Ductility in Metals

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2016 Summer Engineering Seminar

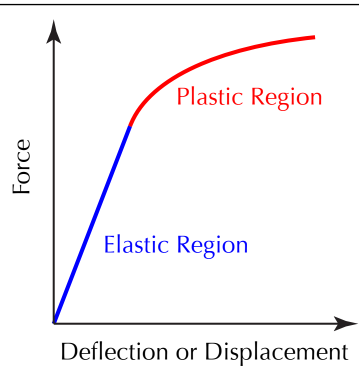
Post 1982 Penny	Pre 1982 Penny

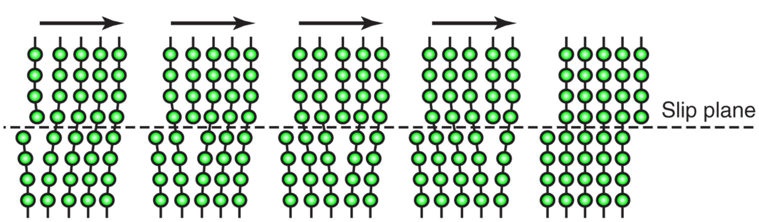
97.5 wt% Zn	95 wt% Cu

DEFORMATION OF METALS:

- Elastic Region: stretching of atomic bonds (similar to springs)

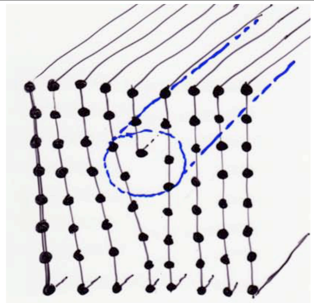
- Plastic Region: permanent deformation...WHY???
  - -Dislocations





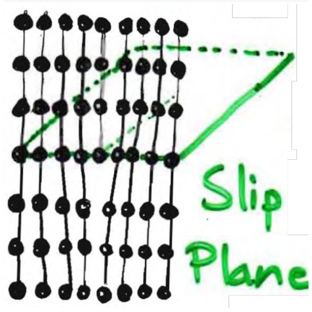
DISLOCATION STRUCTURE:

- A dislocation extends through the material in three dimensions (we can think of it as a line or curve meandering throughout the crystal).



- Dislocation motion (*a.k.a. slip*) occurs more easily in metals compared to covalent solids (*e.g.*, diamond) or ionic solids (*e.g.*, NaCl).

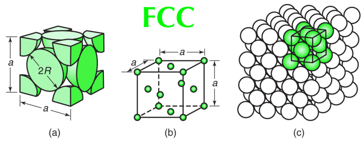
- For "easy" slip want atoms close together in the *slip direction*, but with large separation perpendicular to the slip plane.



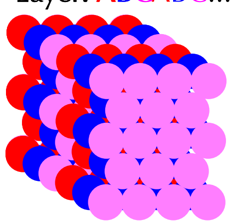
CLOSE-PACKED STRUCTURES:

Face-Centered Cubic

FCC

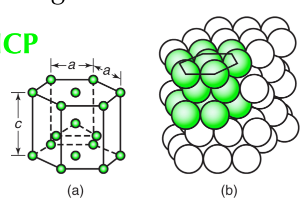


Layer: ABCABC...

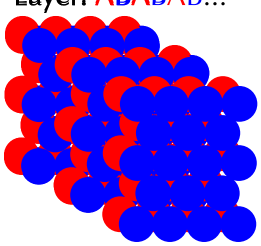


Hexagonal Close Packed

HCP



Layer: ABABAB...



Post 1982 Penny

Zn is HCP

Pre 1982 Penny

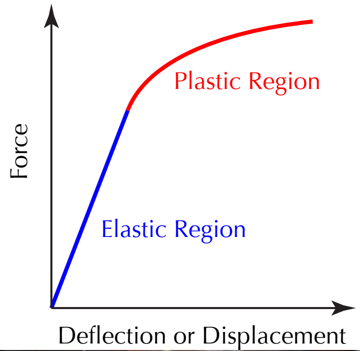
Cu is FCC

STRAIN HARDENING IN METALS:

- Higher force needed for continued plastic deformation.
- Dislocation movement becomes more difficult as deformation proceeds.
- Dislocations get “tangled” up with one another and it becomes harder for them to move, so more force is required to continue deforming the metal.

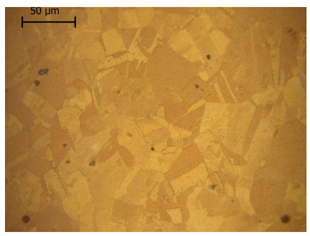
In a heavily deformed metal, there can be as much as ≈10^{12} cm of dislocation line per cm^3 of material.

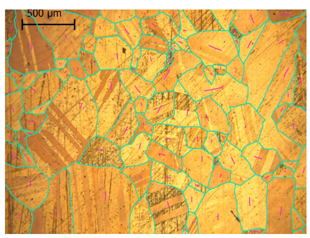
10^{12} cm = 10^7 km ≈ 25 × distance to the moon

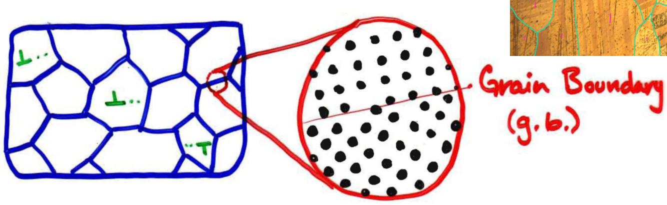


MICROSTRUCTURE IN SOLIDS:

- Solids formed from solidification; this leads to many micro-crystals called grains.
- Difficult for dislocations to cross a grain boundary
- By cooling faster, smaller grains are formed; *i.e.*, more grain boundaries.
- When a solid is heated, large grains grow at the expense of smaller grains.







SUMMARY:

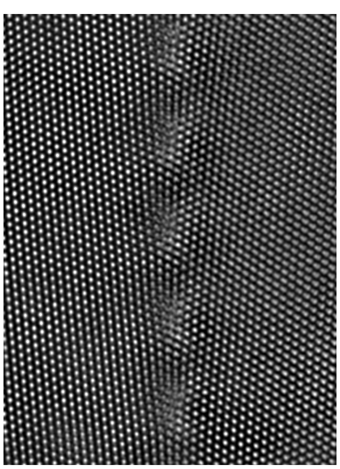


Image by: SETH T. TAYLOR, *Nature Materials*, **3** 682 (2004).

- Stretching of atomic bonds is reversible and occurs during elastic deformation.
- Dislocation motion is irreversible and leads to permanent or plastic deformation.
- Solids are usually composed of several microscopic crystals known as grains.
- The size of grains increases (grain growth) when a solid material is exposed to higher temperatures.
- Dislocation motion is impeded by grain boundaries; hence, smaller grained metals tend to be more difficult to deform plastically.

LAB WORKSHEET

1) Write the names of your group members below.

__________________________ __________________________

__________________________ __________________________

__________________________ __________________________

2) Write the letter of your brass sample here ________.

3) Write the hardness values you measured for your sample below.

__________ __________ __________

4) After consulting with the other members in your group, write the temperature at which each sample was annealed (500°C, 600°C, 700°C, or 800°C) below.

__________	__________	__________	__________
Sample A	Sample B	Sample C	Sample D

5) Which sample do you expect to have the smallest grain size, and which sample do you expect to have the largest grain size?

__________	__________
smallest grains (A, B, C, or D)	largest grains (A, B, C, or D)

6) On the back of this page, briefly explain how you came to your conclusions for 4) and 5).