Lattice Defects
Types of lattice defects

• Point defects
• Line defects
• Surface defects
• Volume defects
Point defects

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

![Vacancy](image1)
![Interstitialcy](image2)
![Impurity](image3)
Point defects

- In ceramic materials point defects occur in pair to maintain the electroneutrality.
- A cation-vacancy and a cation-interstitial pair is known as a Frenkel defect.
- A cation vacancy-anion vacancy pair is known as a Schottky defect.
Line defects

Dislocations

- Dislocation is the region of localized lattice distortion which separates the slipped and unslipped portion of the crystal.
- The upper region of the crystal over the slip plane has slipped relative to the bottom portion. The line (AD) between the slipped and unslipped portions is the dislocation.
- The magnitude and direction of slip produced by dislocation (pink shaded) is the Burger vector, $b$, of the dislocation.
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.

Edge Dislocations

- Extra half-plane
- Slip vector
Screw Dislocations

- The other type of dislocation is the screw dislocation where the Burger vector is parallel to the dislocation line (AD).
- The trace of the atomic planes around the screw dislocation makes a spiral or helical path (pink shade) like a screw and hence, the name.
- Atomic positions along a screw dislocation is represented in Fig. (b)
The Burger vector can be found by the gap in the Burger circuit which is obtained by moving equal distances in each direction around the dislocation.
Dislocation movement and deformation

- The theoretical shear stress to produce plastic deformation in metals, \( \tau = \frac{G}{2\pi} \)
- \( G \), the shear modulus for metals is in the range of \( = 20 - 150 \) GPa yielding \( \tau = 3 - 30 \) GPa
- However, actual measured values of \( \tau = 0.5 - 10 \) MPa.
- This discrepancy can be explained by the presence of dislocations in the lattice.
- Dislocations assist in plastic deformation since it is easier to move the atoms at the dislocations core.
- The movement of dislocations produces a slip step of one Burger vector or one interatomic distance.
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.
Observing dislocations

Dislocations appear as lines when observed under transmission electron microscope (TEM)
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
Bulk or volume defects

- Porosity
- Inclusions
- Cracks

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

- 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
Evaluation

At the end of this chapter one should

- Understand different types of lattice defects.
- Be able to differentiate between screw and edge dislocation.
- Be able to describe Burger vector and dislocation movement.
- Understand grain and grain boundaries
References

http://people.virginia.edu/~lz2n/mse201/mse201-defects.pdf
http://henry.wells.edu/~cbailey/solidstate/Defects.ppt

Key words. Lattice defects; Point defects; Line defects; Dislocations; Edge dislocation; Screw dislocation; Burger vector; Slip; Surface defects; Grain boundary.
Quiz

1. How many types of lattice 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?