CRYSTAL DEFECTS IN MATERIALS

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CRYSTAL DEFECTS

- Almost all crystals contain defects, i.e. the atoms are not perfectly arranged according to their crystal structures.
- Defects affect the properties of materials.

- Crystal defects can be classified into the following categories:
    - Point defects (vacancy, interstitial, etc.)
    - Line defects (dislocations)
    - Surface defects (grain boundaries)
    - Volume defects (voids)

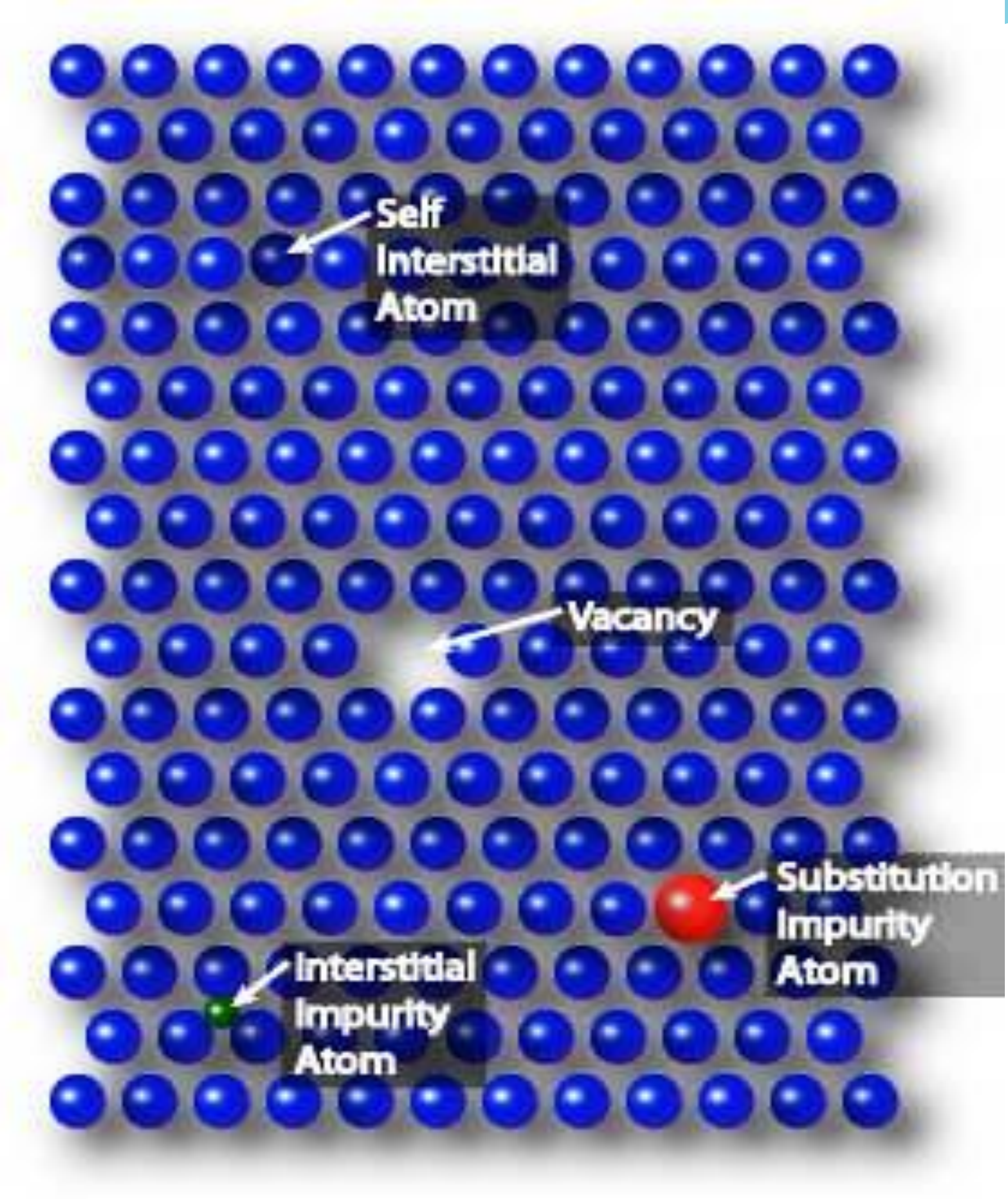
Point Defects

- Where an atom is missing or
- Is in an irregular place in the lattice structure.
- Point defects include:
    - Self-interstitial atoms (an extra atom that has crowded its way into an interstitial void),
    - Interstitial impurity atoms (occur only in low concentrations in metals because they distort and highly stress the tightly packed lattice structure),

Point Defects

- Substitutional atoms (atom of a different type than the bulk atoms, which has replaced one of the bulk atoms in the lattice).
- Usually close in size (within approximately 15%) to the bulk atom.
- In brass, zinc atoms with a radius of 0.133nm have replaced some of the copper atoms, which have a radius of 0.128nm.
- Vacancies or voids (empty spaces where an atom should be).

Point Defects



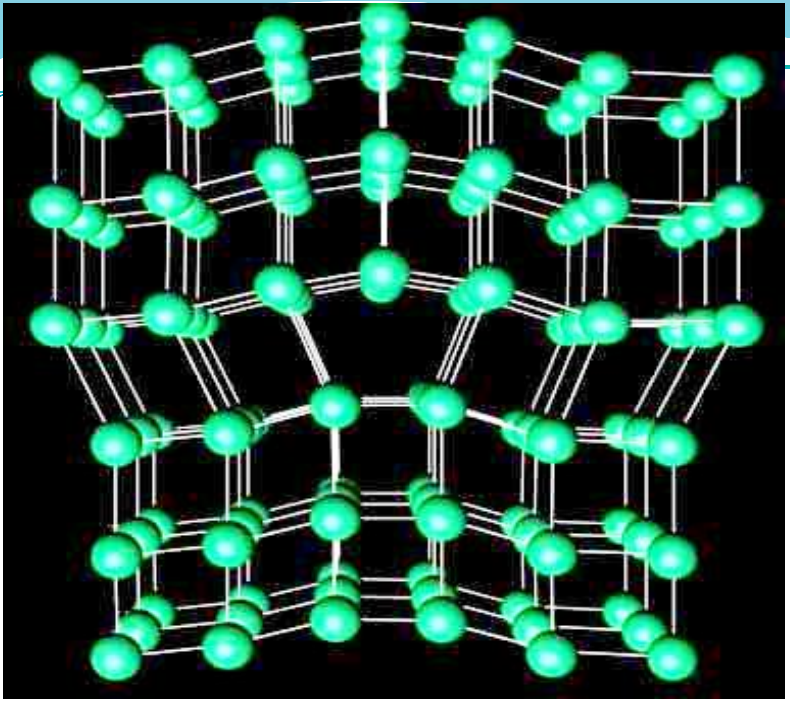
Line or Linear Defects - Dislocations

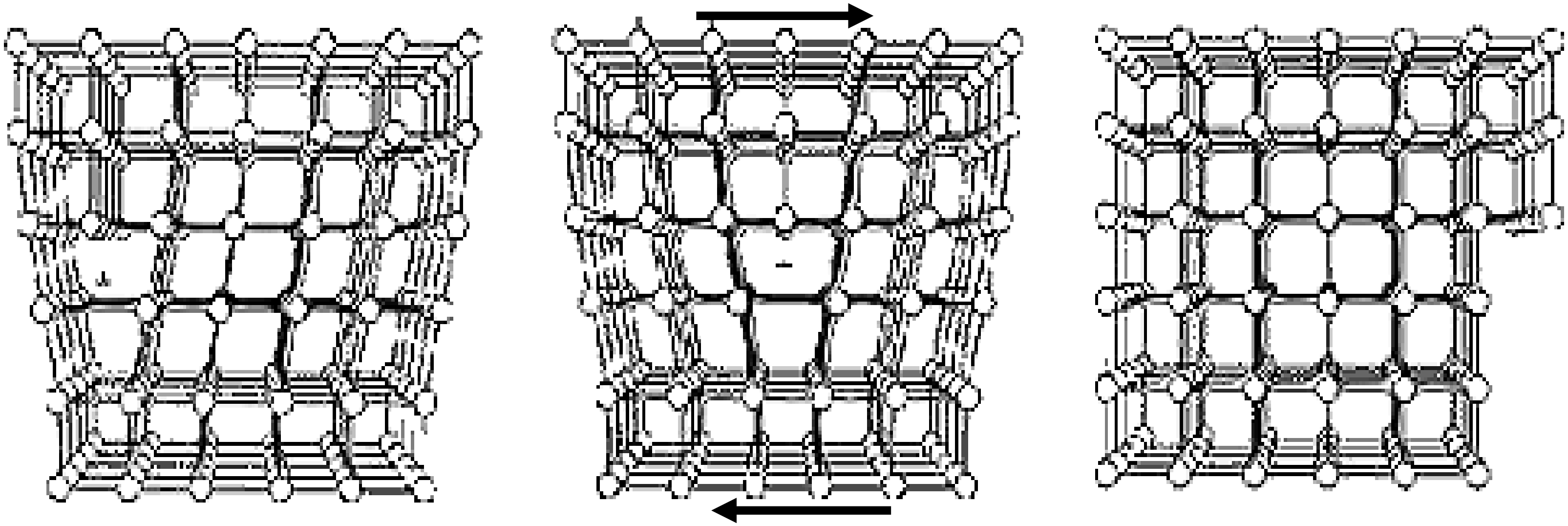
- Areas were the atoms are out of position in the crystal structure.
- Generated and move when a stress is applied.
- Motion of dislocations allows slip – plastic deformation to occur. Properties of a metal could be greatly changed by solely by forming (without changing the chemical composition).
- Two basic types of dislocations: **Edge dislocation** and **Screw dislocation**.
- Many dislocations are a hybrid of the edge and screw forms.

Edge Dislocations

- Easily visualised as an extra half-plane of atoms in a lattice.
- Called a line defect because the locus of defective points produced in the lattice by the dislocation lie along a line.
- This line runs along the bottom of the extra half-plane.
- The inter-atomic bonds are significantly distorted only in the immediate vicinity of the dislocation line.

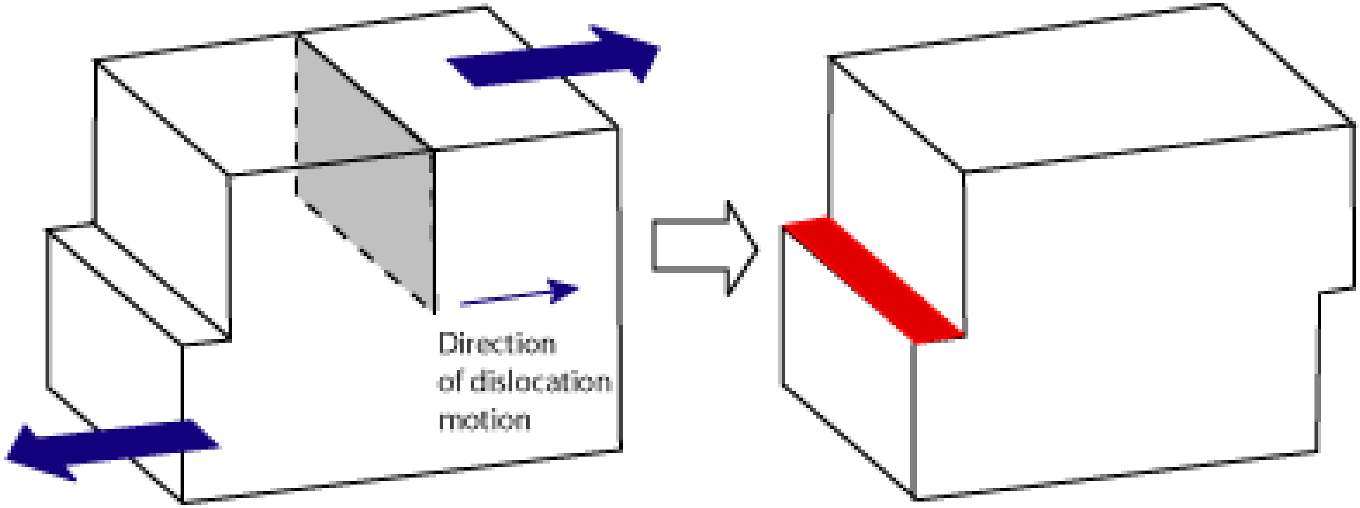
Edge Dislocations





Edge Dislocations

- Dislocation motion is analogous to movement of a caterpillar. The caterpillar would have to exert a large force to move its entire body at once. Instead it moves the rear portion of its body forward a small amount and creates a hump. The hump then moves forward and eventual moves all of the body forward by a small amount.

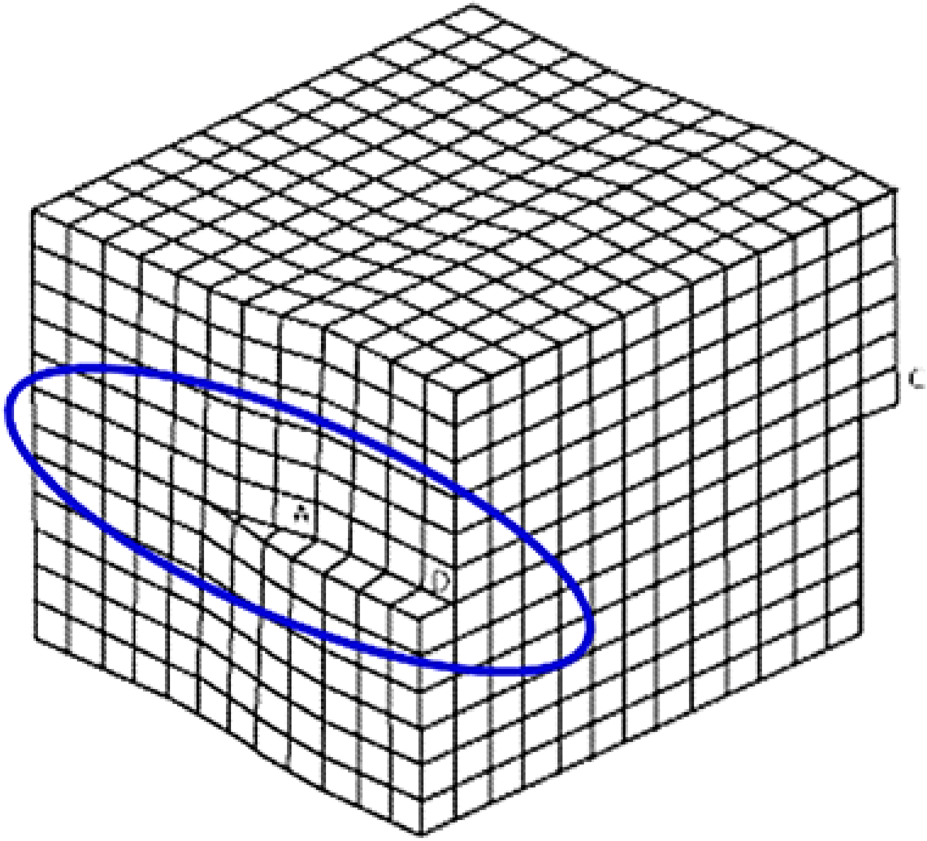


Screw Dislocations

- Slightly more difficult to visualize.
- Motion of a screw dislocation is also a result of shear stress.
- But the defect line movement is perpendicular to direction of the stress and the atom displacement

Screw Dislocations

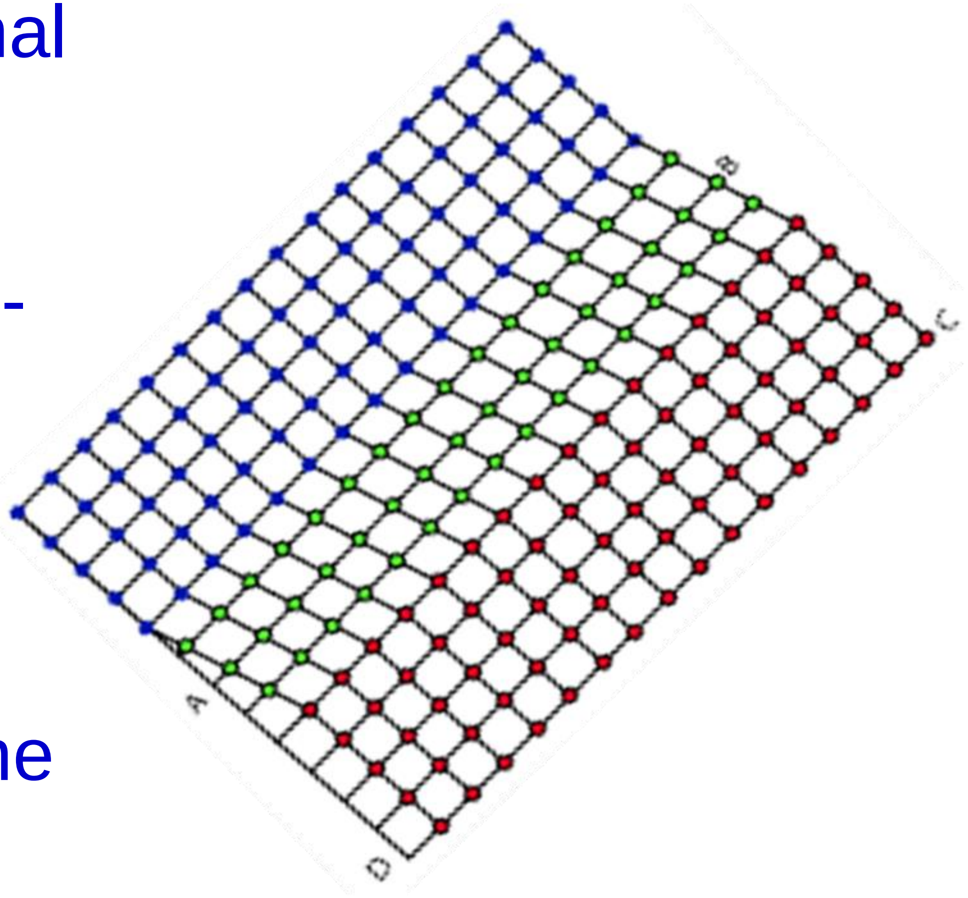
- To visualize a screw dislocation, imagine a block of metal with a shear stress applied across one end so that the metal begins to rip, shown in the upper image.
- Lower image shows the plane of atoms just above the rip.



Screw Dislocations

- Blue atoms have not yet moved from original positions. Red atoms have moved to new positions and have re-established metallic bonds.

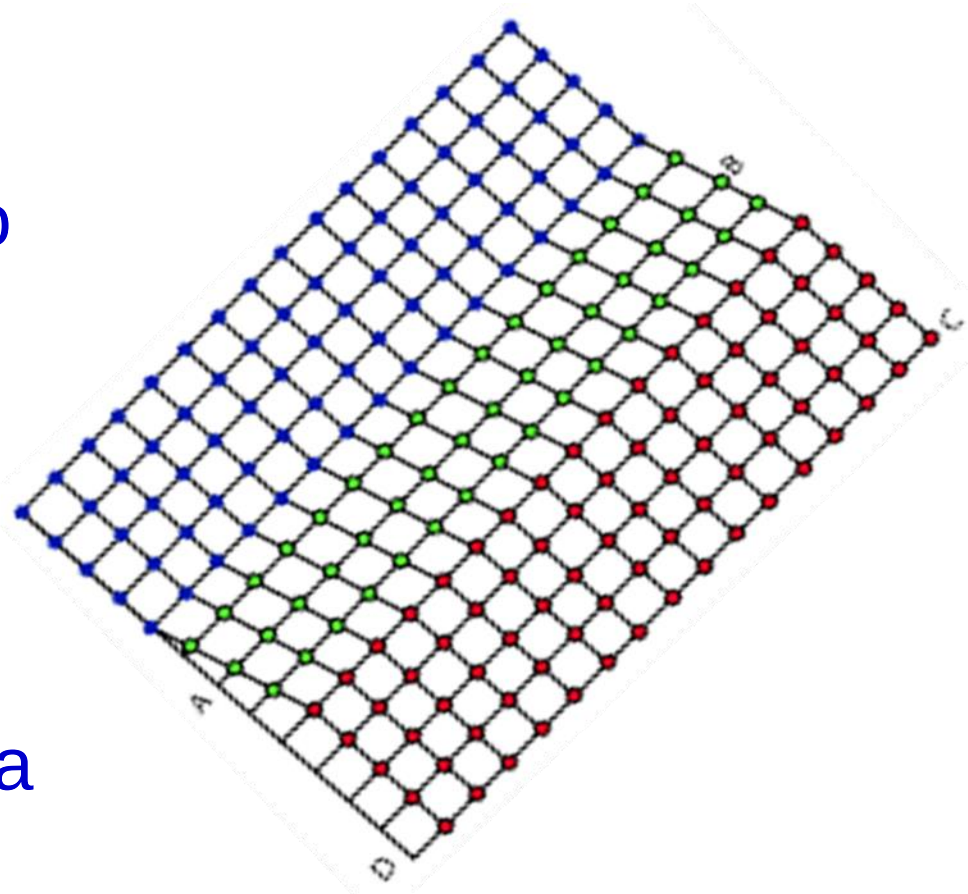
- Green atoms are in the process of moving.



Screw Dislocations

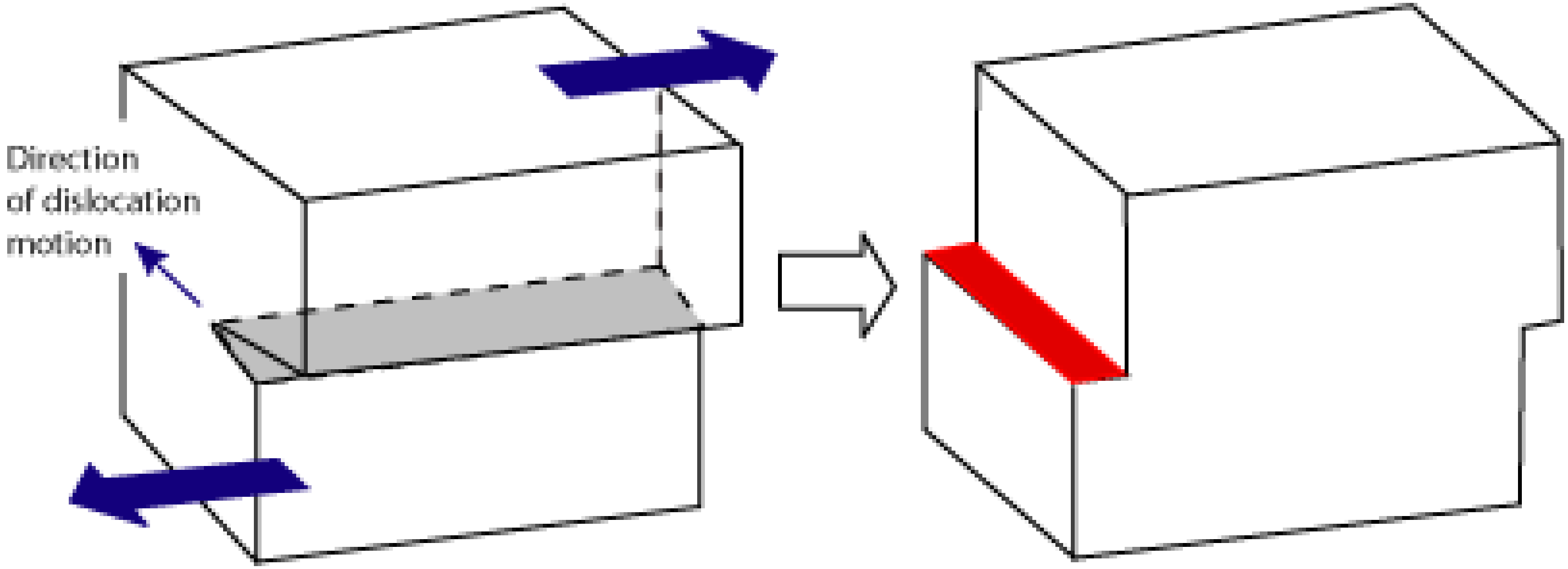
- If the shear force is increased, the atoms will continue to slip to the right. Into the red positions

- Only a portion of the bonds are broken at a time.



Screw Dislocations

- Movement in this manner requires much smaller force than breaking all the bonds across the middle plane simultaneously.
- If the shear force is increased, the atoms will continue to slip to the right until the entire plane slips.



Surface, Plane or Planar Defects

Stacking Faults and Twin Boundaries

- A disruption of the long-range stacking sequence can produce two other common types of crystal defects:

  1) a stacking fault and

  2) a twin region.

- A change in the stacking sequence over a few atomic spacings produces a stacking fault whereas a change over many atomic spacings produces a twin region

Surface, Plane or Planar Defects

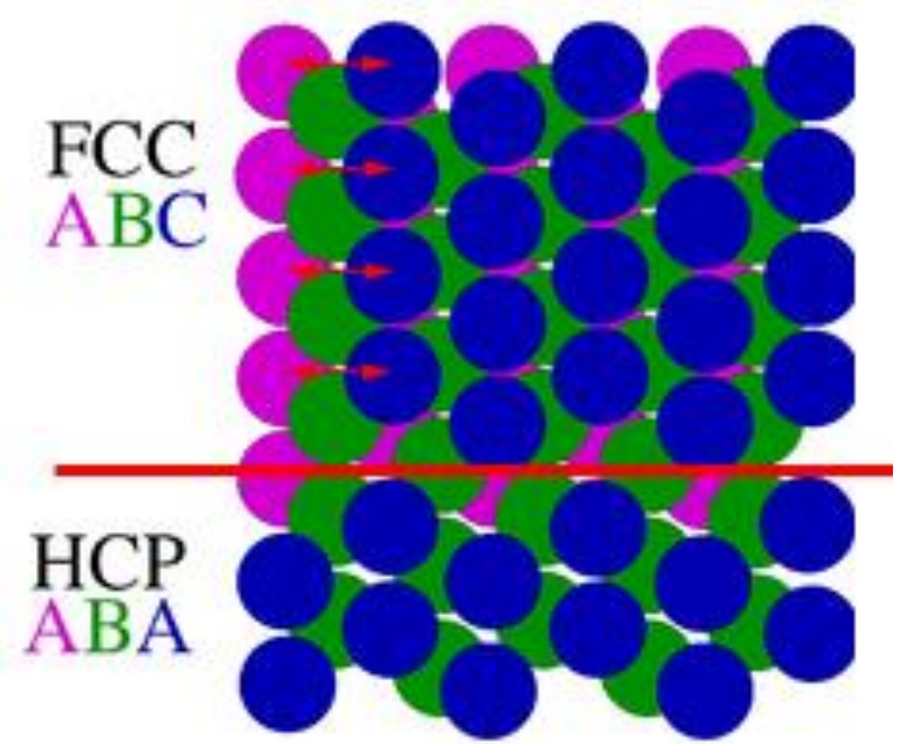
Stacking Fault

- is a one or two layer interruption in the stacking sequence of atom planes.
- occurs in a number of crystal structures, but is easiest to see how they occur in close packed structures.
- E.g.: face centred cubic (fcc) structures differ from hexagonal close packed (hcp) structures only in their stacking order.
- For hcp and fcc, the first two layers arrange themselves identically, and are said to have an AB arrangement

Surface, Plane or Planar Defects

Stacking Fault

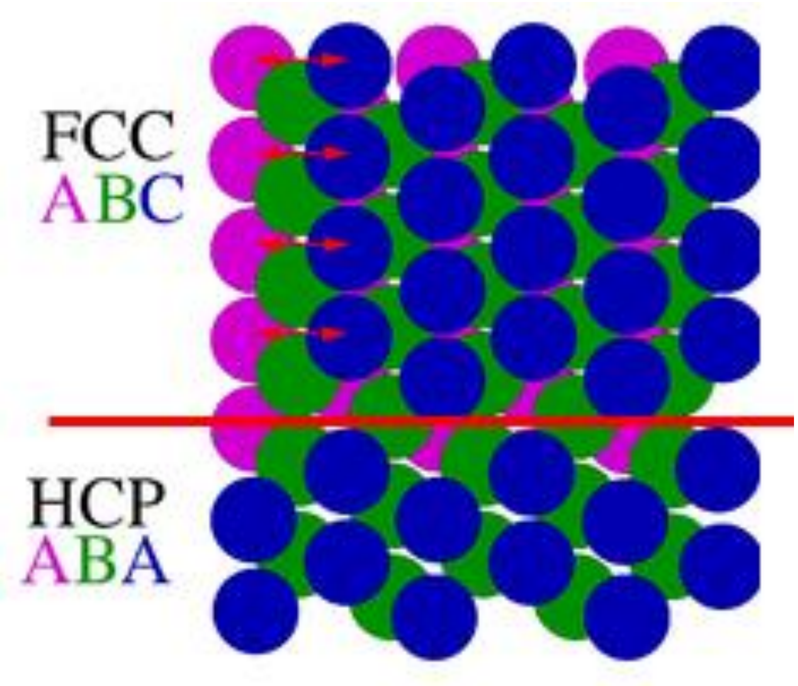
- If the third layer is placed so that its atoms are directly above those of the first (A) layer, the stacking will be ABA.
- This is the hcp structure, and it continues ABABABAB



Surface, Plane or Planar Defects

Stacking Fault

- But it is possible for the third layer atoms to arrange themselves so that they are in line with the first layer to produce an ABC arrangement which is that of the fcc structure.



- So, if the hcp structure is going along as ABABAB and suddenly switches to ABABABCABAB, there is a **stacking fault** present, along the red line in the figure.

Surface, Plane or Planar Defects

Stacking Fault

- Alternately, in the fcc arrangement the pattern is ABCABCABC.
- A stacking fault in an fcc structure would appear as one of the C planes missing.
- In other words the pattern would become ABCABCAB_ABCABC.

Surface, Plane or Planar Defects

Twin

- If a stacking fault does not correct itself immediately but continues over some number of atomic spacings, it will produce a second stacking fault that is the twin of the first one.
- E.g., if the stacking pattern is ABABABAB but switches to ABCABCABC for a period of time before switching back to ABABABAB, a pair of twin stacking faults, or simply a twin, is produced.

Surface, Plane or Planar Defects

Twin

- The red region in the stacking sequence that goes
- ABCABCACBACBABCABC is the twin plane and the twin boundaries are the A planes on each end of the highlighted region.

Surface, Plane or Planar Defects

Grain Boundaries in Polycrystals

- Solids generally consist of a number of crystallites or grains.
- Grains can range in size from nanometres to millimetres across
- Their orientations are usually rotated with respect to neighbouring grains.
- Where one grain stops and another begins is known as a grain boundary. Grain boundaries limit the lengths and motions of dislocations.

Surface, Plane or Planar Defects

- Therefore, having smaller grains (more grain boundary surface area) strengthens a material.
- Grain size can be controlled by the cooling rate in heat treatment.
- Generally, rapid cooling produces smaller grains whereas slow cooling result in larger grains.

Volume or Bulk Defects

These are defects occurring on a much bigger scale than the rest of the crystal defects. These include:

- Voids

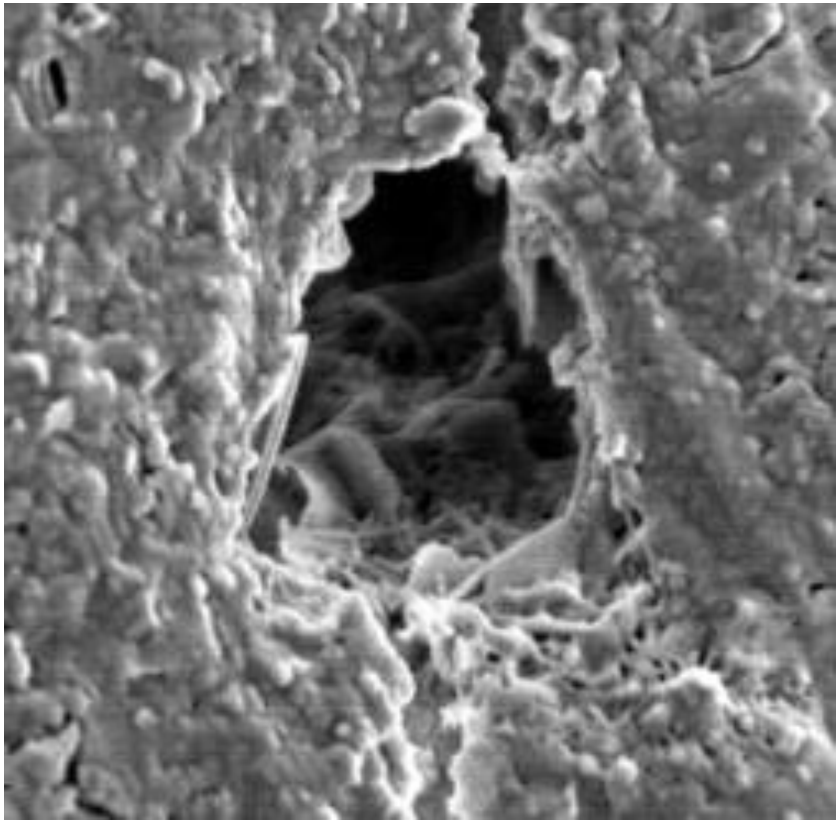
and

- Impurity atoms cluster

Volume or Bulk Defects

Voids

- regions where there are one or a large number of atoms missing from the lattice. The image to the right is a void in a piece of metal (large number of atoms missing).

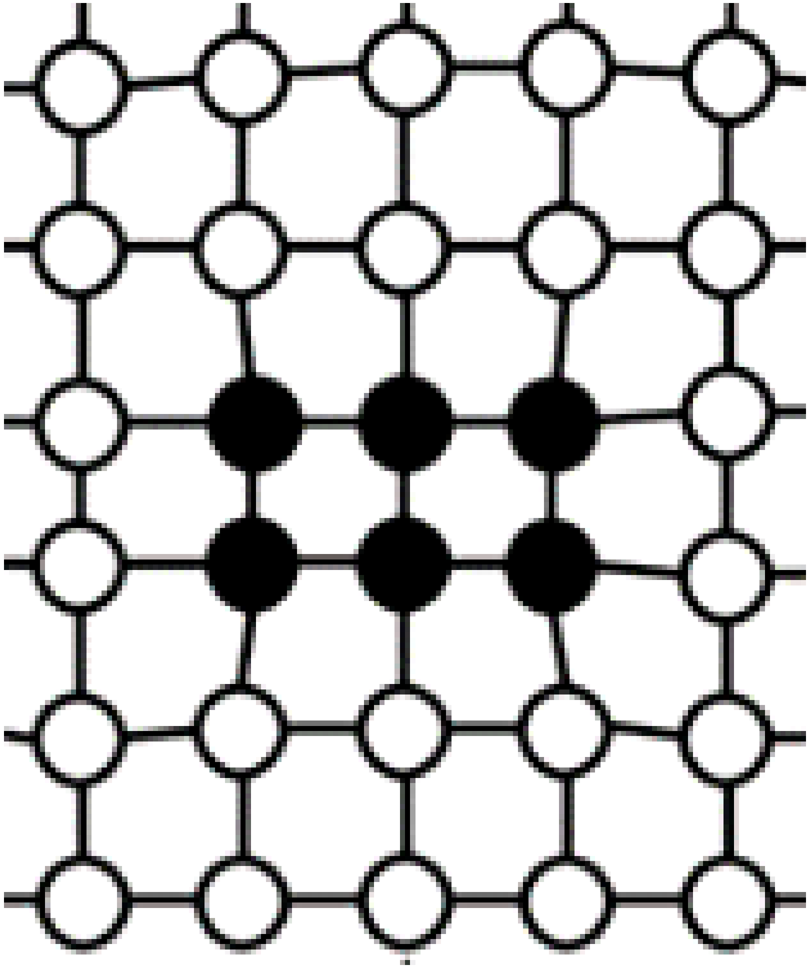


- Voids can occur for a number of reasons (due to entrapped air = **porosity**; due to shrinkage = **cavitation**).

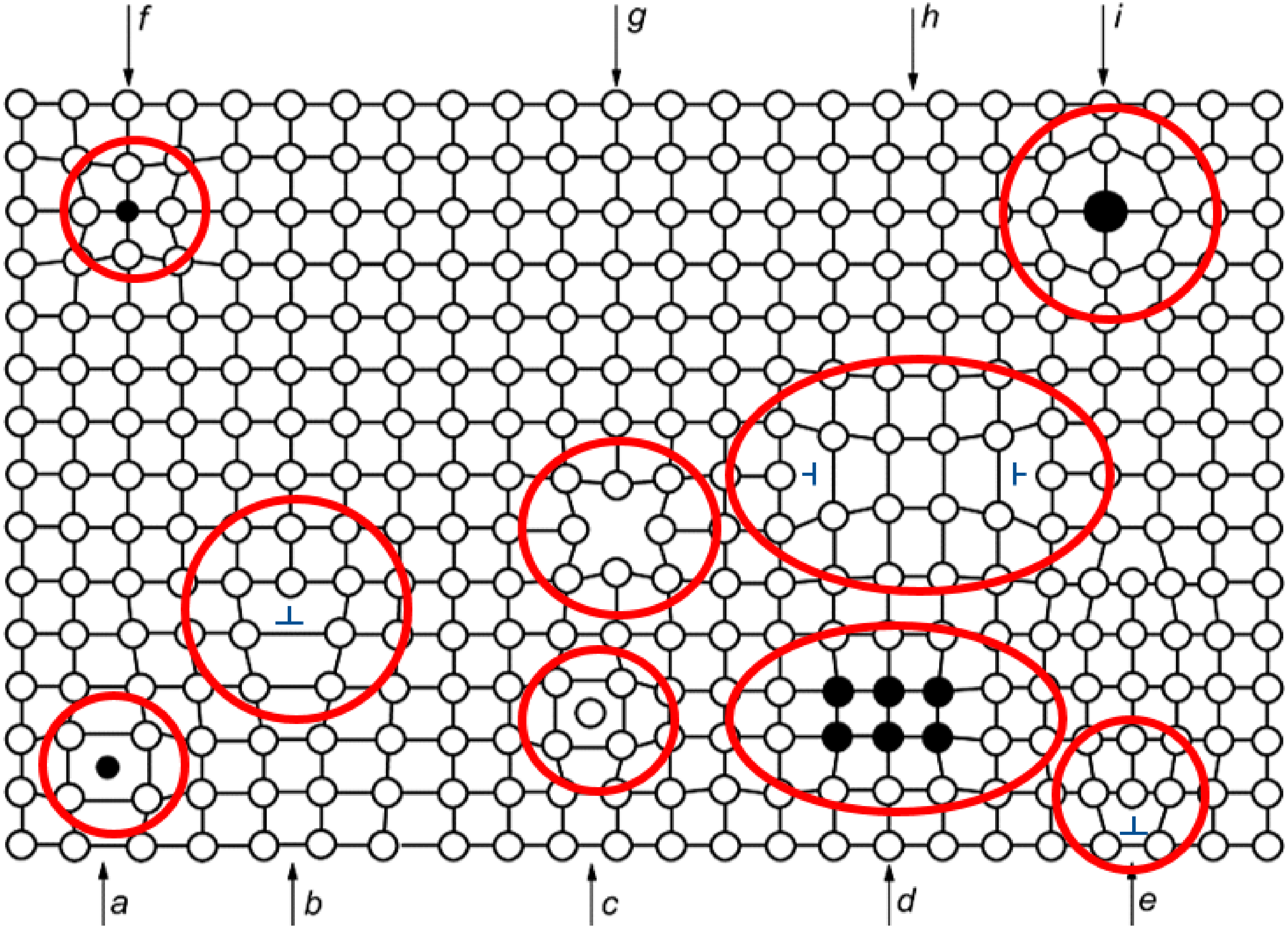
Volume or Bulk Defects

Impurity atoms cluster

- 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.



Summary of Crystal Defects



Summary of Crystal Defects

From the figure, Crystal Defects can be summarized as follows:

a) Impurity interstitial
b) Dislocation
c) Self-interstitial
d) Cluster of impurity atoms
e) Extrinsic dislocation loop
f) Small substitutional impurity
g) Vacancy
h) Intrinsic dislocation loop
i) Large substitutional impurity

The End

But Wait!!!

Next week:

<u>Quiz before lecture</u>

The End

For Real!!!