Practical 1P1a
Background Information

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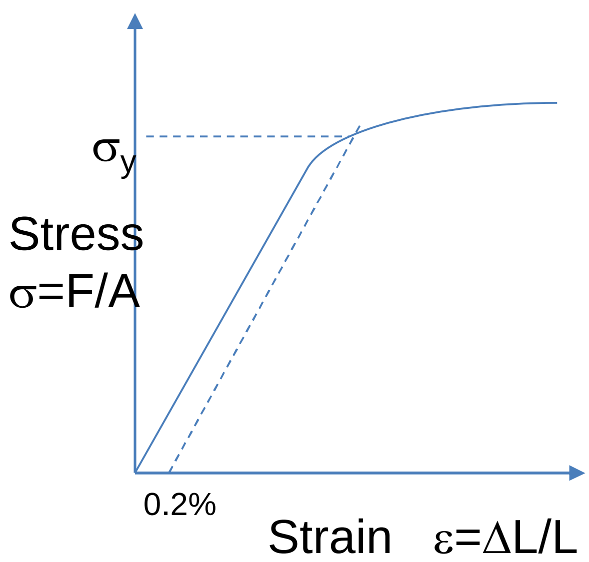
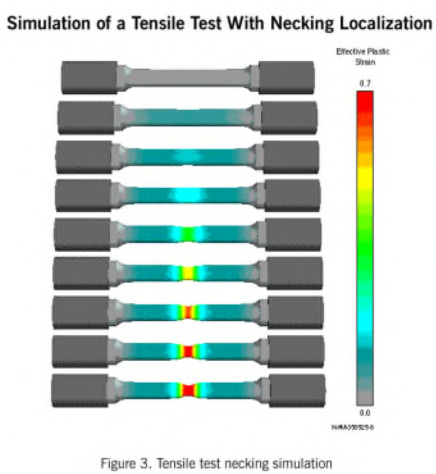
Strength of Materials

- ***Strength*** is the ability of a materials to withstand an applied stress without failure
- ***Yield Strength*** is the lowest stress to cause permanent deformation (e.g. 0.2% strain)



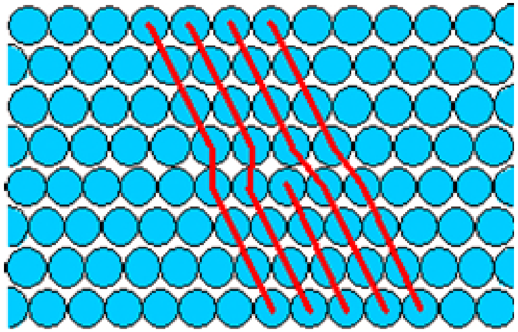


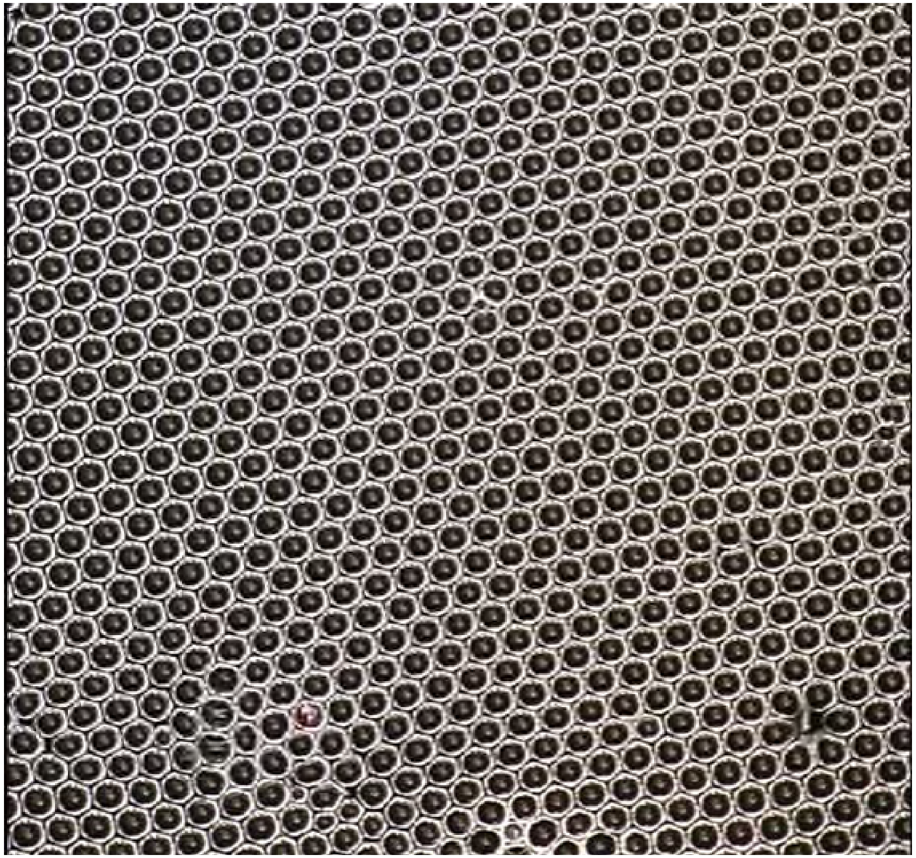
Why are some materials stronger than others?

- Strength depends upon microstructure
- Plastic deformation occurs by the motion of dislocations through the material
- Strength is due to the cumulative effect of
  - Solid Solution Strengthening
  - Particle/Precipitate Strengthening
  - Grain boundary strengthening
  - Work Hardening

Dislocations - a Bubble Raft model

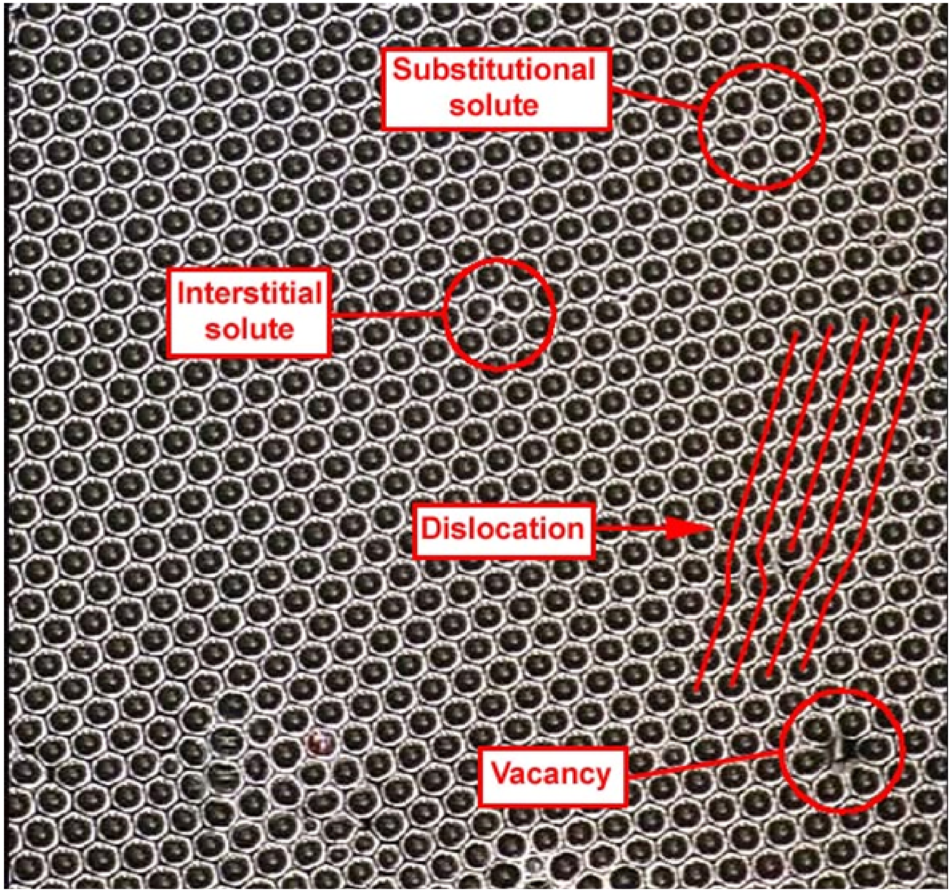
A dislocation is the line defect created by an extra plane of atoms in the crystal structure



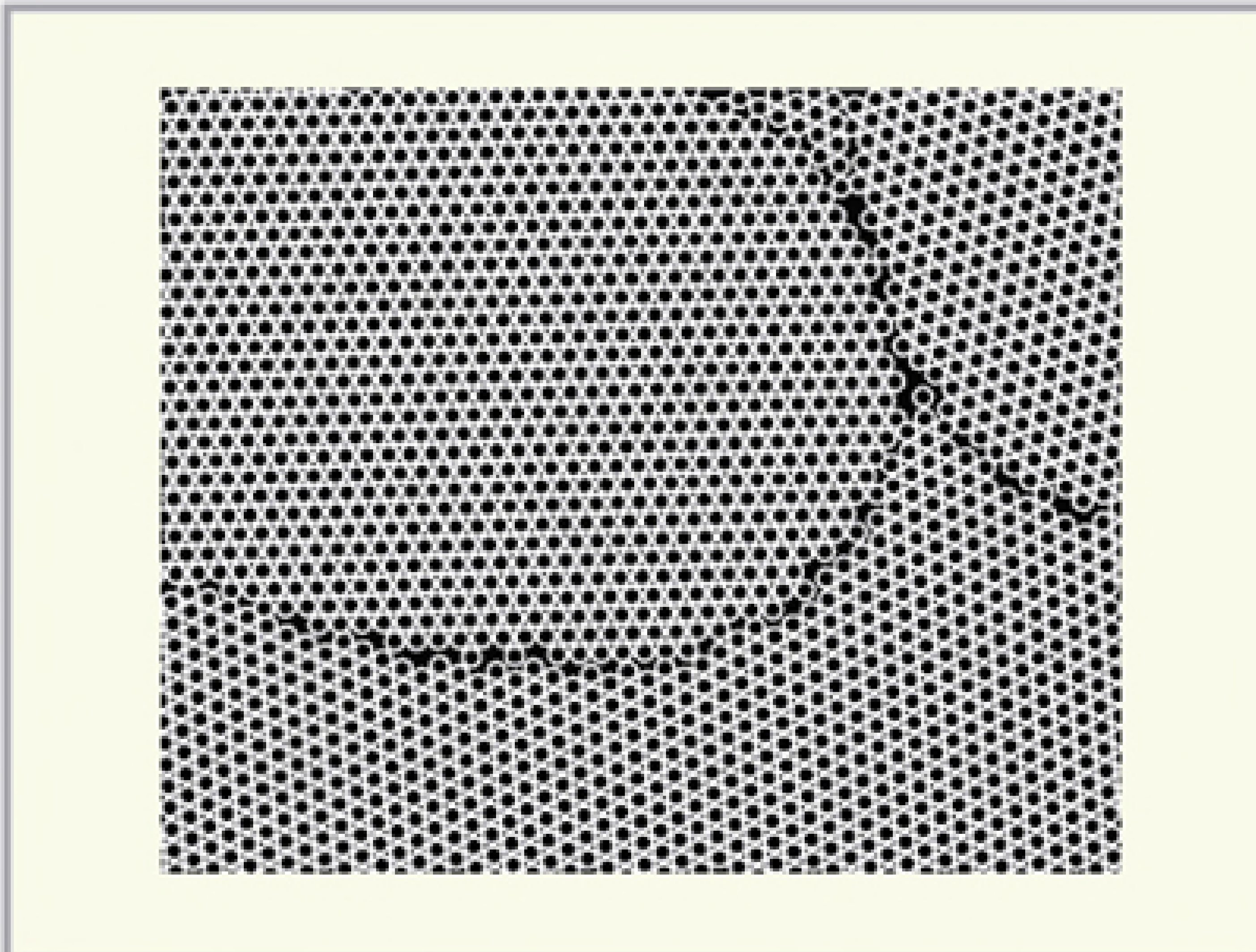


Where is the dislocation?

Defects in a Bubble Raft model



Grain Boundary in Bubble Raft



Dislocation motion

- Video of dislocations moving in an electron microscope on YouTube

Grain Strengthening

- Grain boundaries hinder the motion of dislocations
- Dislocations pile-up at grain boundaries and the stress fields around each dislocation accumulate effectively reducing the external stress necessary to propagate the deformation
- Large grains can contain larger pile-ups of dislocation causing higher local stress concentrations at the grain boundaries so the external stress necessary for yield is lower
- Smaller grains means more grains and lower local stresses due to smaller pile-ups so the external stress needed for yield is higher

Hall Petch Equation

- Yield Stress is inversely proportional to the square-root of grain size

$$\sigma_y = B + \frac{A}{\sqrt{d}}$$

- i.e. smaller grain size makes stronger material

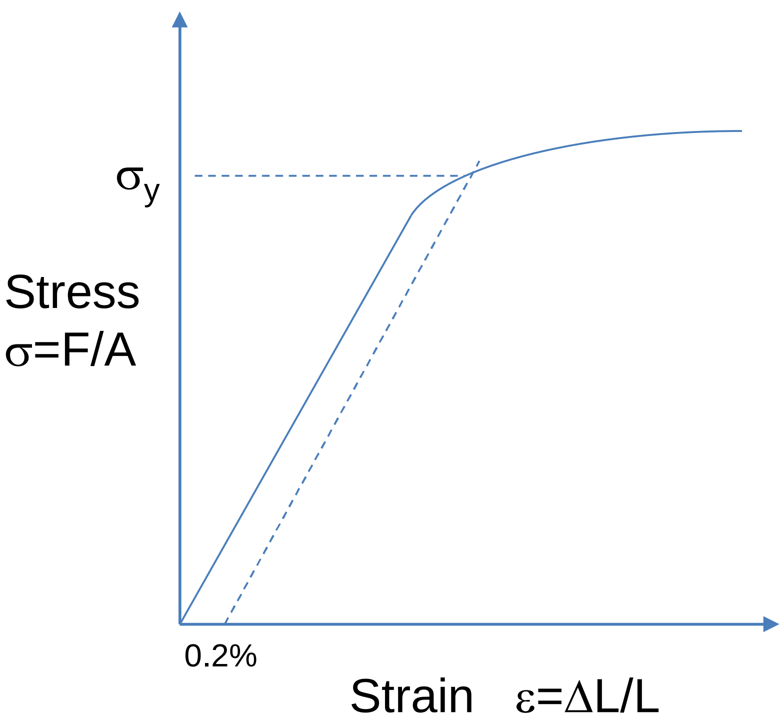
Hall Petch – an Experiment

- Make a series of alloys with different grain sizes (try to keep everything else the same!)
- Measure the average grain size of each alloy, *d*
- Measure the yeild strength of each alloy σ_y
- Compare data against the Hall Petch equation

- Ideally follow recognised standards when making measurements

How to measure yield stress

- Measure extension under increasing load.
- E.g. Hounsfield Tensometers



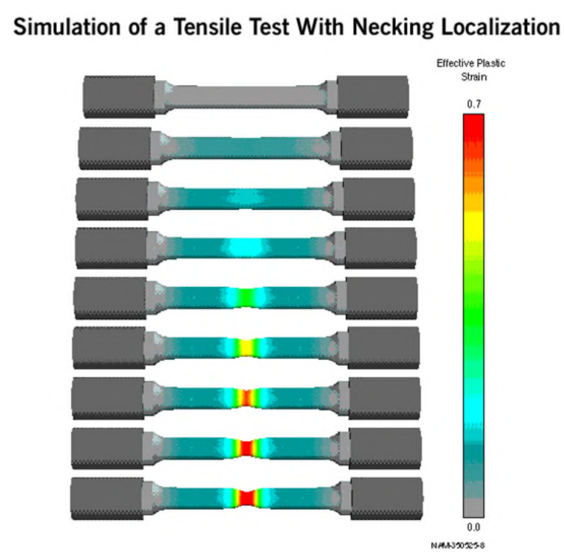


Figure 3. Tensile test necking simulation

How to measure grain size

- Metallographic observation of microstructure
- Mean Lineal Intercept Length L_L is related to the number of intercepts per length N_L for a total length L_T with P intercepts at magnification M.
- The mean lineal intercept length is proportional to the grain size

$$\overline{L}_L = \frac{1}{\overline{N}_L} = \frac{L_T}{PM}$$

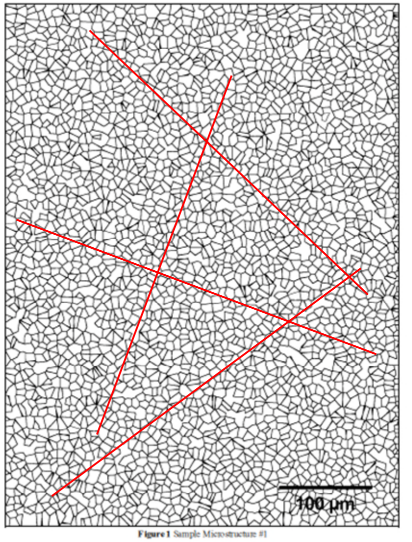


Figure 1 Sample Microstructure #1

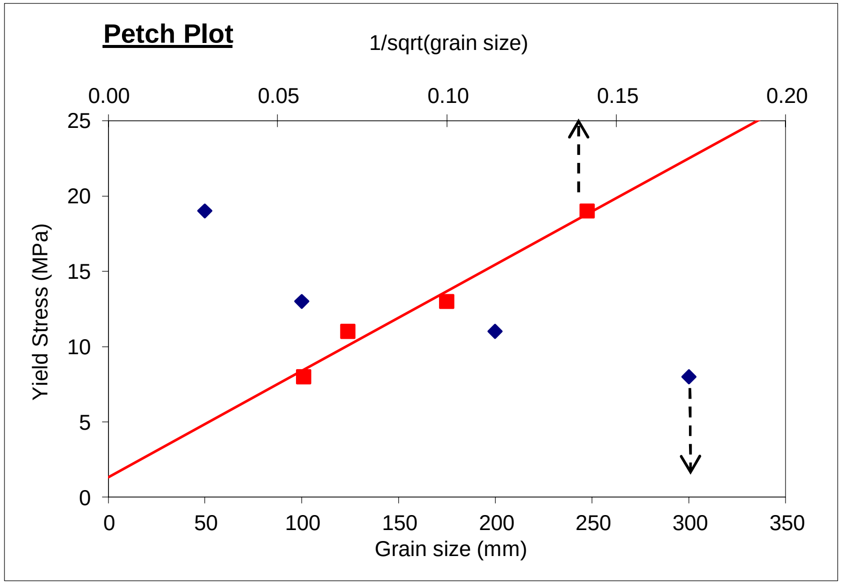
Model Data

- Spreadsheet containing the model data for grain-size and yield stress

d (mm)	1/sqrt(d)	Stress (MPa)
50		19
100		13
200		11
300		8

Results Analysis

- Plot σ vs d
- Plot σ vs √d
- Use TREND and LINEST to find best fit line
- Plot best fit line
- Insert graph into brief report or "write-up"



What about Errors?

- Only one tensile test specimen so only one measurement. Error is measurement due to precision of measurement.
- Grain size measurement is the average of many measurements and it is possible to calculate the standard deviation as a measure of the error

$$\sigma = \sqrt{\frac{\Sigma(d_i - \bar{d})^2}{N}}$$

grain size is d ± 2σ (95% confidence)

Results with errorbars