Surface and Volume defects

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Surface Defects

Area of distortional lie on surface which have negligible thickness compared to other two dimensions of the surface.

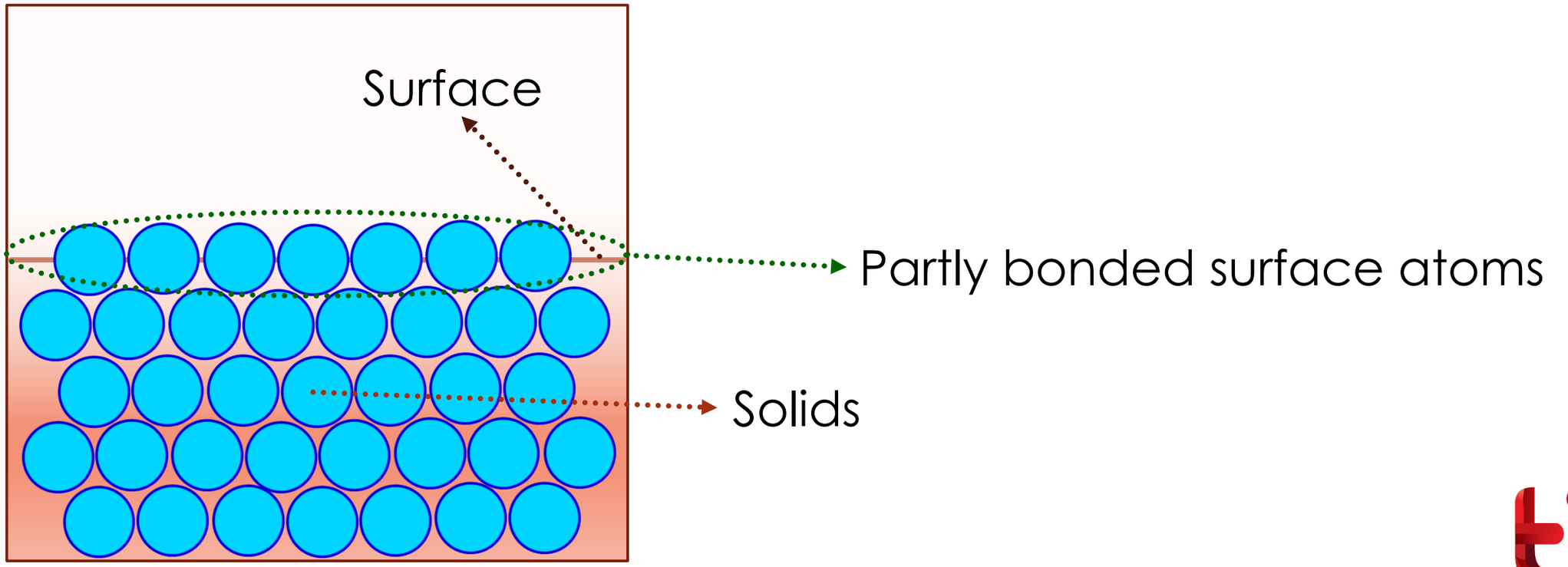
These defects are thermodynamically unstable and are present as metastable defects. Means under suitable condition these defects can be removed.

- Types of Surface Defects:
  - Free surfaces
  - Grain boundaries
  - Twin boundaries
  - Stacking faults

Surface defects normally divide regions of the materials with different crystal structures and/or crystallographic orientations

Free surfaces

- Free surfaces are also known as external surfaces.
- Formed during the growth of crystal when stopped abruptly at the surface.
- Atoms in the free surfaces of solids (or even liquid) have no neighbours and have no cohesive-bonds on one side.



Grain boundary

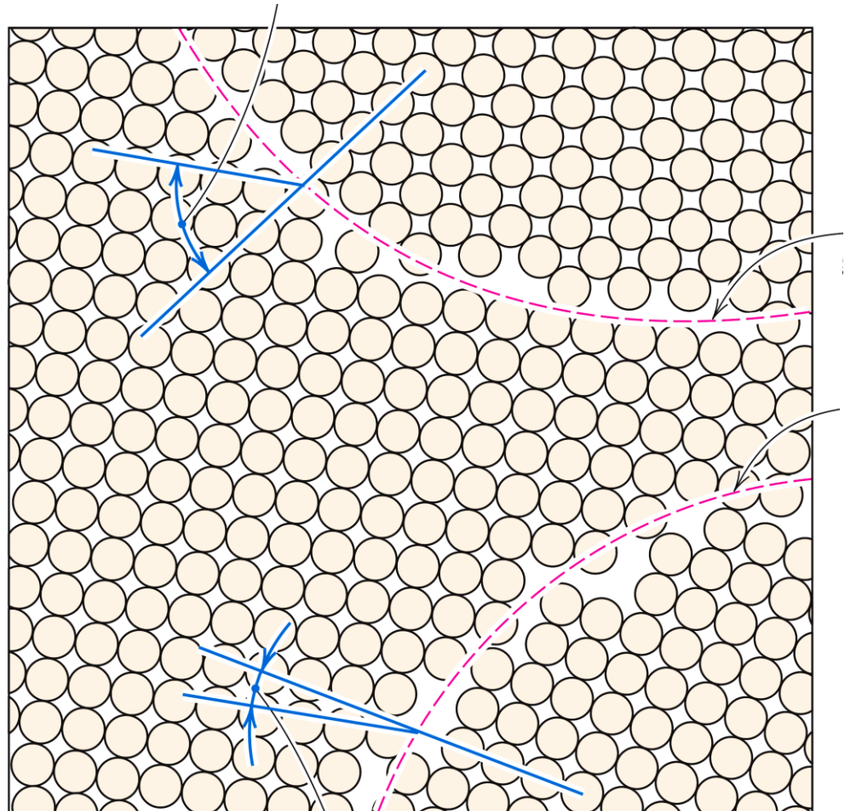
In a single phase polycrystalline material, a grain boundary is a two dimensional surface, which separate two regions with respect to there orientation of their crystal axes. Grain boundaries have disorder structure.

Classification based on difference in orientation

1. Low angle boundaries: difference in orientation is between adjacent grain is less than ~ 10°.

2. High angle boundaries: two adjacent grains have orientation difference more ~ 10° , very large.

Angle of misorientation



High-angle grain boundary

Small-angle grain boundary

Grain boundary

Low angle grain boundaries are boundaries between adjacent grains of same crystal structure, but with small difference in orientation. These boundaries might be considered to have an array of parallel dislocations (along the plane of the boundary)

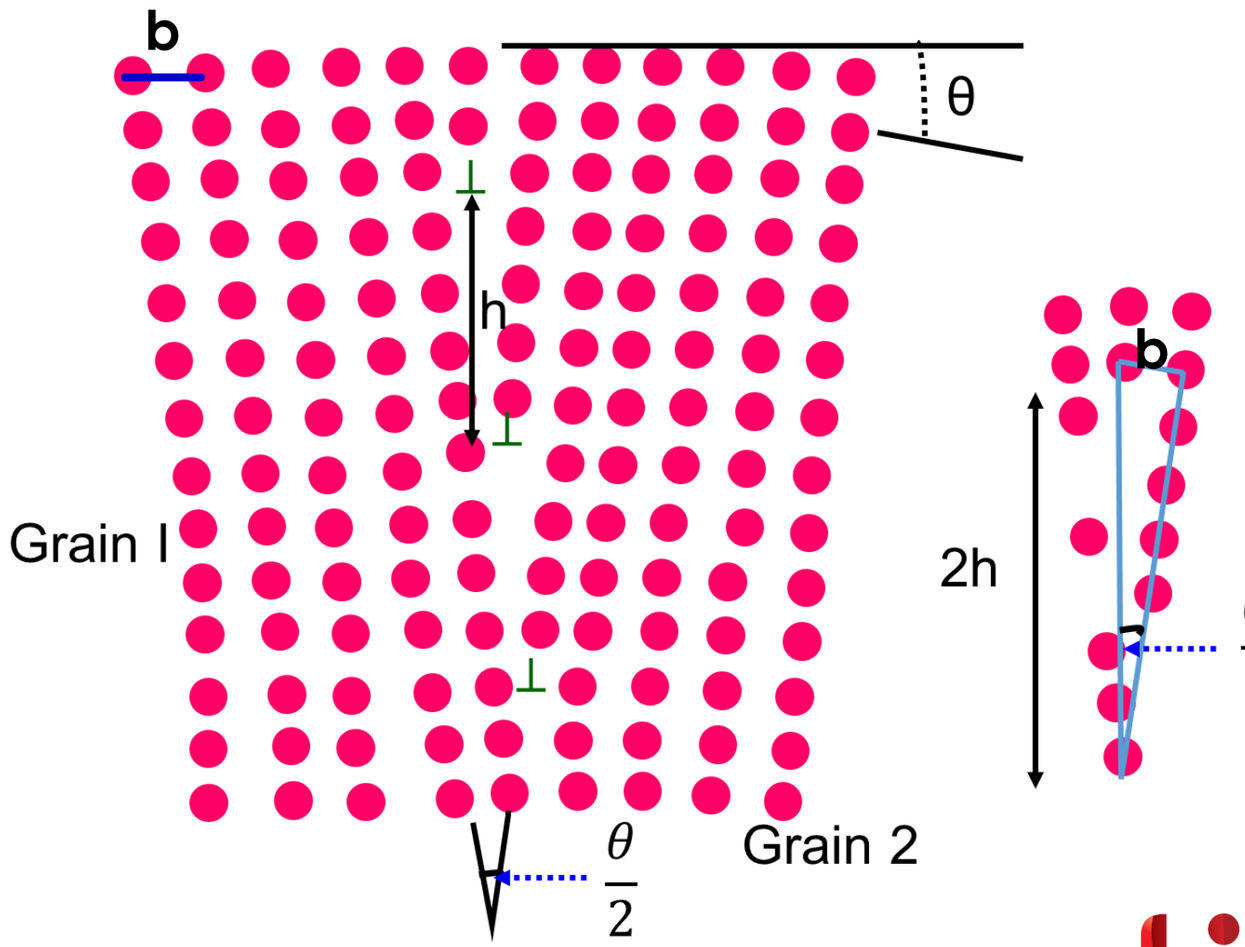
Here theta (θ) is the angle of misorientation or angle of tilt

$$\tan\frac{\theta}{2} = \frac{b}{2h}$$

Where b is the Burgers vector of dislocation in the boundary and h is the spacing between the two adjacent dislocation.

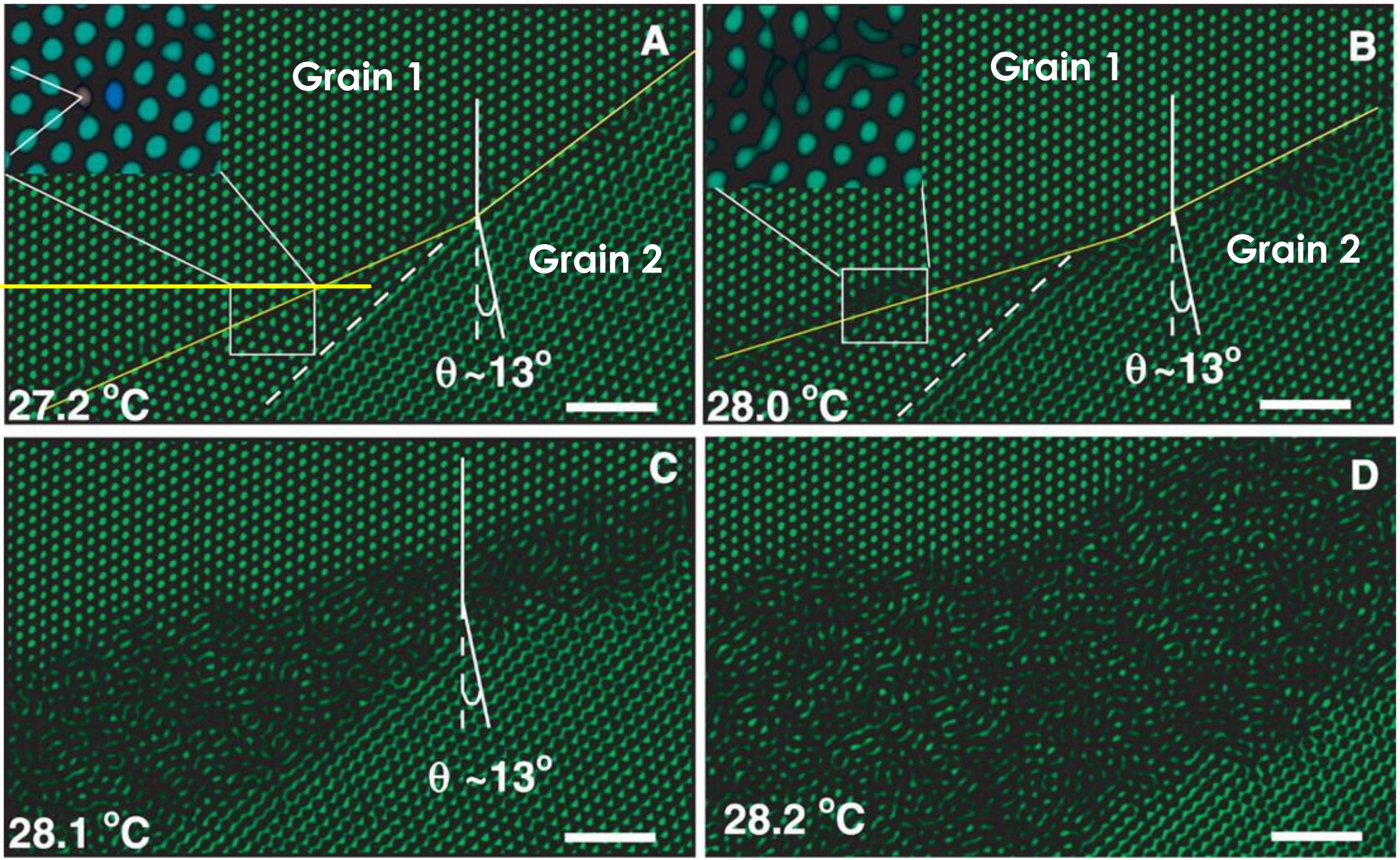
The angle of tilt is very small, it means $\tan\frac{\theta}{2} = \frac{\theta}{2}$ and

$$\theta = \frac{b}{h}$$



Grain boundary

Grain boundary

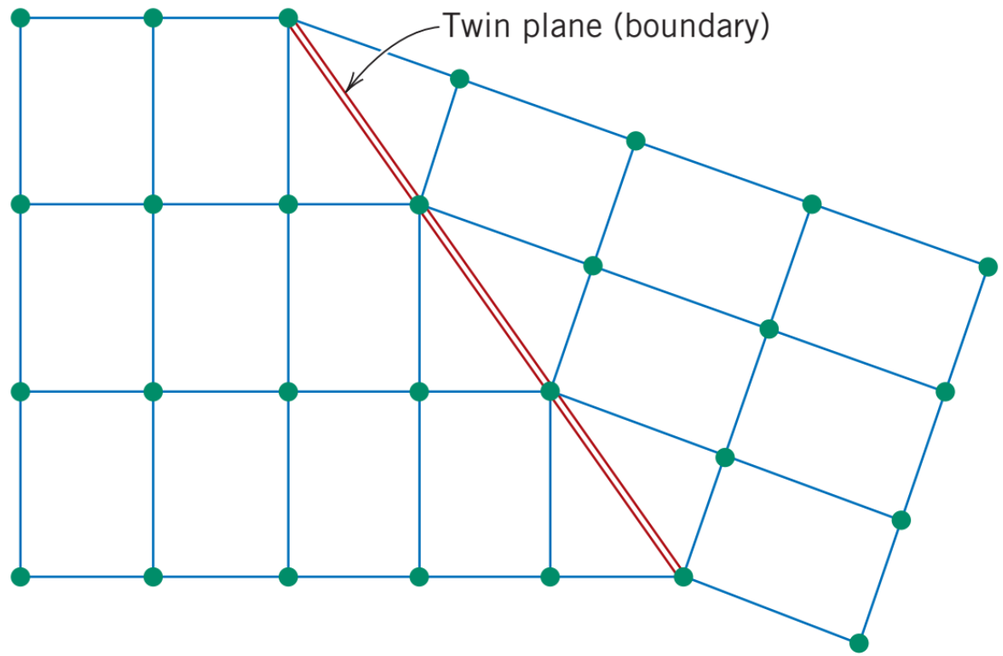


Twin boundary

- These are the boundaries in the grains at which the atomic arrangement on one side of the boundary is mirror image of atoms on the other side.

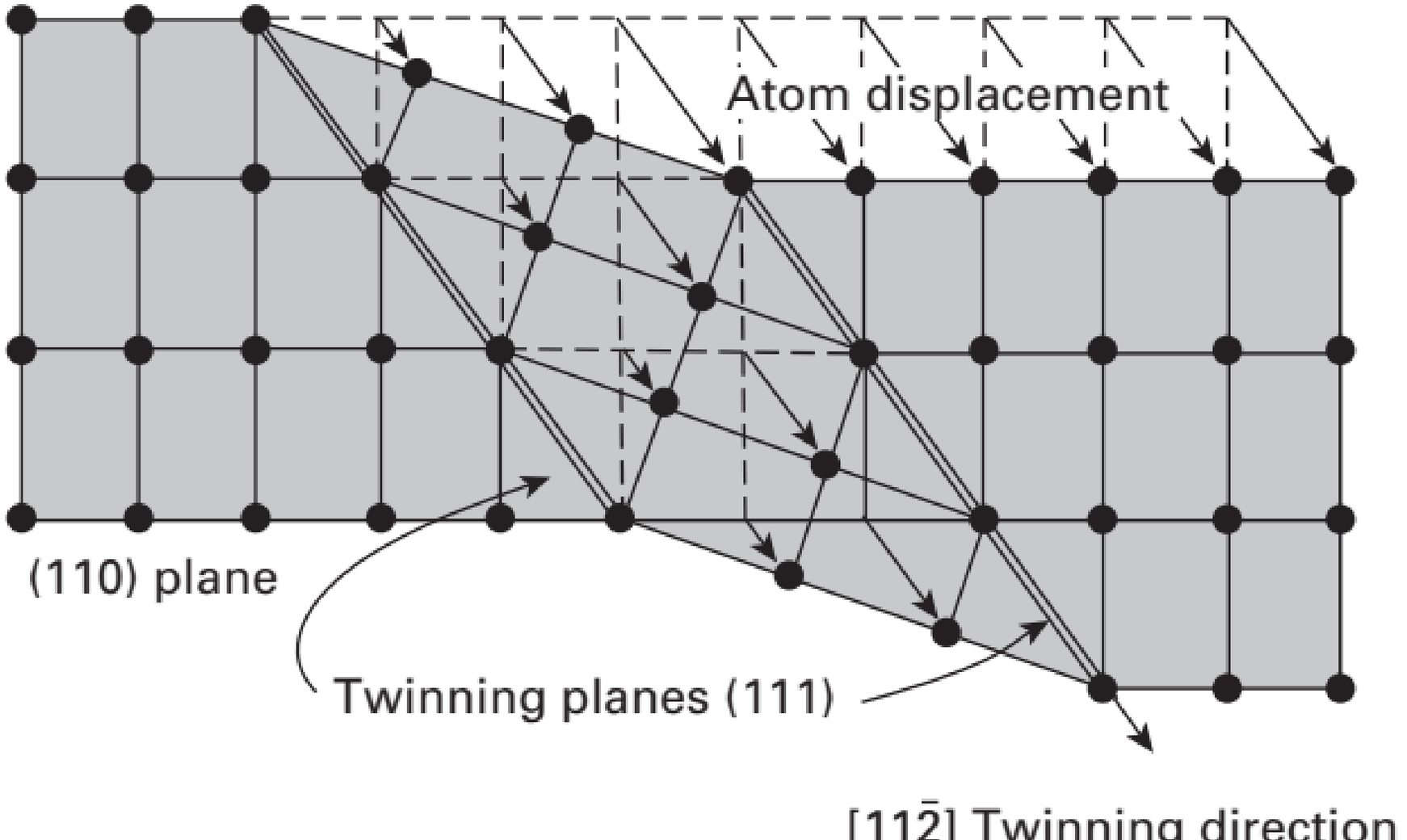
- Twins are occur in pairs. If change in orientation (of atoms) introduced by one boundary, then it is restored by the other boundary. The region between the pair of boundaries is called the twinned region.

- Twins are formed during deformation i.e. plastic deformation. They are called deformed twins.

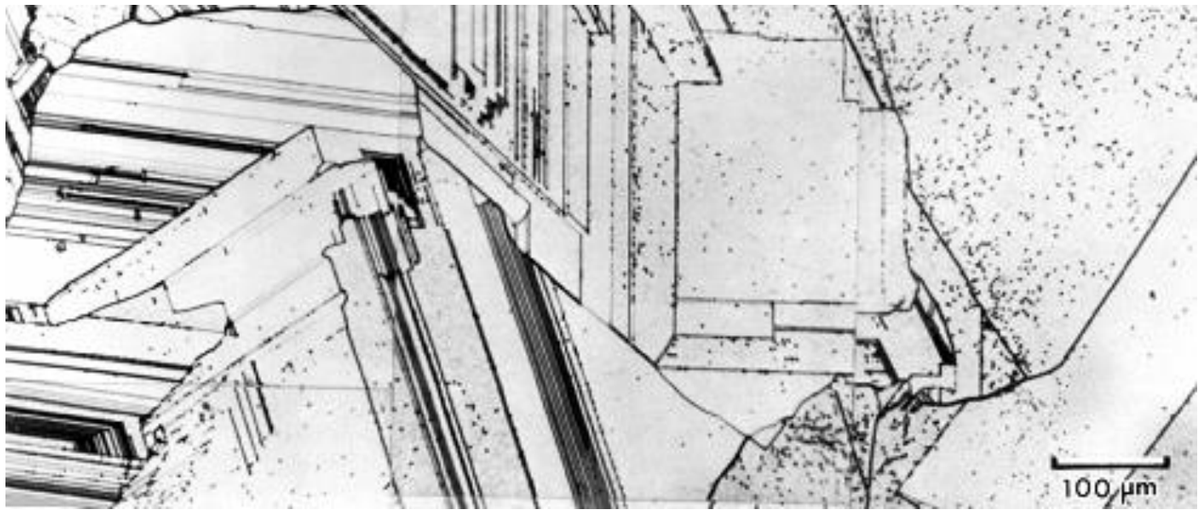


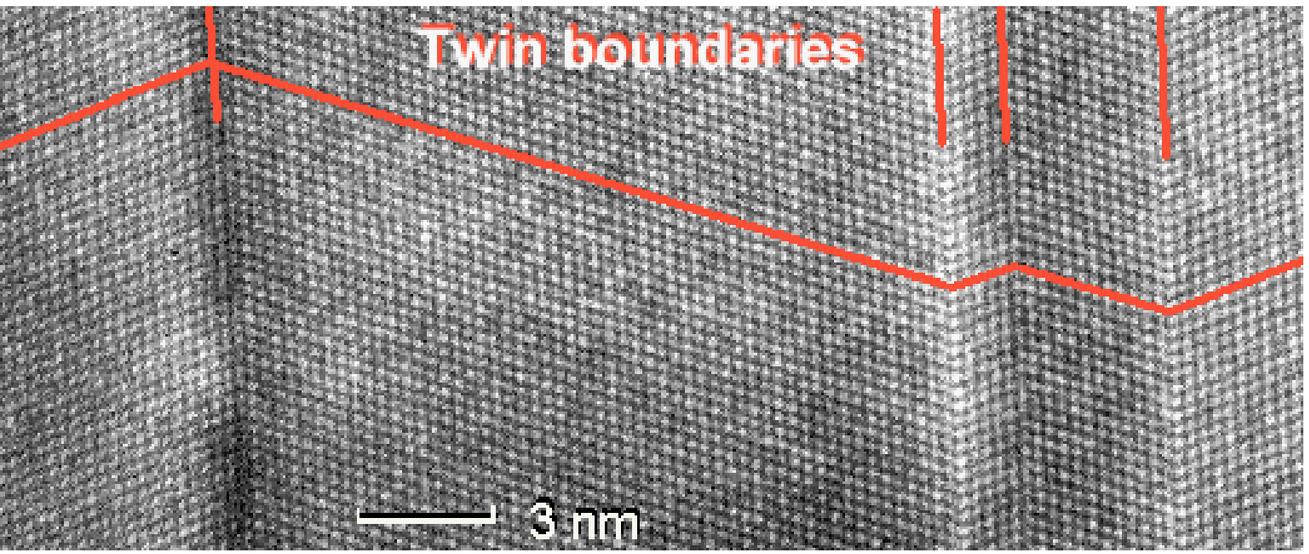
Twin boundary

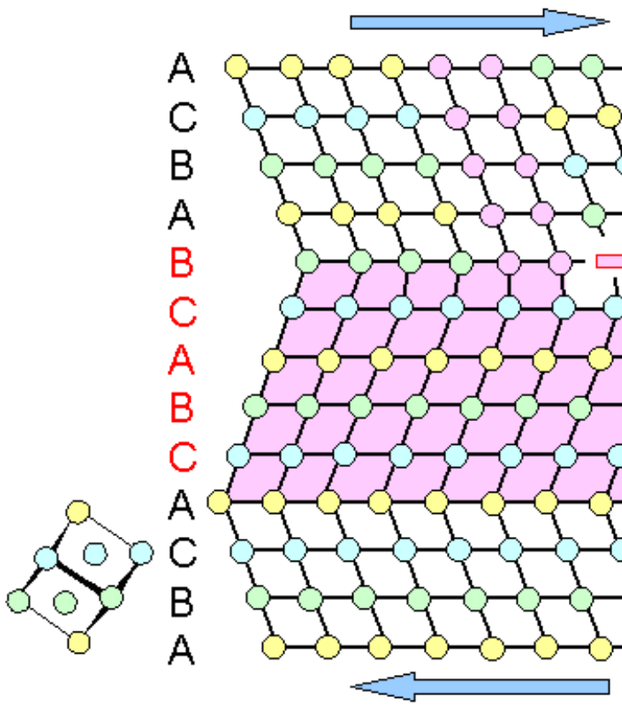
Twinning in FCC metals



Twin boundary







Stacking Fault

- Formed by fault (mistake) in the stacking sequence of atomic planes in crystals.
- These defects can produced by plastic deformation or by collapse of a large number of vacancies on one plane.
- Considering stacking arrangement in FCC

A B C A B C A B C A B C A B C

A is missing here

A B C A B C B C A B C A B C

Stacking Fault

- This thin region is a surface defect and is called stacking faults.

Intrinsic Stacking Fault

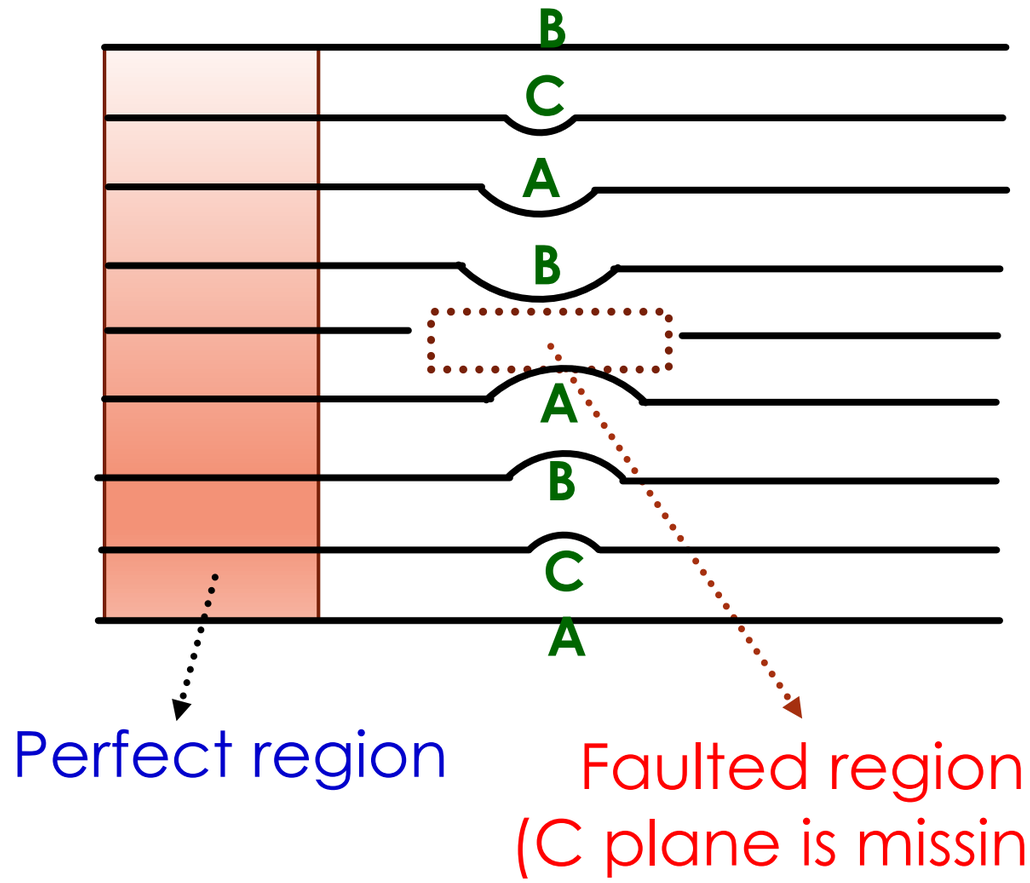
This is formed by vacancy agglomeration and there is a missing plane with sequence, for example

Missing Plane (C)

ABC ABC ABC ABC ABC

ABCABC AB ABC ABC

Here we see the four layers of an HCP stacking sequence in stacking fault in the FCC stacking sequence.



Intrinsic Stacking fault

Extrinsic Stacking Fault

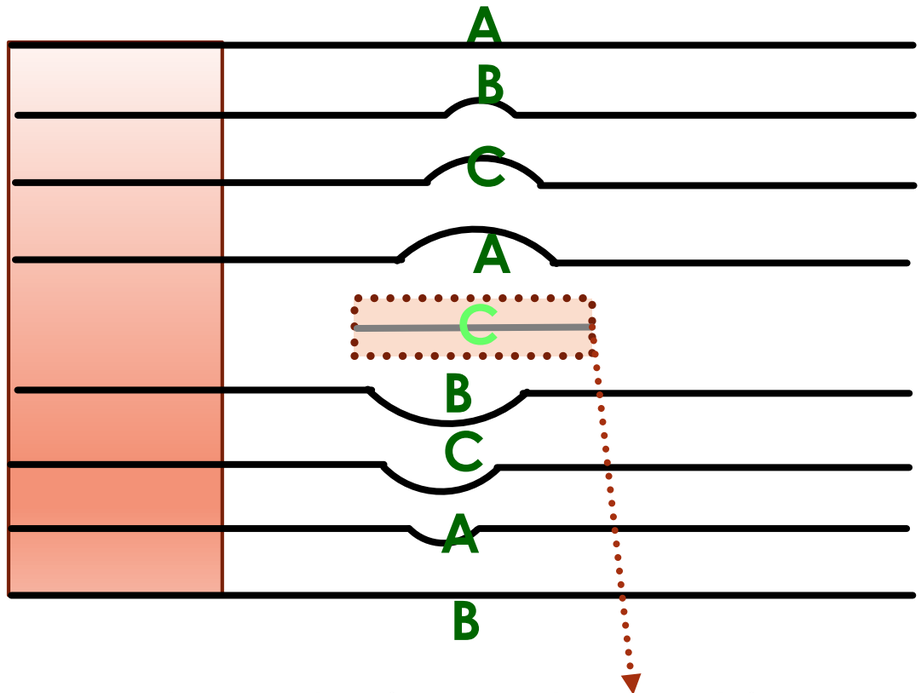
This is formed from interstitial agglomeration, where there is an extra plane with sequence, for example

Extra plane added (C)

ABC ABC ABC ABC ABC

ABC ABC ACBC ABC ABC

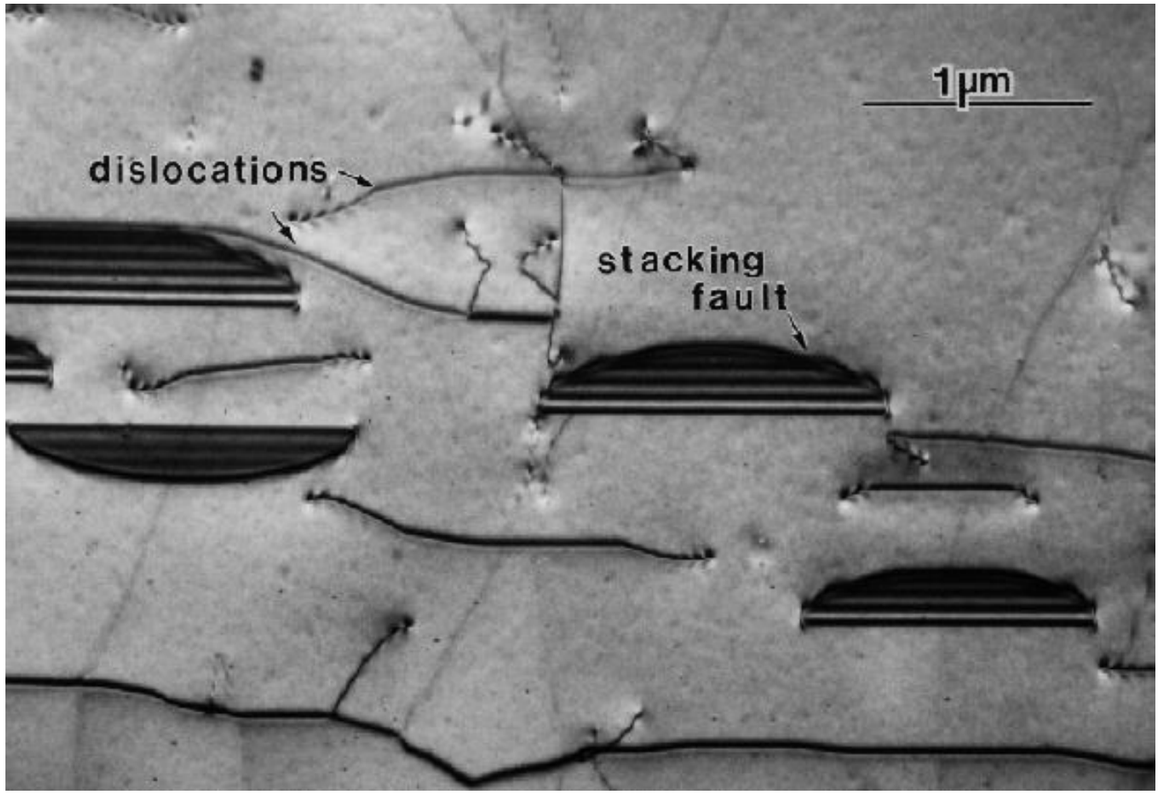
The three layers ACB constitute a twin (of BCA). Thus extrinsic stacking fault in FCC crystal is also called twin stacking.

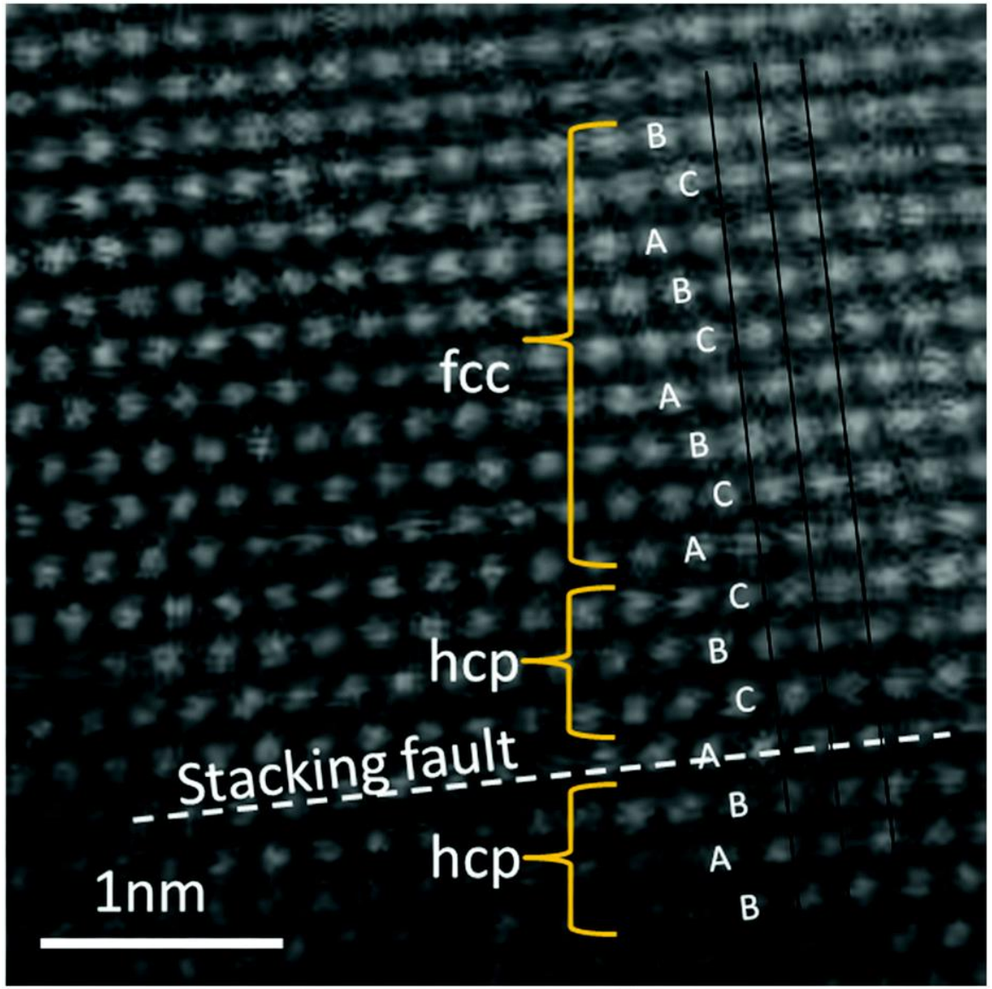


Two breaks introduced into stacking sequence (extra C plane is added)

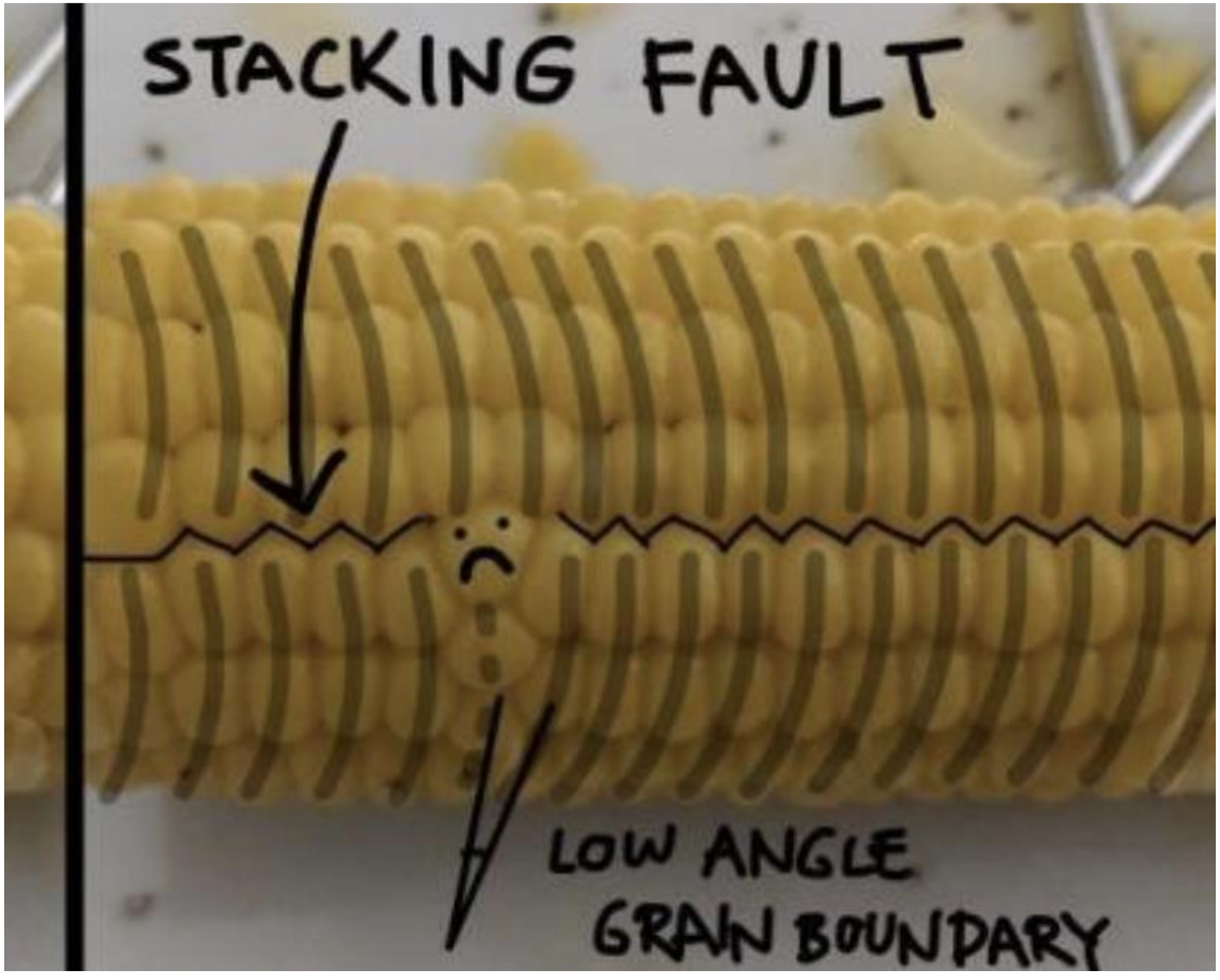
Extrinsic Stacking fault

Stacking Fault





Stacking Fault

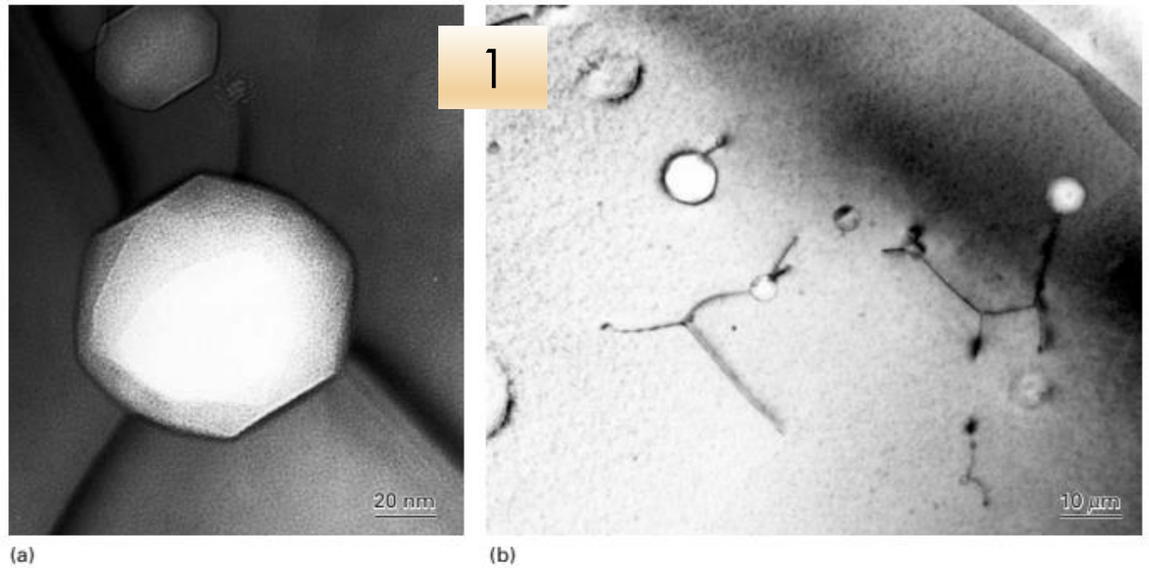


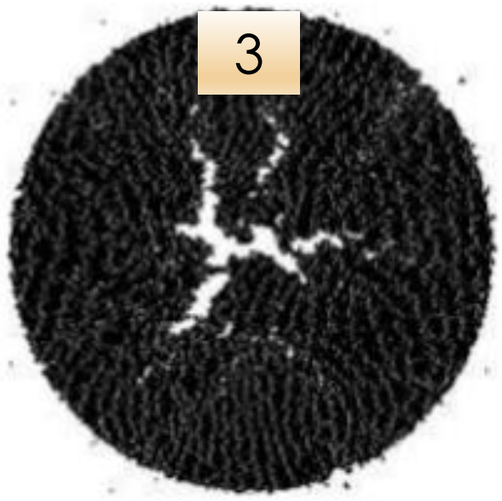
Three Dimensional Defects: Bulk or Volume defects

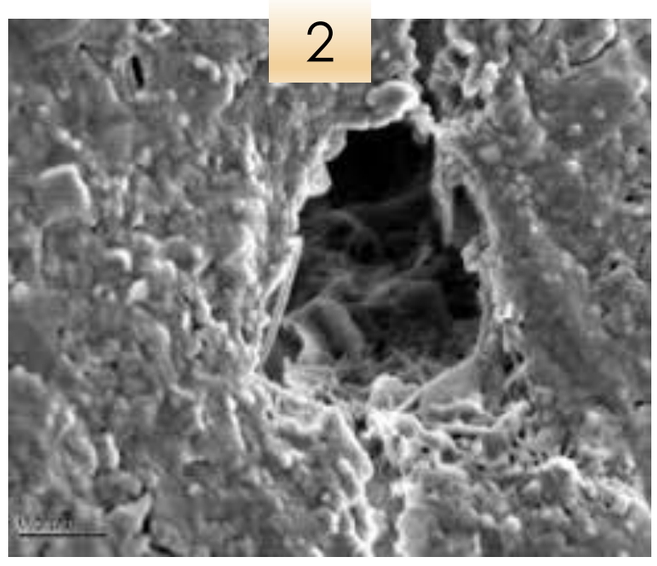
These defects form during manufacturing processes for various reasons and are harmful to the materials

Common 3-D defects

1. Precipitates
2. Voids
3. Pores (Porosity)
4. Inclusions
5. Cracks







Summary

1. All free surfaces are kind of a defect.
2. In low angle grain boundary, the misorientation angle is less then 10º.
3. In high angle grain boundary, the misorientation angle is greater then 10º.
4. Stacking fault formed by missing a plane.

Assignments

1. The small angle boundary in FCC copper is due to extra (100) planes of atoms as edge dislocations. If the angle of disorientation is 1°, what is the distance between two neighboring edge dislocations? Given lattice parameter for Cu = 3.62 Å.
2. Calculate the spacing between dislocation in a low angle tilt boundary in Iridium (FCC) when the angles of tilts are 1° and 3°. Lattice constant of Ir is 3.84 Å.