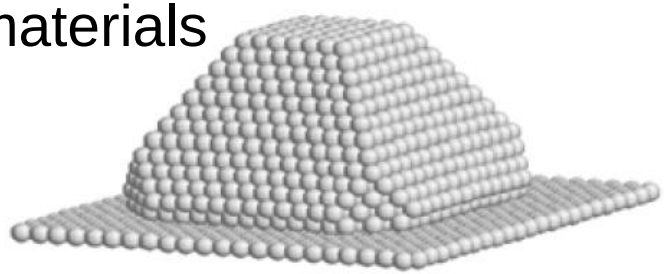
NTNU

Norwegian University of Science and Technology

# TMT4320 Nanomaterials
# August 24th, 2016

- Unique properties of Nanomaterials



# Unique properties-Learning objectives

- Defects in nanocrystalline materials (day 2)
- Effect of grain size on physical properties (melting point, elastic constants, diffusivity, magnetic, electrical, optical and thermal properties)-(day 3)
- Effect of grain size on mechanical properties (hardness, yield strength, ductility, toughness and creep) – (day 4)
- Grain growth behaviour in nanomaterials- (day 5)

# Microstructure and defects

Introduction

If we are able to arrange atoms in graphite we could make diamonds!

# Microstructure and defects

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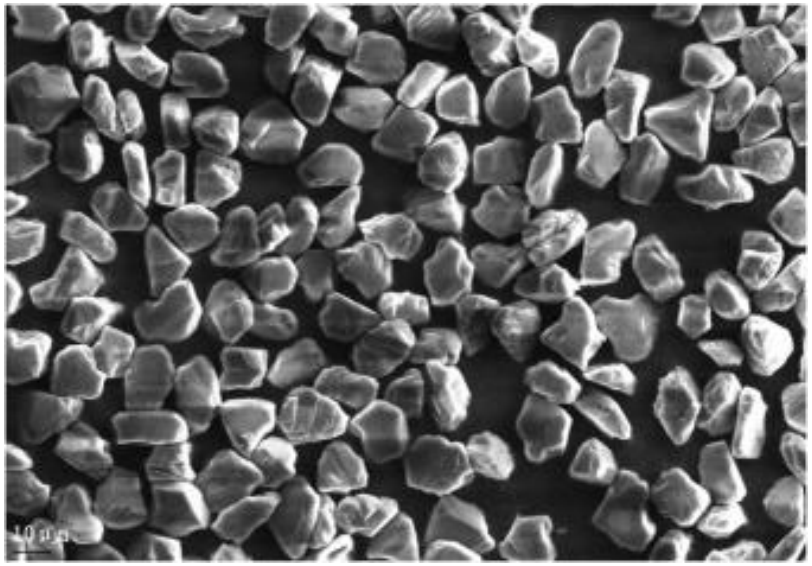
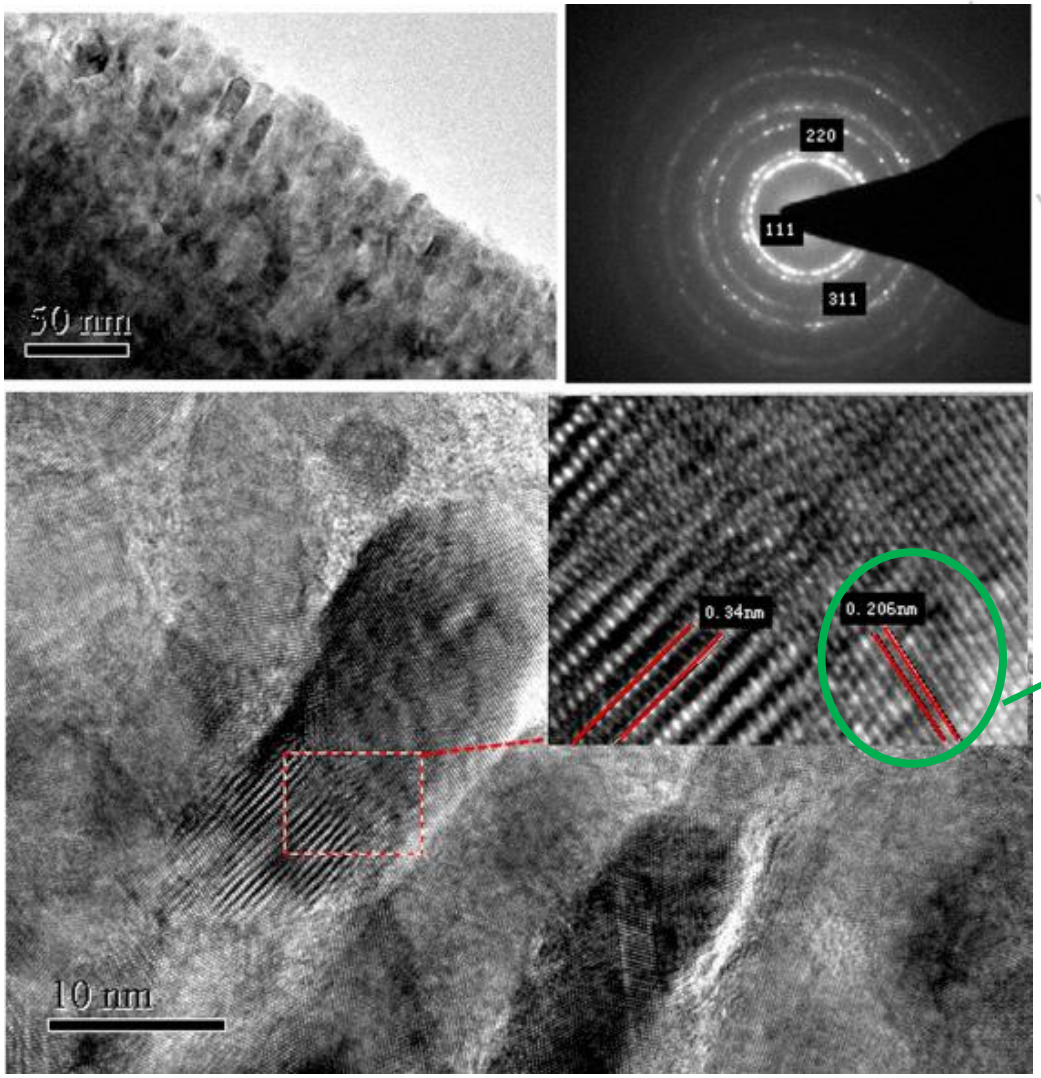


SEM (left) photograph of synthetic fine diamond particles.

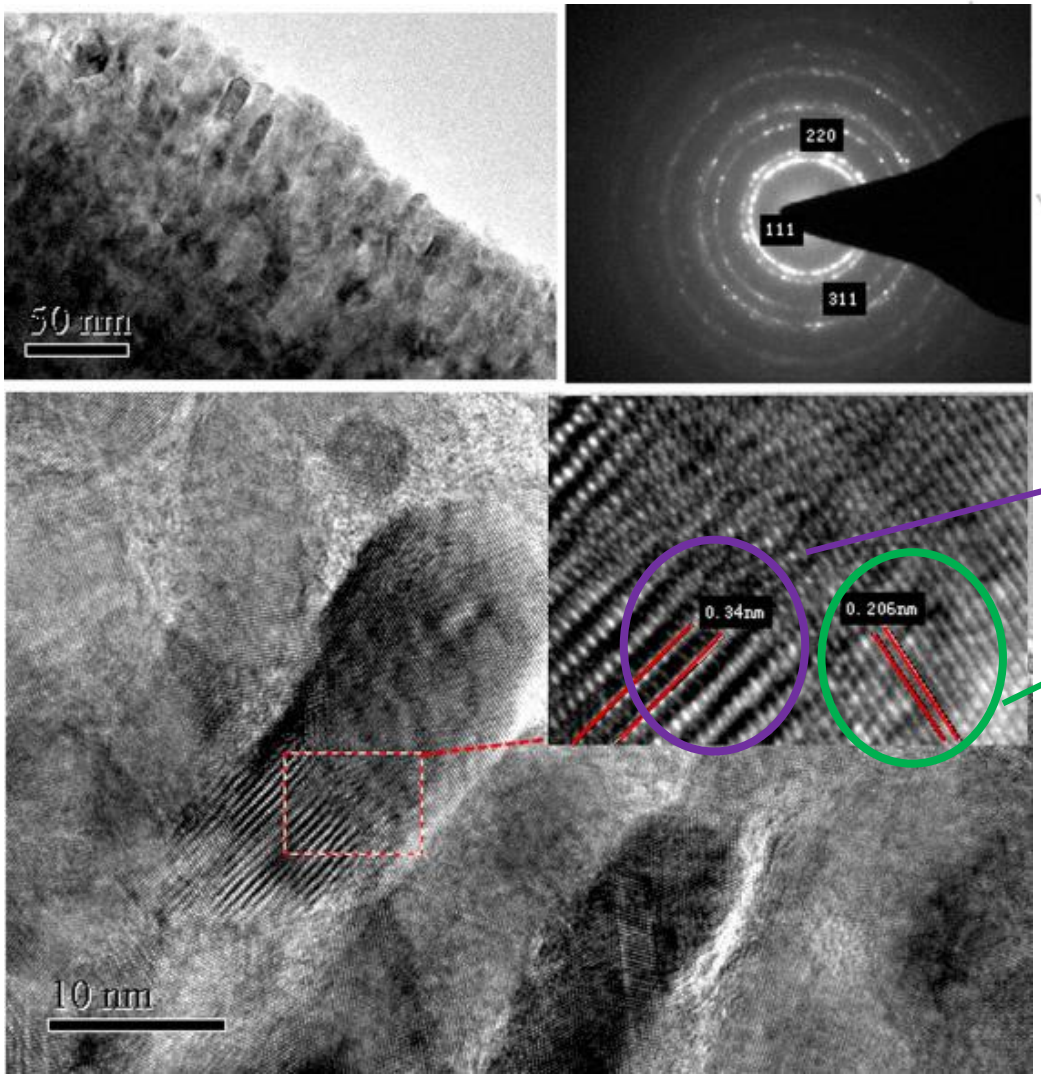
# Microstructure and defects




(111) plane of diamond.

HRTEM image of synthetic fine diamond particles.

# Microstructure and defects

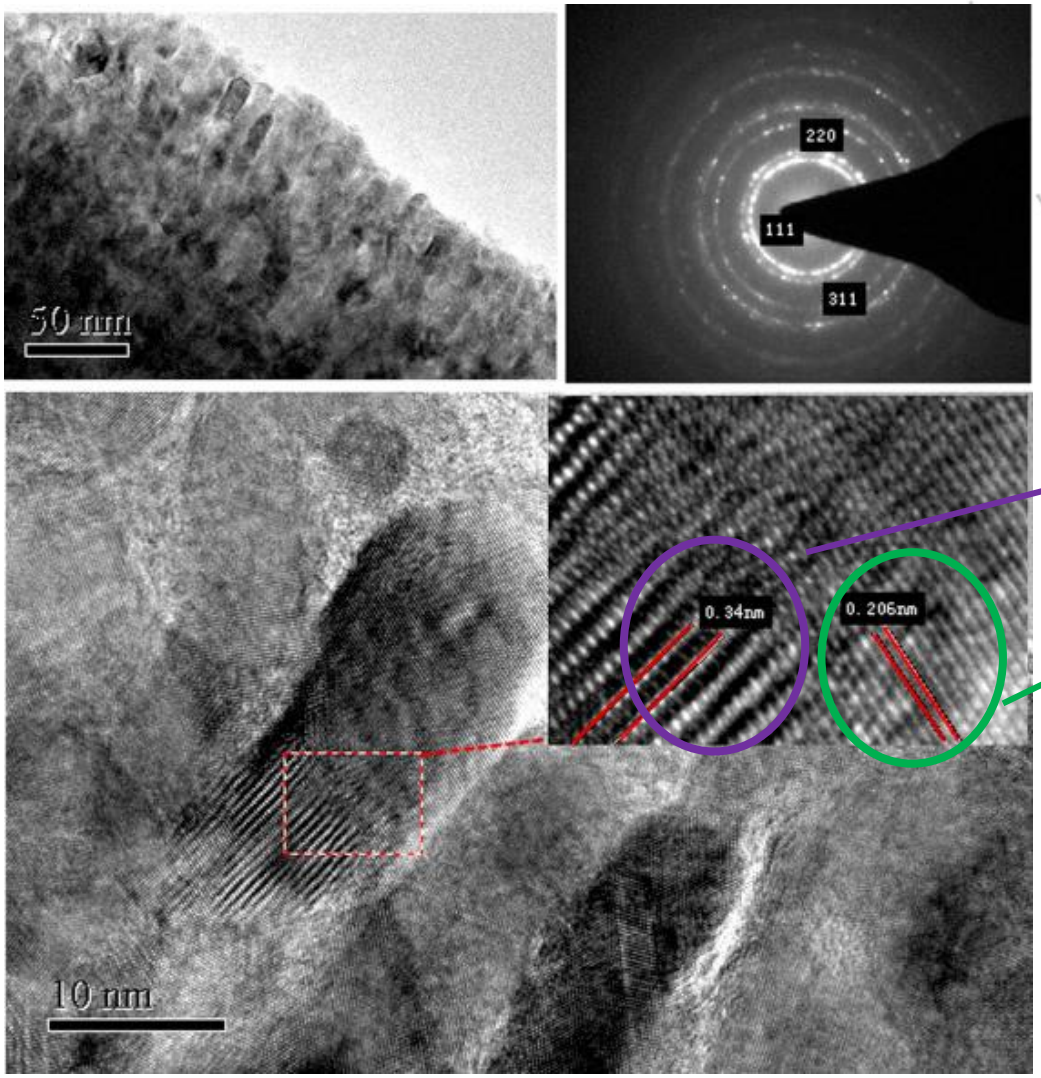



(002) planes of graphite.

(111) plane of diamond.

HRTEM image of synthetic fine diamond particles.

# Microstructure and defects




SAED image

(002) planes of graphite.

(111) plane of diamond.

HRTEM image of synthetic fine diamond particles.

# Microstructure and defects

Introduction

Important to understand relationship between structure and properties.

Microstructural features in nanomaterials include:

- Grain size, distribution and morphology.
- The nature of grain boundaries and interphase interfaces.
- Nature of intragrain defects
- Composition profiles across grains and interfaces
- Residual impurities from processing.

# Microstructure and defects

Defects in Crystalline materials

What is a crystal?

What is a defect?

How are deffects classified?

# Microstructure and defects

Defects in Crystalline materials

What is a crystal?

– Crystals are three-dimensional, periodic arrangements of atoms/molecules in space

What is a defect?

– Defects are any imperfection that lead to a disruption of this periodicity.

How are deffects classified?

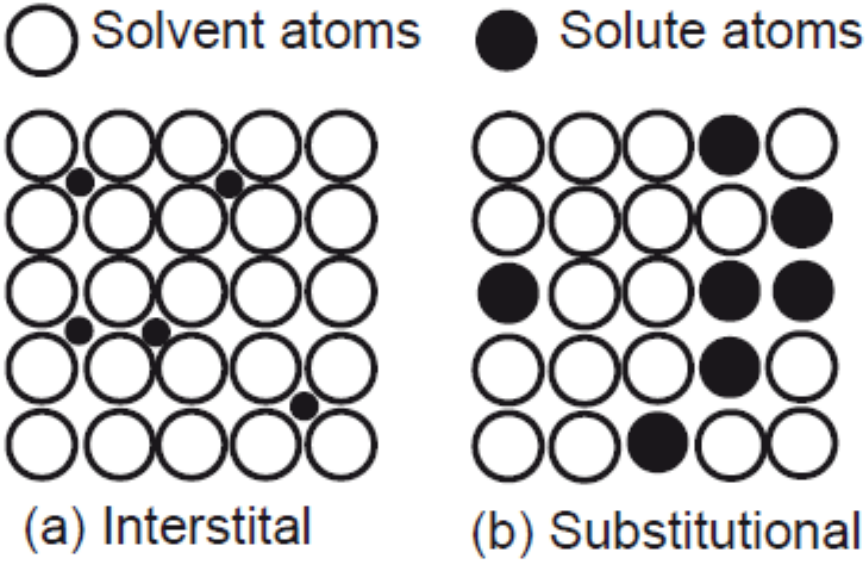
– Point deffects (0D)
– Line deffects (1D)
– Surface defects (2D)
– Volume defects (3D)

# Microstructure and defects

Defects in Crystalline materials

How are defects classified?

– Point defects (0D)
  - Metal and alloys → Vacancies, substitutional and interstitial



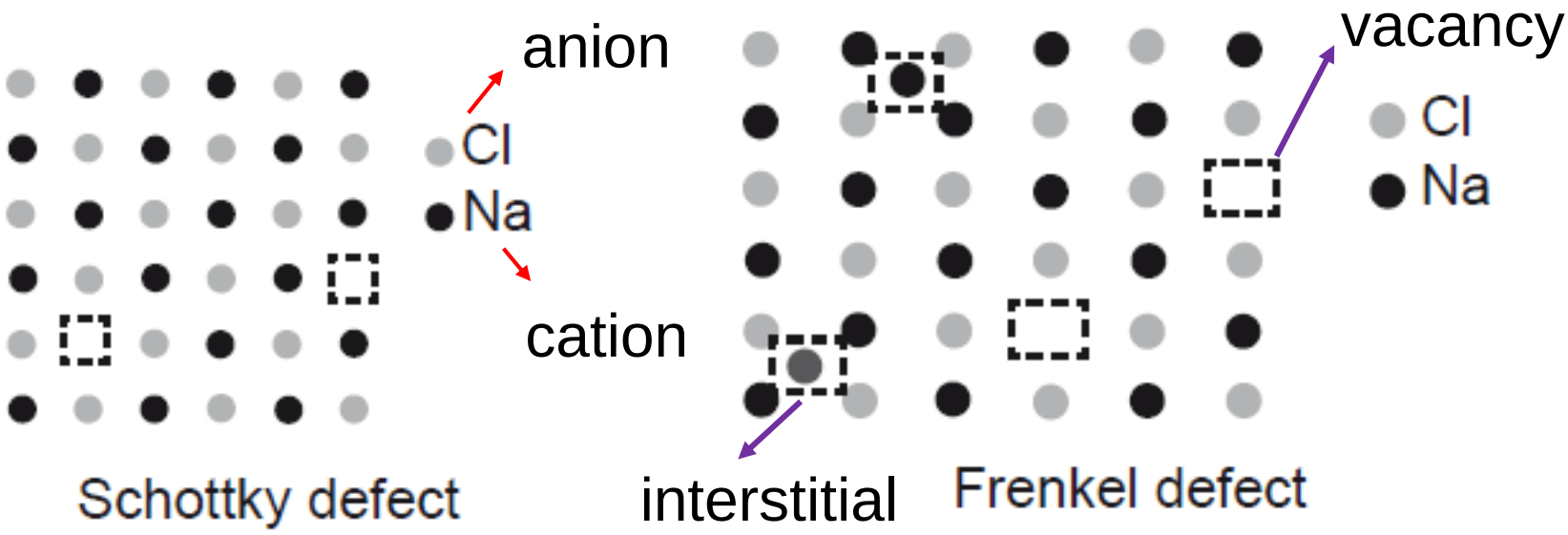

Common point defects

# Microstructure and defects

## Defects in Crystalline materials

How are defects classified?

- Point defects (0D)
  - Metal and alloys → Vacancies, substitutional and interstitial
  - Ionic solids → **Schottky** (anion-cation vacancy pairs) and **Frenkel** (vacancy-interstitial pairs) defects

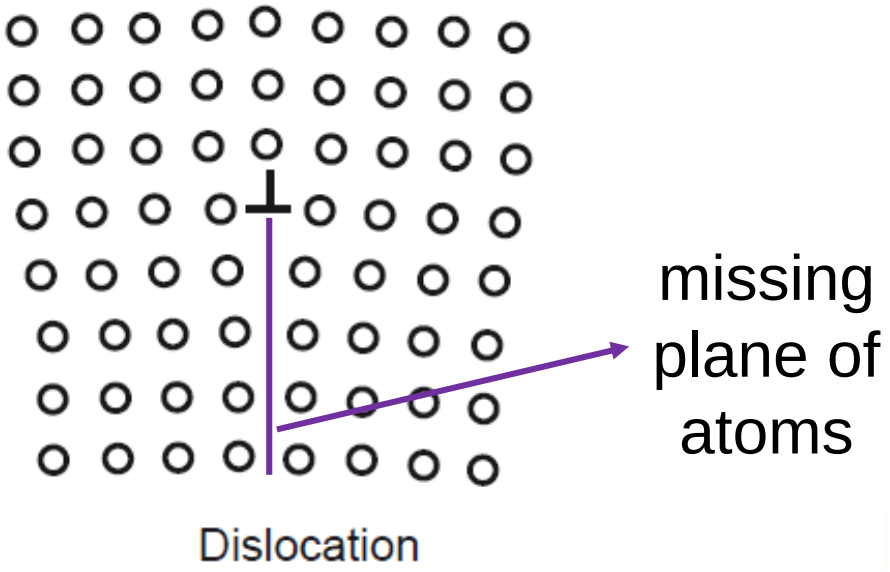


# Microstructure and defects

Defects in Crystalline materials

How are defects classified?

- Point defects (0D)
- Line deffects (1D)
  - Dislocations: missing plane of atoms



# Microstructure and defects

Defects in Crystalline materials

How are defects classified?

- Point defects (0D)
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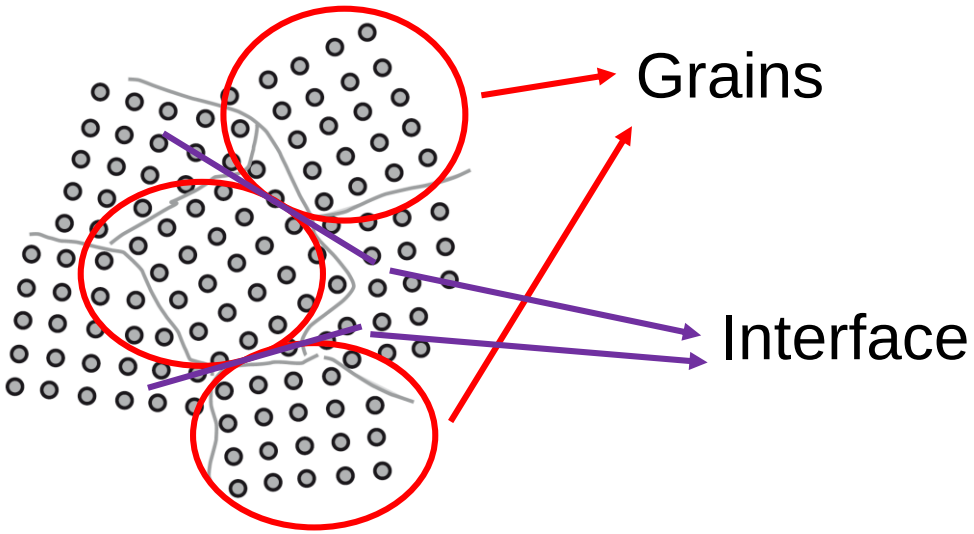
- Surface defects (2D)
  - Grain boundaries, twins and stacking faults




Grain boundaries

**Grain boundary (GB):** the interface between two grains, or crystallites, in a polycrystalline material

# Microstructure and defects

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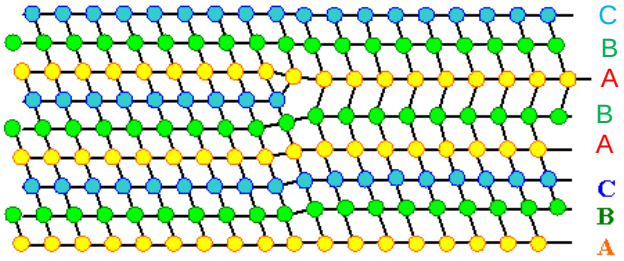


Stacking faults

**Stacking fault:**
Incorrect stacking of crystal planes associated with the presence of partial dislocations

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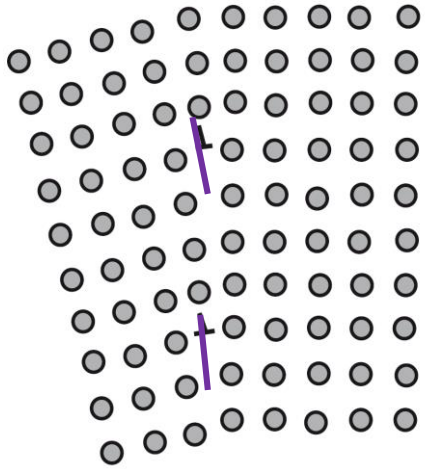

Twin boundary

**Twin boundary:** A slight misorientation that exists between two crystals

# Microstructure and defects

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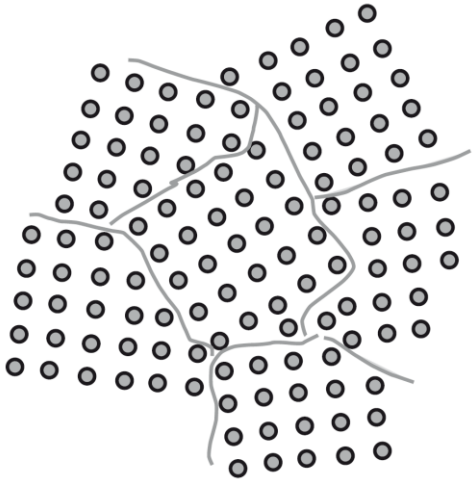
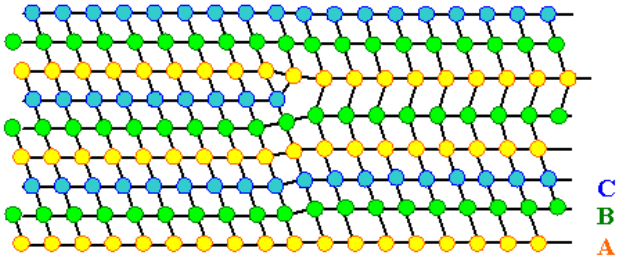
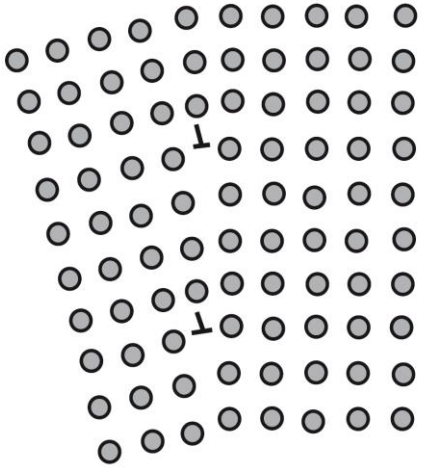


Grain boundaries




Stacking faults



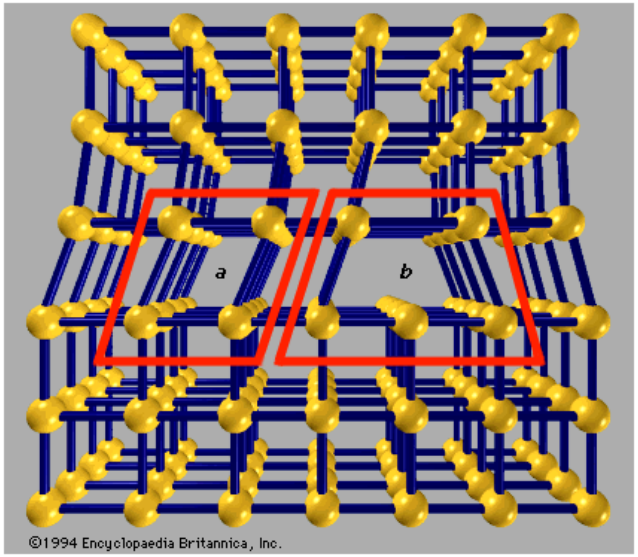
Twin boundary

# Microstructure and defects

## Defects in Crystalline materials

How are defects classified?

- Point defects (0D)
- Line deffects (1D)
- Surface defects (2D)
- Volume defects (3D)
  - Voids and microcracks.




**Void**: The absence of a number of atoms to form internal surfaces in the crystal

# Microstructure and defects

## Defects in Crystalline materials

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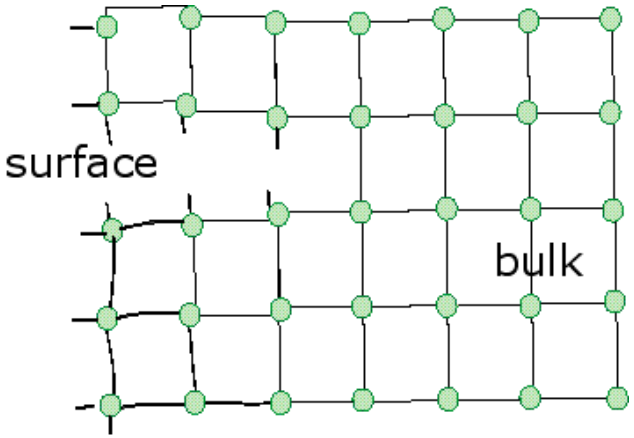


A **Microcrack** occurs where internal broken bonds create new surfaces.

# Microstructure and defects

Defects in Crystalline materials

How are defects classified?

- Point defects (0D)
  - Metal and alloys → Vacancies, substitutional and interstitial
  - Ionic solids → Schottky (anion-cation vacancy pairs) and Frenkel (vacancy-interstitial pairs) defects
- Line deffects (1D)
  - Dislocations: missing plane of atoms
- Surface defects (2D)
  - Grain boundaries, twins, stacking faults and free surfaces.
- Volume defects (3D)
  - Voids and microcracks.

# Summary

- Introduction to Nanomaterials
  - Definition of Nanomaterials
  - Introduction to properties, applications, challenges and concerns
  - Problem A

- Unique properties of Nanomaterials
  - Basic definitions
  - Classification: 0D, 1D, 2D, 3D

# Next lecture

- Defects
  - Examples
  - Problem B

- Physical properties: size effects
  - Lattice constant
  - Melting point