



University of  
South Australia

# ENR116 Engineering Materials

## Module 1 Introduction to Materials

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Welcome to ENR116 Engineering Materials Module 1



University of  
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ENR116 – Mod. 1- Slide No. 2

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# Crystalline and non-crystalline materials

Crystalline and non-crystalline materials



## Intended Learning Outcomes

**At the end of this section, students will be able to:-**

- Describe the differences between **crystalline** and **non-crystalline** materials.
- Describe some of the important **material properties** dependent on crystallinity.
- Define **diffraction** and describe how this phenomena is used to determine crystal structures.

The intended learning outcomes from this presentation are:

Describe the difference between crystalline and non-crystalline materials

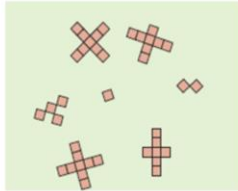
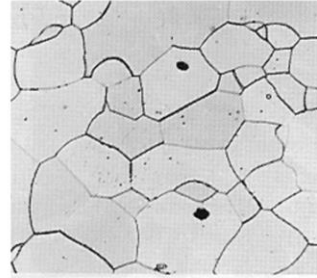
Describe some of the important material properties dependent on crystallinity

Define diffraction and describe how this phenomena is used to determine crystal structure

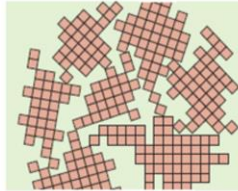


# Polycrystalline Materials

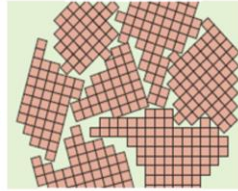
Most materials are not a single crystal.  
They are **polycrystalline** - composed of  
many small single crystal.  
Formation of a polycrystalline material:



(a) **crystallite nuclei**



(b) Growth of **grains**



(c) **Solidification** of  
irregular shaped  
grains



(d) Dark lines are  
**grain boundaries**

Adapted from Fig. 3.18, Callister & Rethwisch 8e.

Polycrystalline materials exist because small crystals grow and touch  
each other

Crystals are separated by grain boundaries



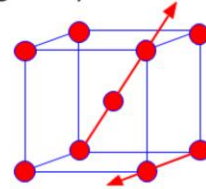
## Single vs. Polycrystals

### Single Crystals:

Properties vary with direction: **anisotropic**

Example: the modulus of elasticity ( $E$ ) in BCC iron

$E$  (diagonal) = 273 GPa



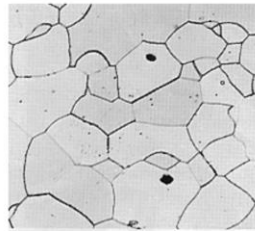
### Polycrystals:

Properties may/may not vary with direction.

If grains are randomly oriented:  
**isotropic**

If grains are textured, **anisotropic**

$E$  (edge) = 125 GPa



Adapted from Fig. 4.14(b), *Callister 7e*.  
(Fig. 4.14(b) is courtesy of L.C. Smith and C. Brady, the National Bureau of Standards, Washington, DC [now the National Institute of Standards and Technology, Gaithersburg, MD].)

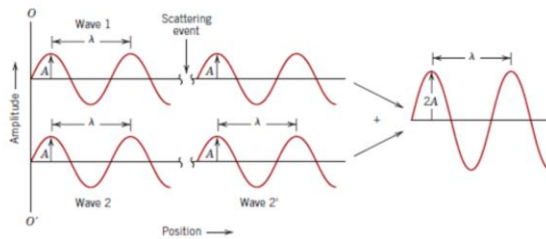
Single crystals are anisotropic

Polycrystals may be isotropic if grains are randomly oriented.

This can have a major effect on the material properties

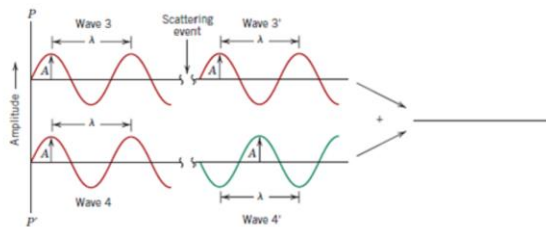


# The diffraction phenomenon



Constructive  
interference

Fig. 3.19, Callister &  
Rethwisch 8e.



Destructive  
interference

Diffraction occurs to waves after interacting with a series of regularly spaced obstacles.

If the path length difference is a multiple of the wavelength, we observe Constructive interference

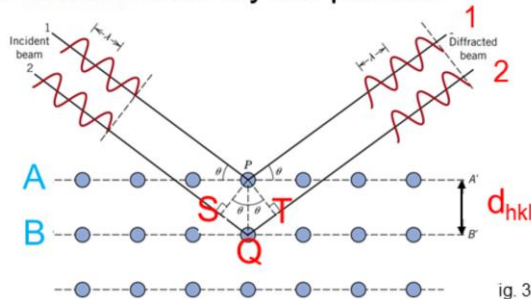
If the path length difference is an integral number of  $\frac{1}{2}$  wavelengths, we observe Destructive interference

Intermediate values of path length difference result in partial constructive interference.



# X-Rays to determine crystal structure

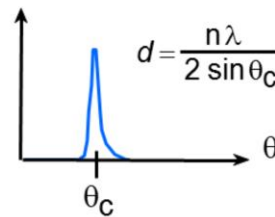
Incoming X-rays **diffract** from crystal planes.



ig. 3.20, Callister & Rethwisch 8e.

Measurement of critical angle,  
 $\theta_c$ , allows computation of  
planar spacing,  $d$

X-ray  
intensity  
(from  
detector)



X-rays are used to determine crystal structure because their wavelength is similar to atomic spacing in solids

Incoming x-rays take different paths. The path length difference for beams 1 and 2 is SQ + QT

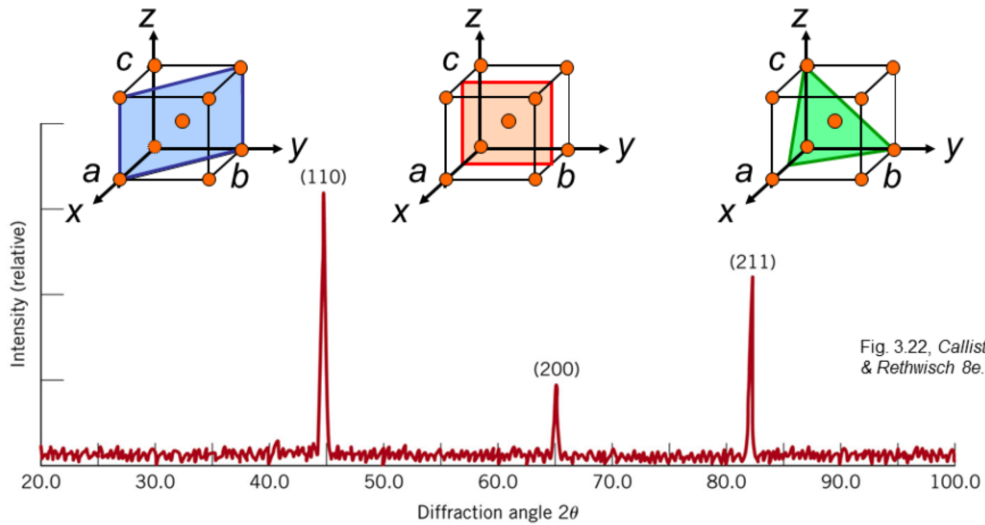
If SQ + QT is a multiple of the wavelength (Bragg's Law) then we observe Constructive interference

By changing the angle of incidence, when a peak is observed, the critical angle can be measured, and the planar spacing determined.





## X-Ray diffraction pattern



Diffraction pattern for polycrystalline  $\alpha$ -iron (BCC)

Polycrystalline iron shows 3 distinct peaks in the Diffraction pattern  
Each peak is attributed to a different crystal structure within the material.



## Summary

- **Single crystals** have atomic order extending over the entire specimen.
- Almost all crystalline materials are **polycrystalline** with **grain boundaries** separating the individual crystals.
- **Non-crystalline** materials exhibit only **short-range ordering**.

In Summary:

Single crystals have atomic ordering extending over the entire specimen

Almost all crystalline materials are polycrystalline with grain boundaries separating the individual crystals.

Non-crystalline materials exhibit only short-range ordering



**Thank you**