Chemical Engineering 378

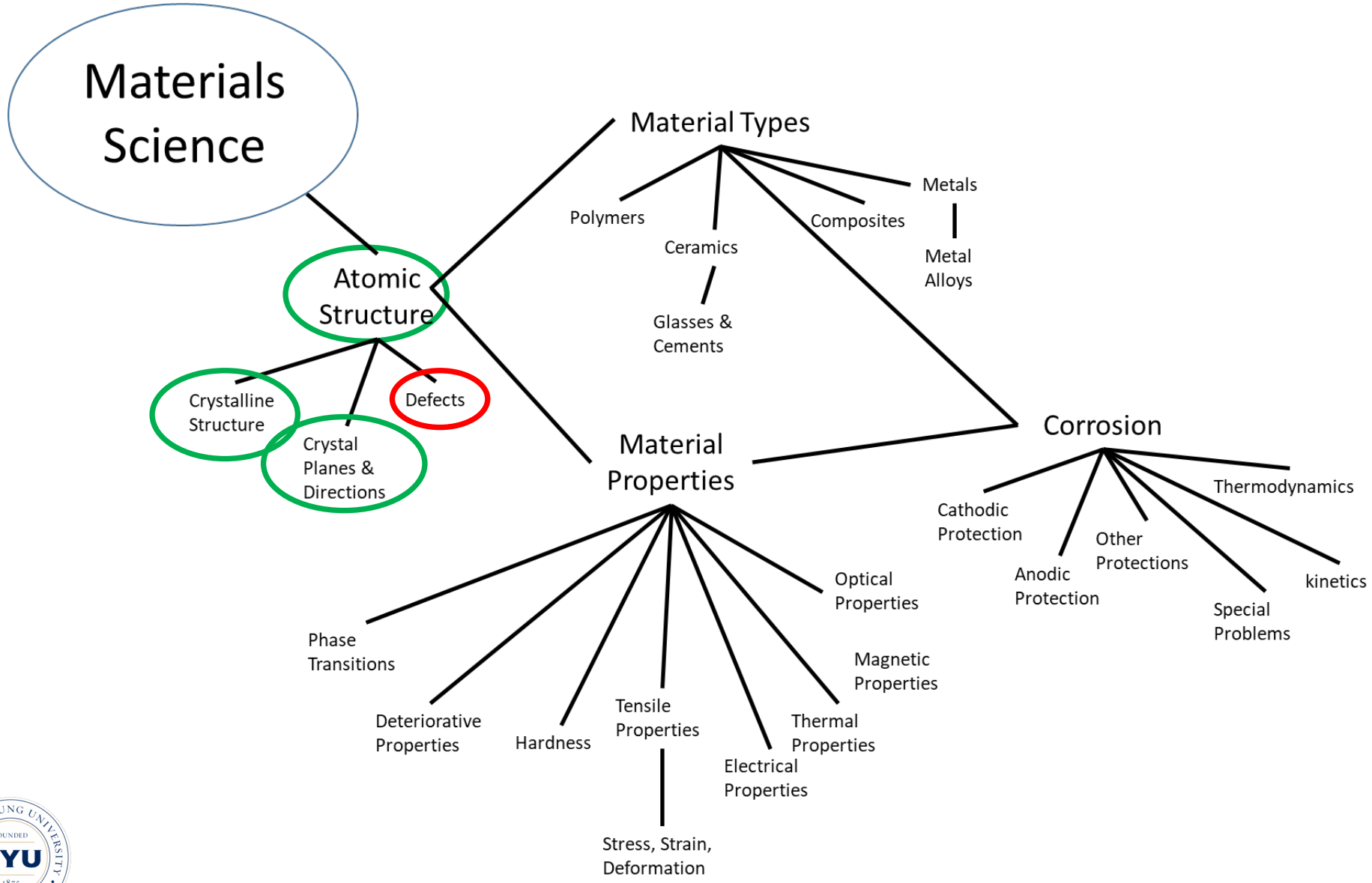
Science of Materials Engineering

Lecture 7

Dislocation Lines and Area Defects

Spiritual Thought

Materials Roadmap



OEP3

OEP3 Statement

Open Ended Problem #3 Congo
Group work okay, Due 9/22/21 at beginning of class

(Don't be afraid to "Google" for reasonable assumptions; just provide references!)

Flawless Diamonds for Lasers

Whoa… did you see those epic 1990's special effects? …cough, cough… I mean, apparently, there is a flawless blue diamond that facilitates high energy, high efficiency laser weapons, hidden in a mine deep in the African Congo! Unfortunately, this diamond mine full of blue diamonds is guarded by trained, killer, giant white gorillas. We don't really want to go there. So let's see if we NEED those diamonds. The only problem with using regular diamonds is that they must be flawless (for the sake of realities, we'll say that flawless means only 100 vacancy point defects or less per gem). At what temperature would a real diamond reach this level of perfection? After all, we really don't want to mess with those vicious white apes…

Edge Dislocation

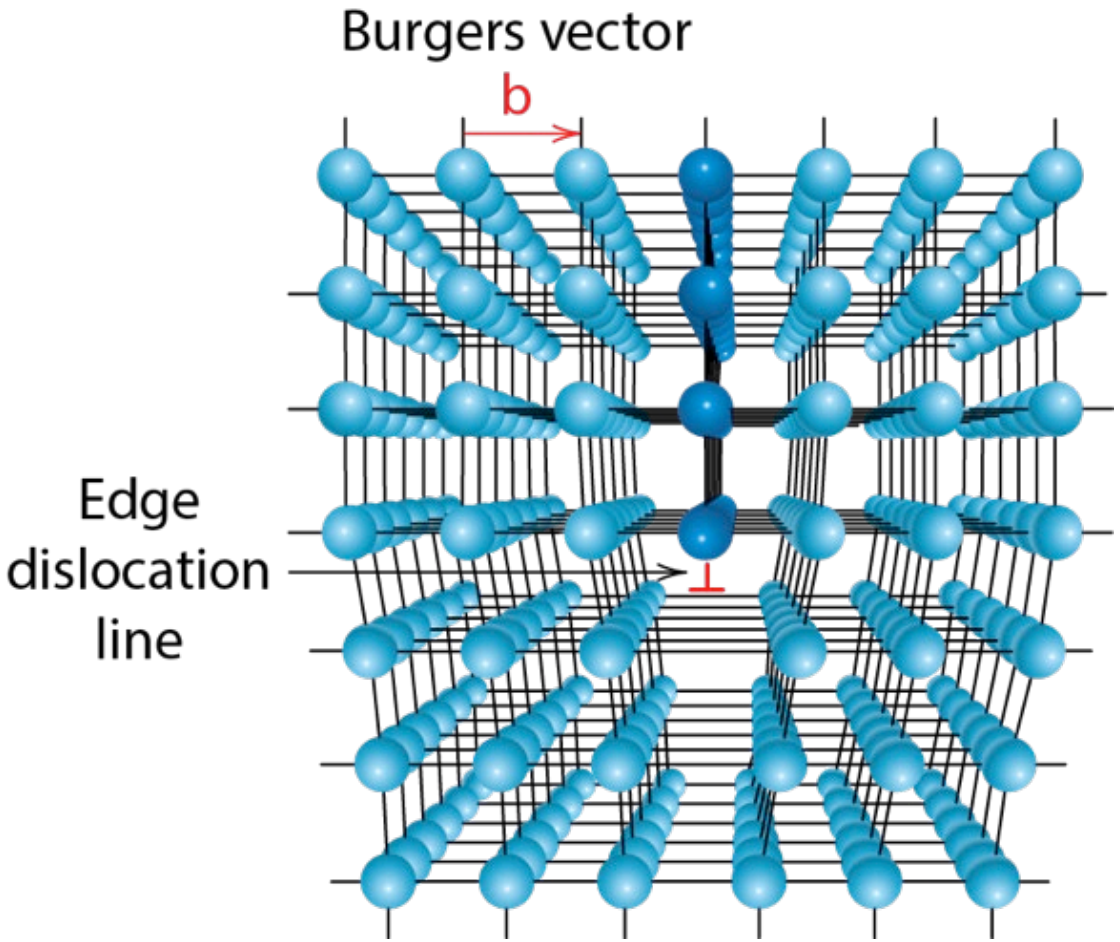
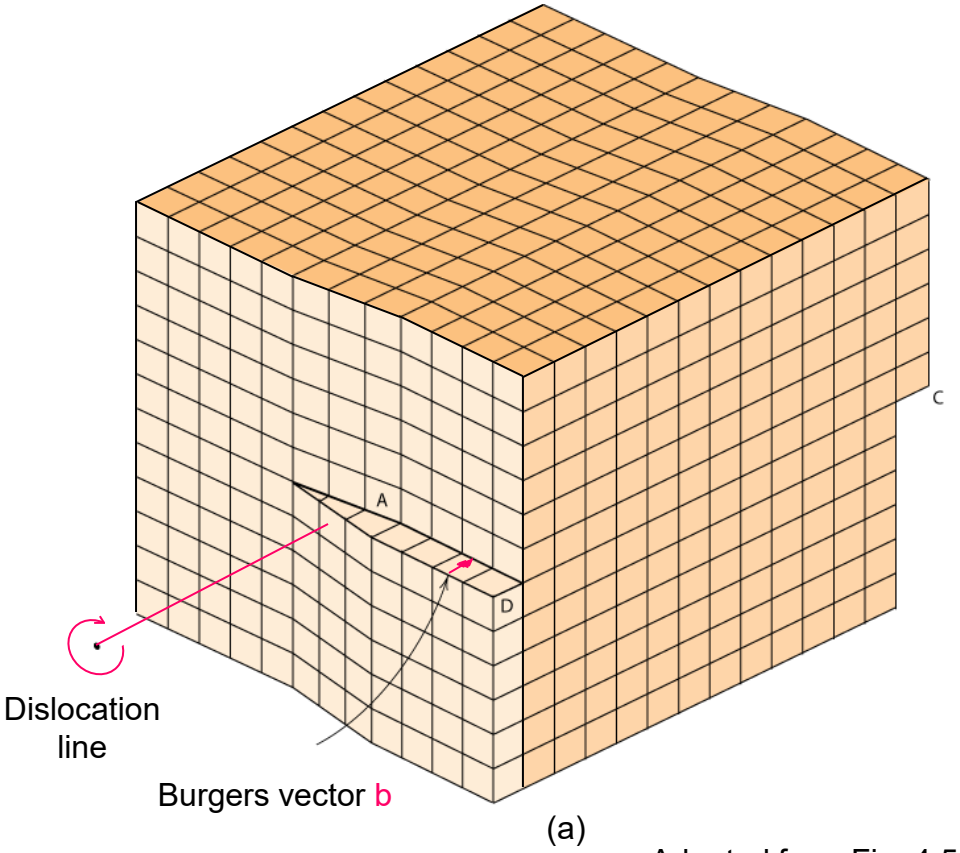


Fig. 4.4, *Callister & Rethwisch 10e.*

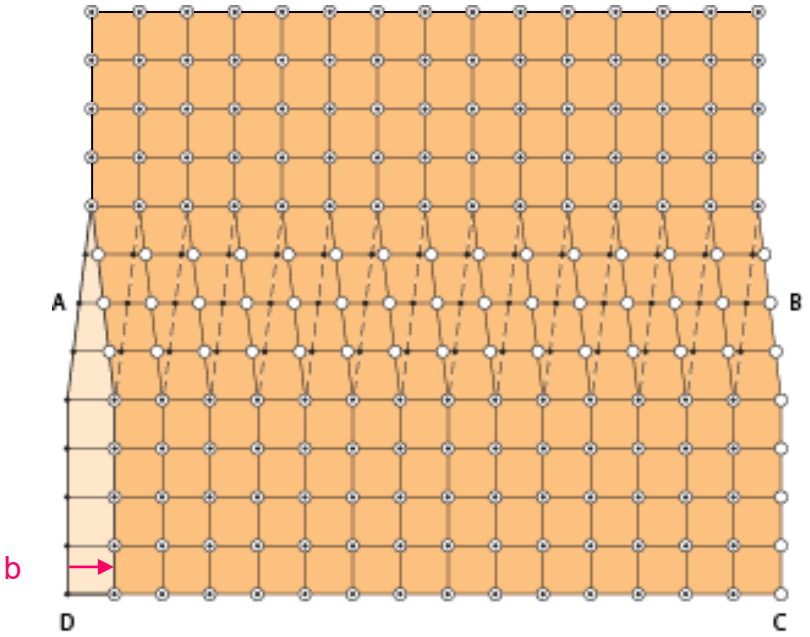
Screw Dislocation

(a) Schematic of screw dislocation in a crystal



(a)

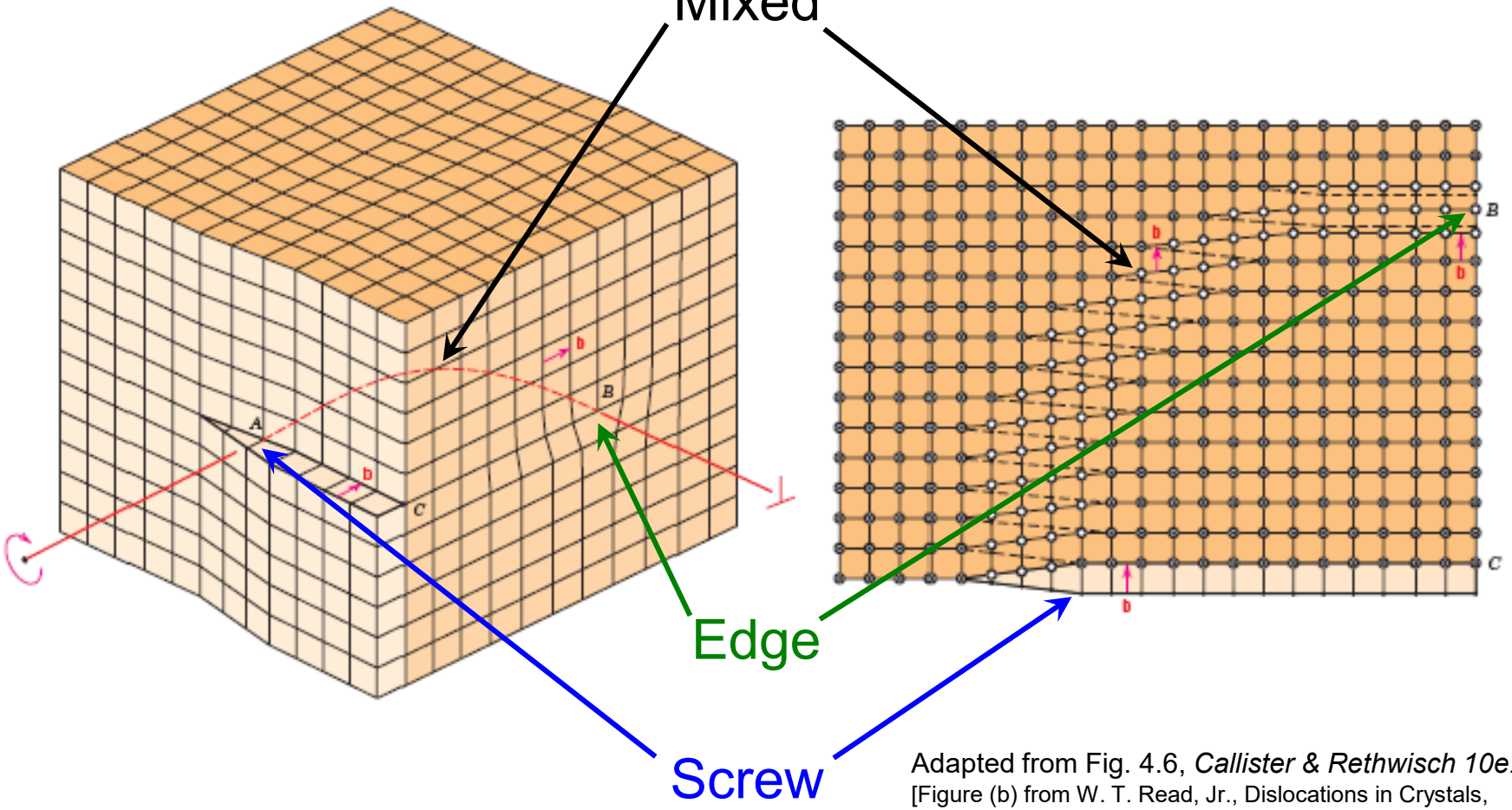
(b) Top view of screw dislocation in (a)



(b)

Adapted from Fig. 4.5, *Callister & Rethwisch 10e.*
[Figure (b) from W. T. Read, Jr.,Dislocations in Crystals, McGraw-Hill Book Company, New York, NY, 1953.]

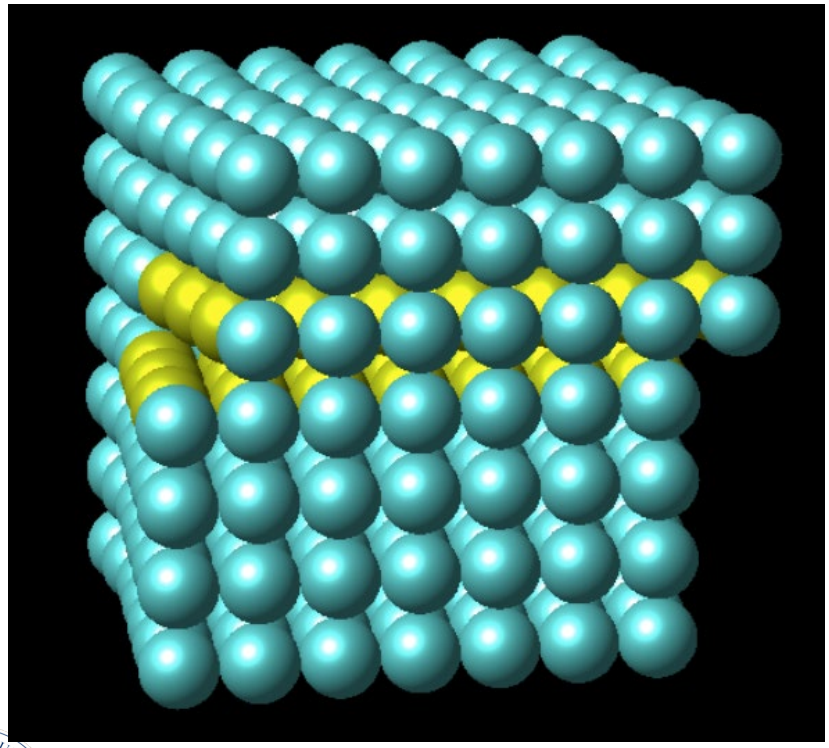
Edge, Screw, and Mixed Dislocations



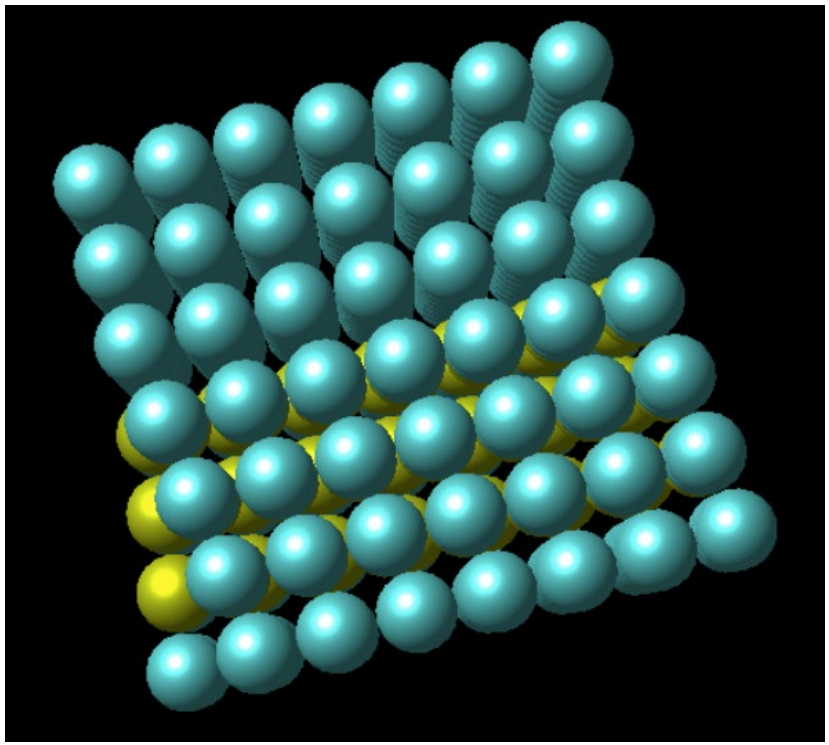
Adapted from Fig. 4.6, *Callister & Rethwisch 10e.*
[Figure (b) from W. T. Read, Jr., Dislocations in Crystals, McGraw-Hill Book Company, New York, NY, 1953.]

VMSE Screenshots of a Screw Dislocation

- In VMSE:
  - crystal region containing screw dislocation—rotated by clicking-and-dragging
  - dislocation motion may be animated



Front View



Top View

Observation of Dislocations

Dislocations appear as dark lines
in this electron micrograph

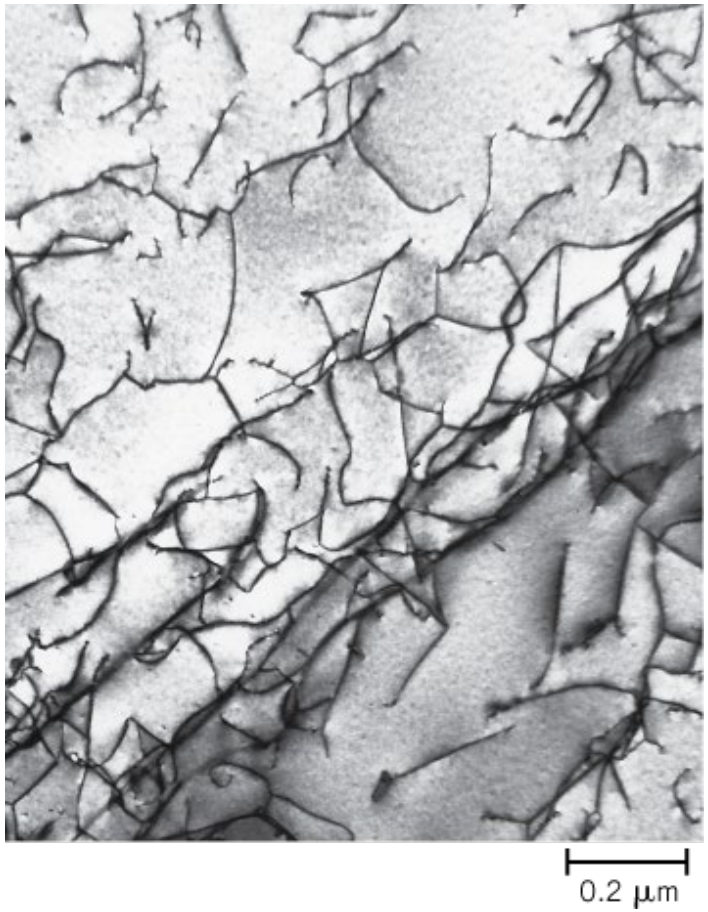


Fig. 4.7, *Callister & Rethwisch 10e.*
(Courtesy of M. R. Plichta, Michigan Technological University.)

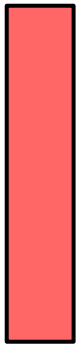
Linear Defects—Dislocations

Dislocations:

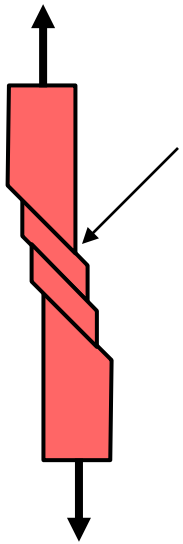
- move when stresses are applied,
- permanent (plastic) deformation results from dislocation motion.

Schematic of a single crystal metal

- unstressed (undeformed)



- after tensile elongation (after plastic deformation)



Steps correspond to plastic deformation: each step is produced by dislocations that have moved to the crystal surface.

Interfacial (Planar) Defects

- Twin boundaries (or planes)
  - Mirror reflections of atom positions of one side of twin plane to the other side.

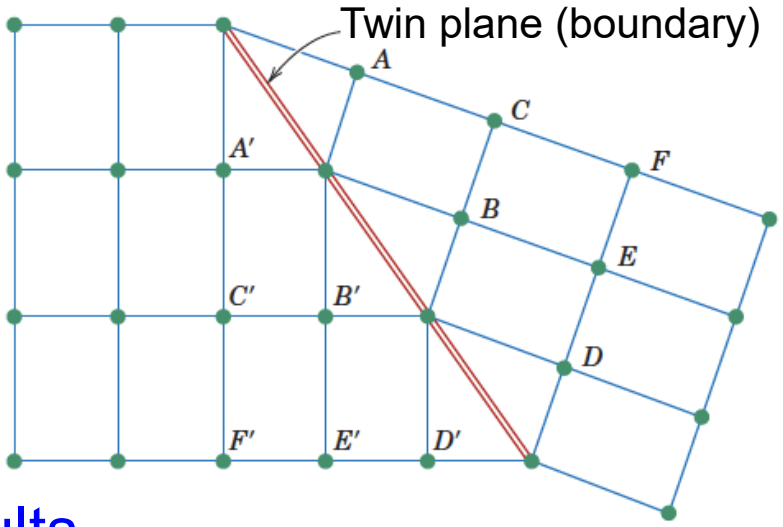


Fig. 4.10, *Callister & Rethwisch 9e.*

- Stacking faults
  - Occur when there is an error in the planar stacking sequence
  - Ex: for FCC metals
    - normal sequence is ABCABC
    - becomes ABCABABC when there is a packing fault

Catalysts and Surface Defects

- A catalyst increases the rate of a chemical reaction without being consumed
- Catalytic reactions normally occur at surface defect sites

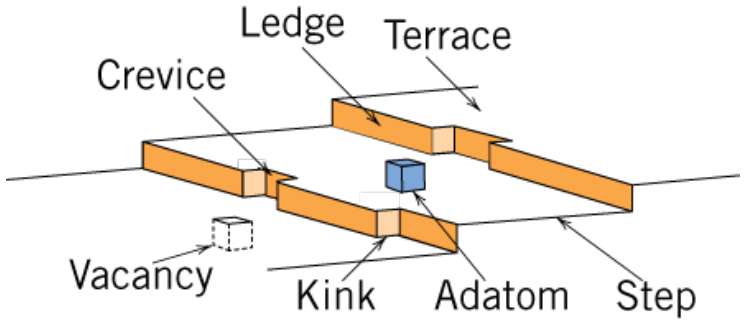


Fig. 4.11, *Callister & Rethwisch 10e.*

Single crystals of $(Ce_{0.5}Zr_{0.5})O_2$ used in an automotive catalytic converter

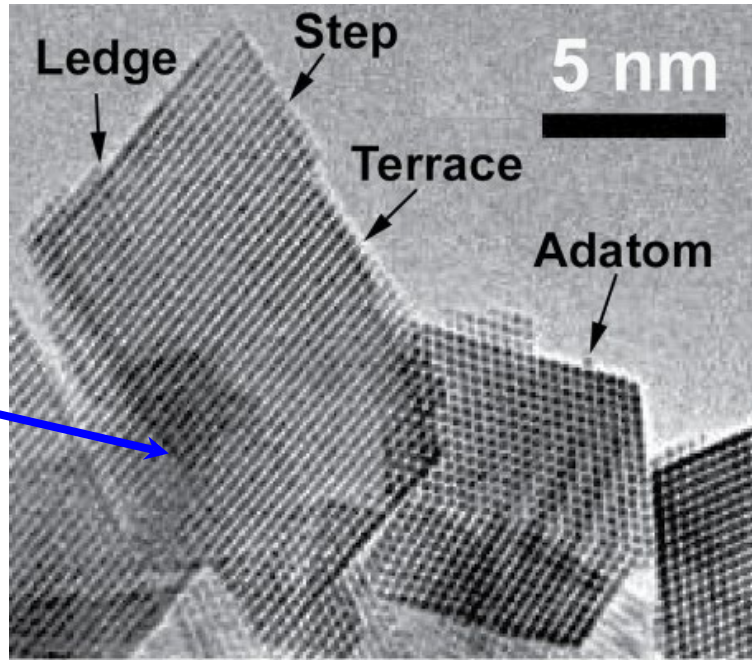


Fig. 4.12, *Callister & Rethwisch 10e.*
[From W. J. Stark, L. Mädler, M. Maciejewski, S. E. Pratsinis, and A. Baiker, "Flame Synthesis of Nanocrystalline Ceria/Zirconia: Effect of Carrier Liquid," Chem. Comm., 588–589 (2003). Reproduced by permission of The Royal Society of Chemistry.]

Microscopic Examination

- Grain size is an important microscopic characteristic.
- Grain size can vary from one material to another.
  - Grain sizes can be quite large
    - ex: large single crystal of quartz or diamond or Si; individual grains visible in aluminum light posts and garbage cans
  - Grain sizes can be quite small (< mm); necessary to observe with a microscope.

Optical Microscopy

- Uses light – useful up to 2000X magnification.
- Polishing removes surface features (e.g., scratches)
- Etching changes reflectance, depending on grain orientation.

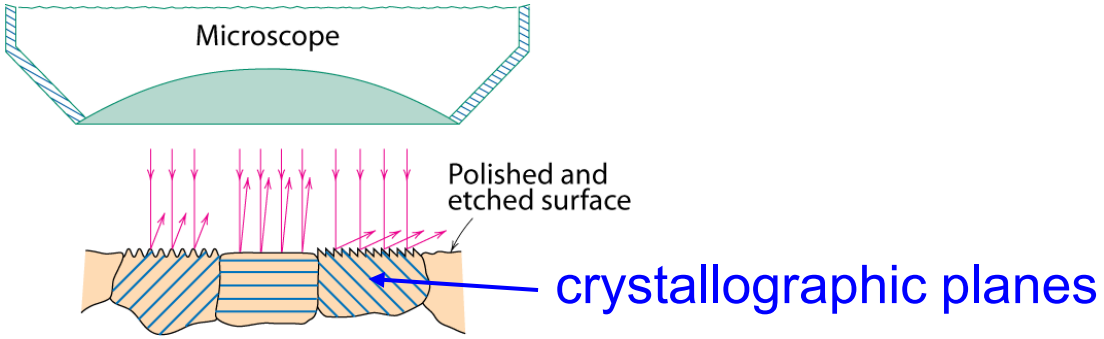
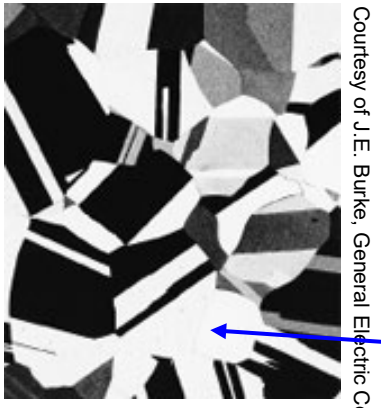


Fig. 4.14(b) & (c), *Callister & Rethwisch 10e.*



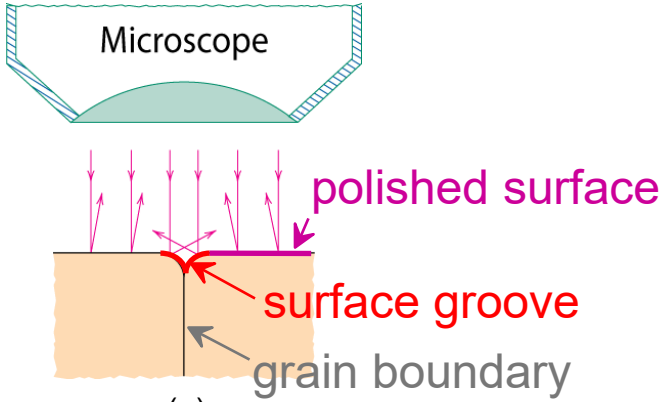
Microstructure of a brass alloy (a Cu-Zn alloy)

grain

Optical Microscopy (cont.)

Grain boundaries...

- are more susceptible to etching
- after etching, grain boundaries appear as dark lines



(a)

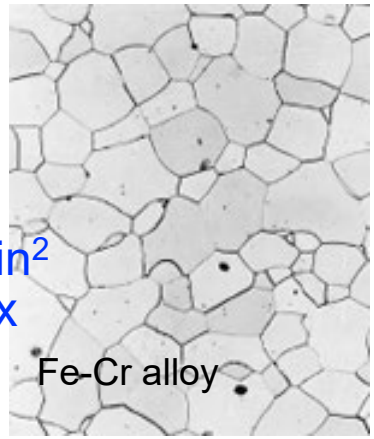
ASTM grain size number

$n = 2^{G-1}$

number of grains/in^2 at 100x magnification

$n_M(\frac{M}{100})^2 = 2^{G-1}$

number of grains/in^2 at other than 100x



(b)

Fig. 4.15(a) & (b), *Callister & Rethwisch 10e.*
[Fig. 4.15(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).]

Optical Microscopy

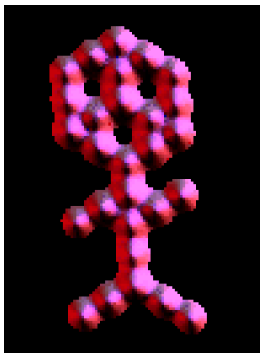
- Polarized light
  - metallographic scopes often use polarized light to increase contrast
  - Also used for transparent samples such as polymers

Electron Microscopy

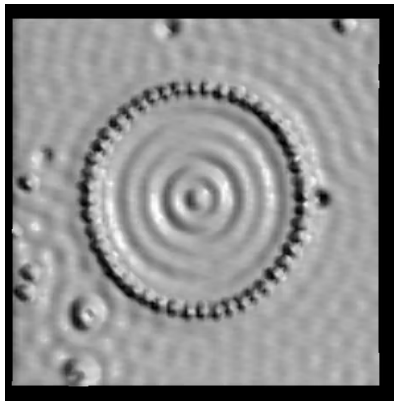
- Best resolution for optical microscopes is ≈ 0.1 μm (100 nm)
- For higher resolution need to use shorter wavelength radiation
  - X-Rays? Difficult to focus.
  - Electron beams
    - Wavelengths as short as 3 pm (0.003 nm) possible
      - (Magnification as high as 1,000,000X are achievable)
    - Atomic resolution possible
    - Electron beams focused by magnetic lenses.

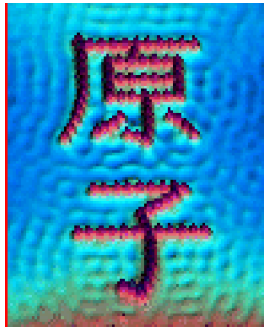
Scanning Tunneling Microscopy

- Surface atoms imaged using a microprobe that tapers to a single atom at its tip.
- Surface atoms can be rearranged by pushing them into the desired position using the probe tip.



Carbon monoxide molecules arranged on a platinum surface in the form of a human.





Iron atoms arranged on a copper surface to form the Japanese Kanji characters that represent the word “atom”.

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