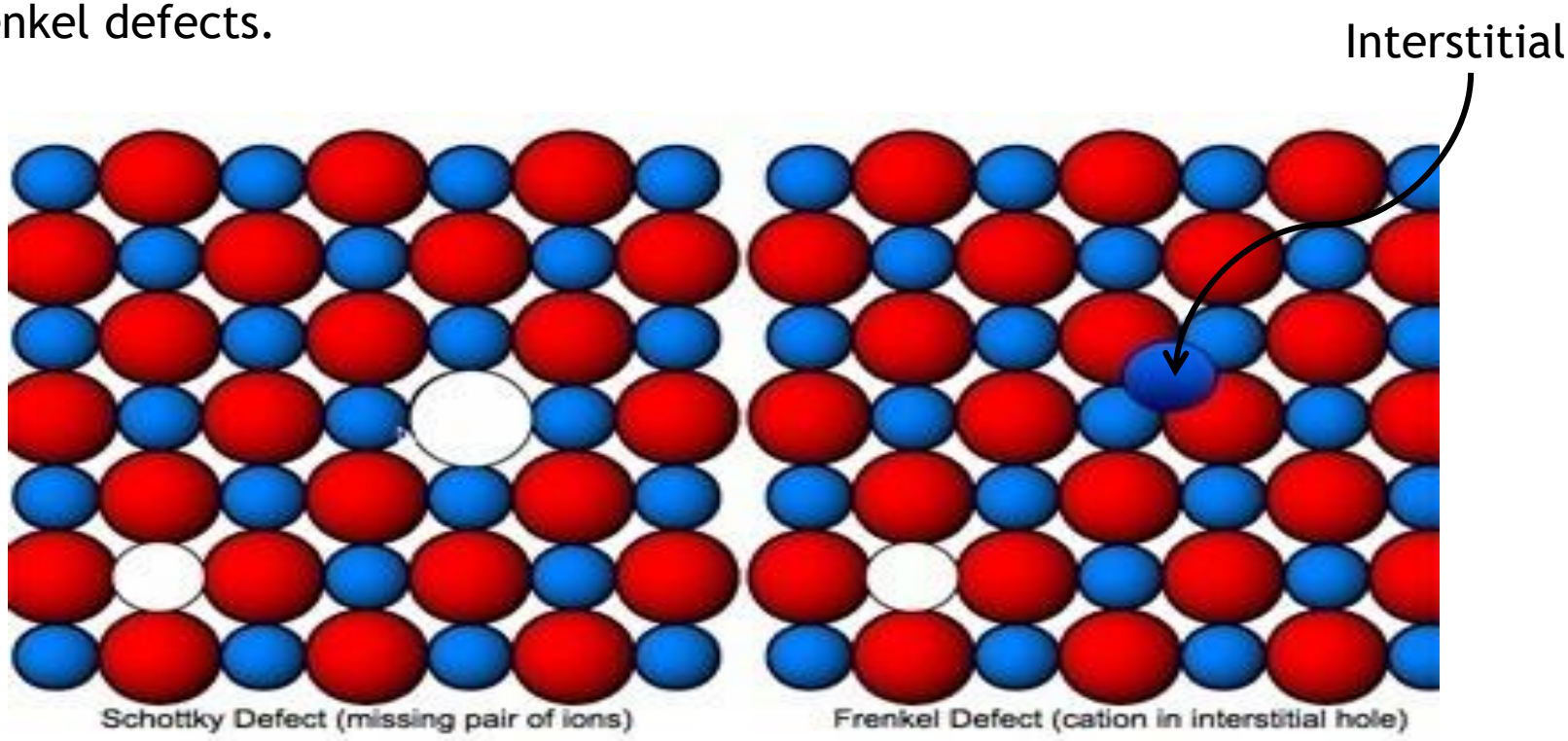
Point defects



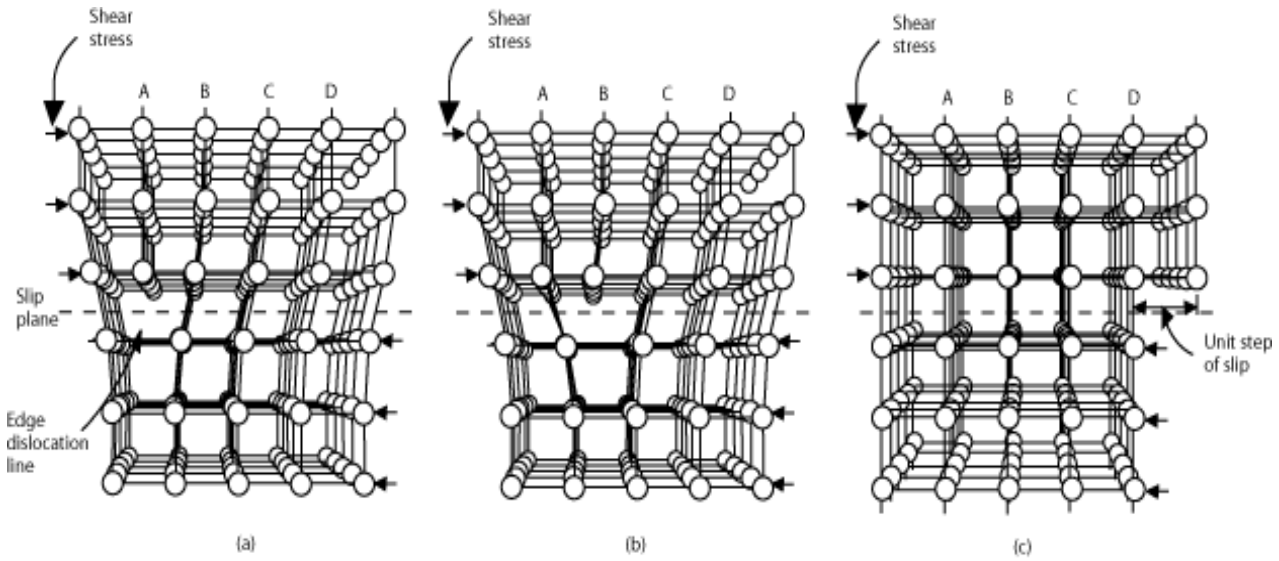


Schottky defects: is a type of vacancy in which an atom being free from regular site, migrates through successive steps and eventually settles at the crystal surface.

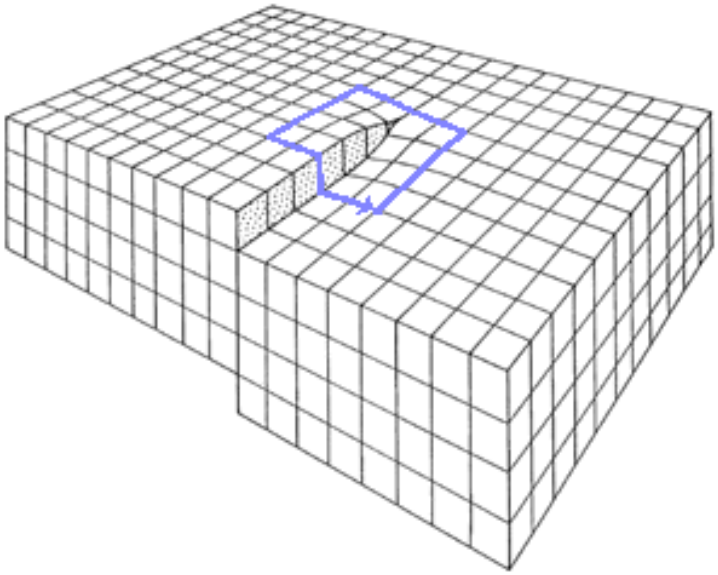
Frenkel defects: The combination of a vacancy and interstitial is called a Frenkel defects.



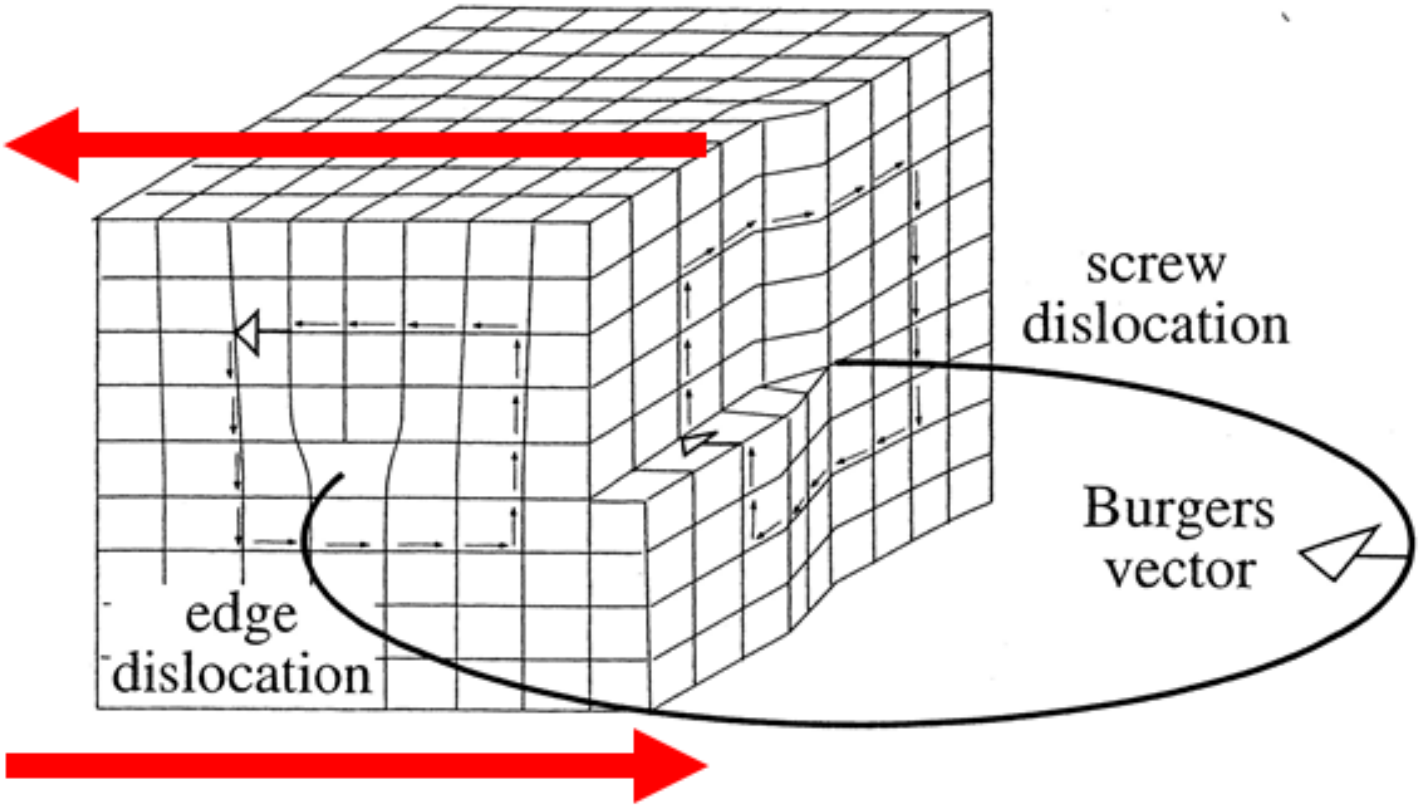
Line Defects or Dislocations



Edge dislocation



Screw dislocation

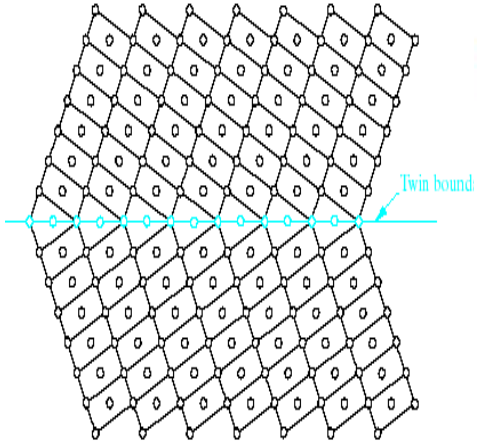

screw
dislocation
Burgers
vector
edge
dislocation

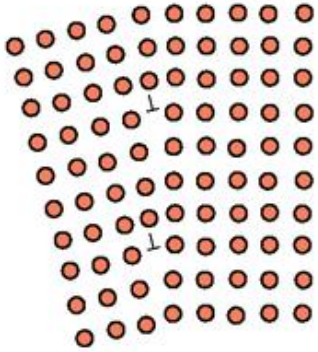
Edge Dislocation	Screw Dislocation
• In edge dislocation, distortion exists along an extra half-plane of atoms. These atoms also define the dislocation line. • Motion is parallel to the direction of stress. • Edge dislocation move in response to shear stress applied perpendicular to the dislocation line. • Motion of many of these dislocations will result in plastic deformation.	• A dislocation produced by skewing of a crystal by one atomic spacing so that a spiral ramp is produced. • The motion of a screw dislocation is also a result of shear stress. Motion is perpendicular to the direction of stress. • The net deformation of both edge and screw dislocations is the same. • Most dislocations can exhibits both edge and screw characteristics. These are called mixed dislocations.

Plane defects

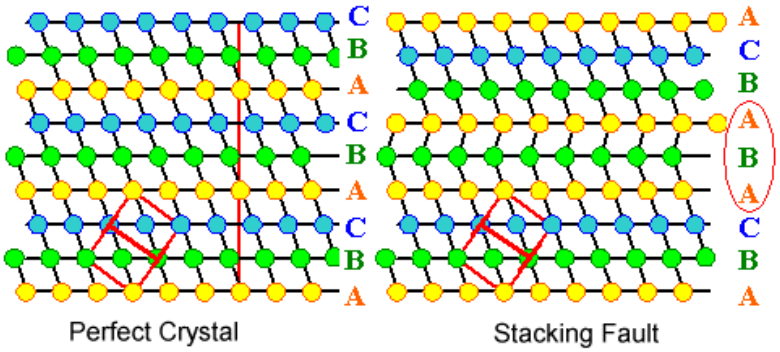
1. External surface: External surface of a solid itself is a defect. Surface atoms have unsatisfied atomic bonds and higher surface energies than bulk atoms. To reduce surface free energy, the material tends to minimize its surface areas against the surface tension.
2. Grain boundaries: It is the region between two adjacent grains which is slightly disordered. The low density in grain boundaries causes high mobility, diffusivity and electrical resistivity.
3. Tilt boundary: A boundary between two slightly misaligned grains appears as an array of edge dislocations in which the rotation axis is parallel to the boundary plane.
4. Twist boundary: Low angle grain boundaries that appear as an array of Screw dislocations in which the rotation axis is perpendicular to the boundary plane.
5. Twin boundaries: These are the boundaries in the grains at which the atomic arrangement on one side of the boundary is the mirror image of the atoms on the other side. The region between the pair of boundaries is called the twinned region.
6. Stacking fault: It is a planar defect and it is formed when regular sequence of stacking is disturbed.

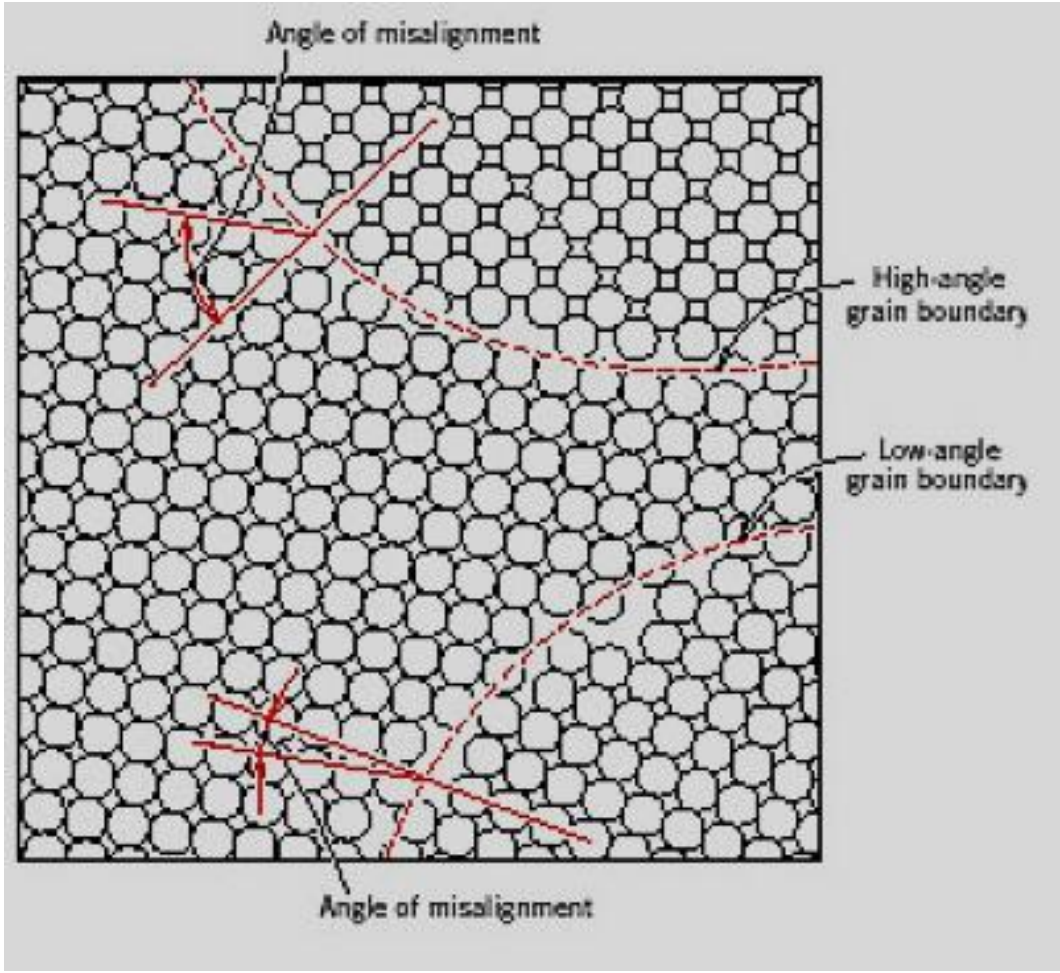
Plane defects





Tilt boundary





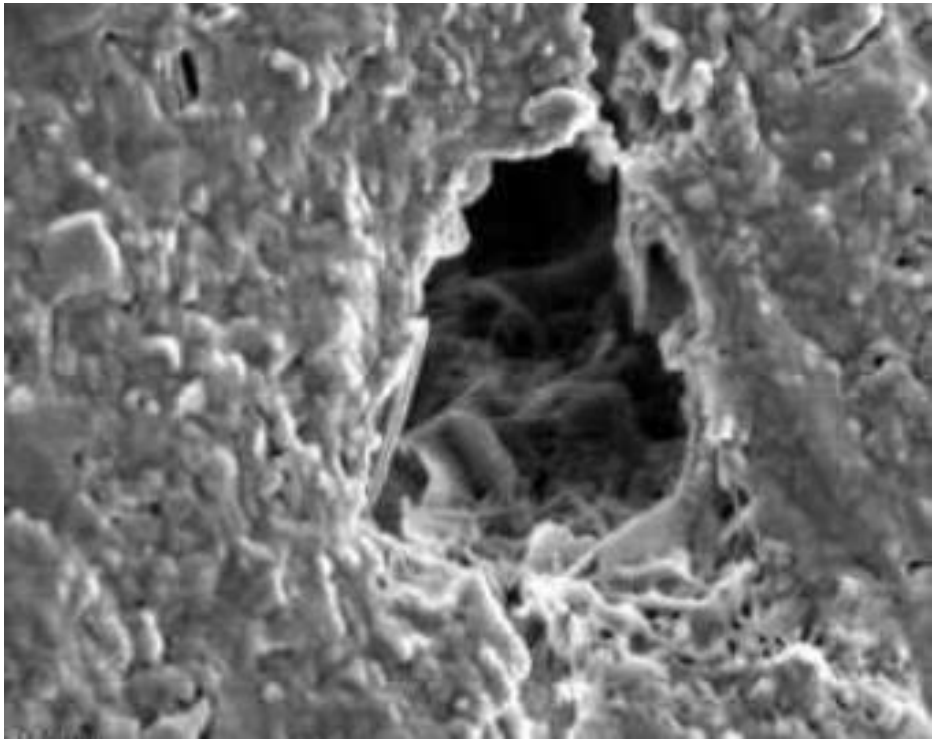
Volume or Bulk Defects

Voids: Voids are regions where there are a large number of atoms missing from the lattice. Voids can occur for a number of reasons. When voids occur due to air bubbles becoming trapped when a material solidifies, it is commonly called pores.

Cavity: When a void occurs due to the shrinkage of a material as it solidifies, it is called cavity.

Inclusions: A type of bulk defect occurs when impurity atoms cluster together to form small regions of a different phase. The term 'phase' refers to that region of space occupied by a physically homogeneous material. These regions are often called precipitates or inclusions.

There are many more volume defects like cracks, precipitate, etc.



Suggestion for Reading

Book: Solid State Physics (2nd Edition)- M. A. Wahab
Chapters: 1-3, 5, 8, 11
Problems: Pages: 9,10, 19-24, 25, 27, 28, 33, 36, 261, 262, 298, 299

Book: Physics for Engineers part-2- Dr. Giasuddin Ahmad
Chapter: Solid State Physics

Book: Concepts of Modern Physics (6th Edition)- Arthur Beiser
Chapter:10

Book: Introduction to Solid State Physics- Charles Kittel
Supplied photocopy of X-ray diffraction chapter.

Please do not miss any topic from the lectures and follow those as guideline during reading the books.