Lecture 23, Mar 17, 2022

Strengthening Metals

- Plastic deformation occurs by the movement of linear dislocations
- The presence of other imperfections, e.g. vacancies, interstitial atoms, etc can affect the dislocation movement
- A linear dislocation itself puts the atoms under tension, which can be slowed down by other imperfections as they also put compression or tension on the atoms
  - This is why alloying can make the metal stronger by affecting dislocation movement
- Annealing: Heating up a metal
  - This relieves residual stress introduced by processing and also promotes grain growth (reduces density grain boundaries)
  - Annealing makes the metal more ductile
- Plastically deforming the metal intrudes more defects, making it harder for dislocations to move and strengthening the metal
  - Repeatedly deforming introduces more and more defects, making it more brittle and eventually breaking
- Grain size has a huge effect on metal strength
  - When grain size is very small (nanocrystalline), the metal is effectively amorphous
  - Smaller grain size and amorphous metals make it much harder for dislocations to move and so makes the metal stronger
  - However it's very difficult to make amorphous metals
- Second phases are 3D defects
  - e.g. aluminum alloy precipitation hardening
- Summary: Strengthening mechanisms in alloys:
  - Work hardening: Plastically deforming the material to induce more dislocations (e.g. bending a bar to make it stronger)
  - Solid solution hardening: Introducing interstitial defects through a solid solution (e.g. putting carbon in iron to make steel)
  - Precipitation hardening: Forcing particles of a second phase to precipitate out (3D defect)
  - Grain refinement: Influencing the grain structure in various different ways (e.g. rolling, forging)