3.40 Oct 5th LECTURE SUMMARY

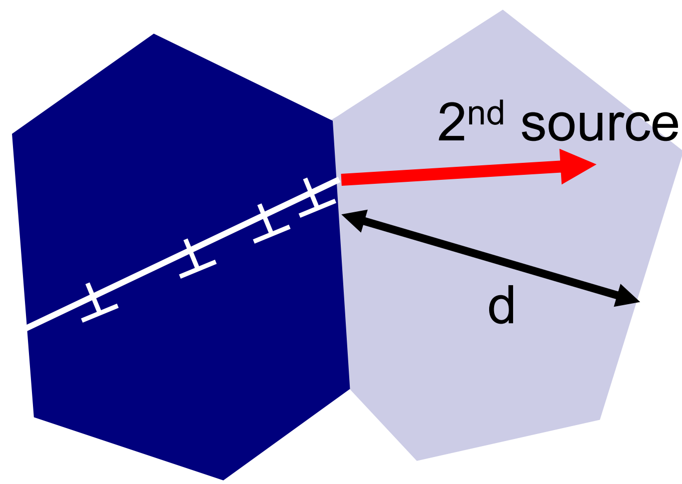
10/07/09

DISLOCATION INTERACTIONS

- Dislocations reduce the stress required to plastically deform materials
- Dislocations interact with
  - Forests of Dislocations
  - Grain Boundaries
    - Hall - Petch Relationship

$$\tau_y \propto \frac{1}{\sqrt{d}}$$

  - Precipitates
  - Solutes



Courtesy of Markus Buehler. Used with permission.

Schematic of a Dislocation Pile up at a Grain Boundary

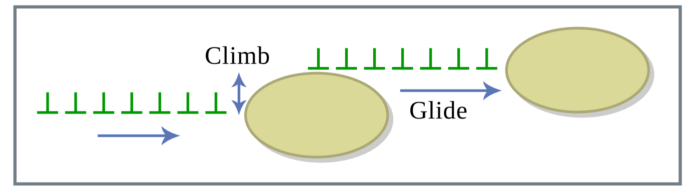
Mechanical Metallurgy, Dieter G., 3rd Edition

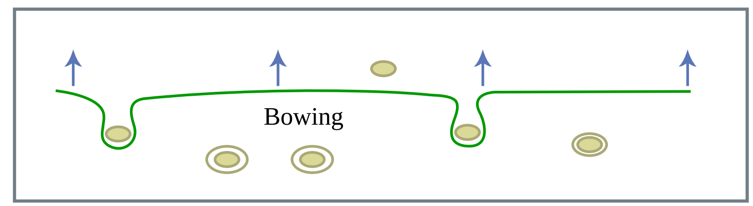
http://en.wikipedia.org/wiki/File:Dislocation_pileup.png

OROWAN LOOPING

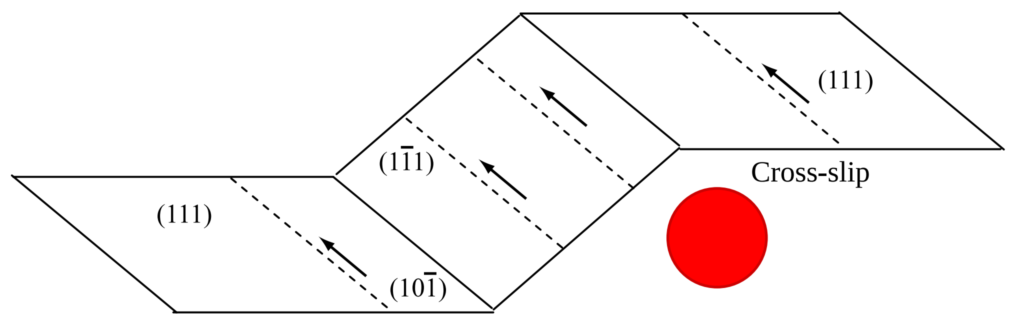
- Precipitates act as pinning points for dislocations

- Bowing leads to unpinning leaving behind dislocation loops around the particles





Figures by MIT OpenCourseWare.



Courtesy of Krystyn Van Vliet. Used with permission.

Please also see "Strengthening Processes: Dispersion Hardening." *aluMATTER*, University of Liverpool.

Dislocation bypass around precipitates

http://www.cemes.fr/r2_rech/r2_sr3_mc2/videos

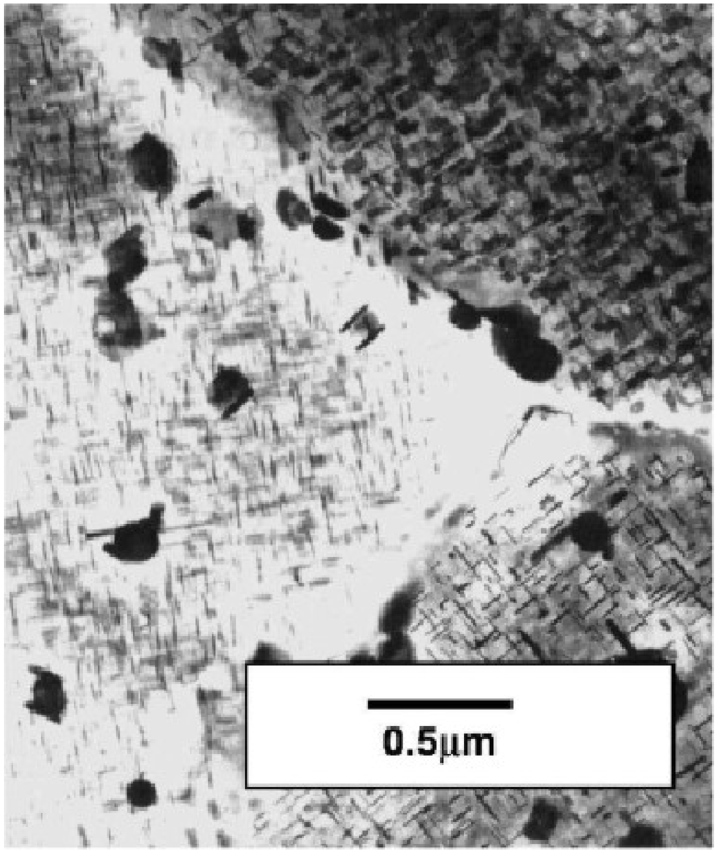
http://aluminium.matter.org.uk/

OROWAN LOOPING

- Yield Stress to overcome obstacles:

$$\tau_y \approx \frac{\mu b}{L} = \alpha \mu b \sqrt{\rho_\perp}$$

- Dislocation density has units of 1/Area
- Ageing Treatment
  - Precipitation Hardening
  - eg. Al – Cu alloys
  - "Overageing"



Microstructure of an aged Al – 4 % Cu alloy showing CuAl2 precipitates

http://aluminium.matter.org.uk/

Fig. 1204.03.18 in Jacobs, M. H. "1204 Precipitation Hardening." *Introduction to Aluminium Metallurgy*. TALAT, 1999.

WORK HARDENING

- Orowan's Equation:

$$\tau_y \approx \alpha' \mu \sqrt{b\gamma} \approx K\sqrt{\gamma}$$

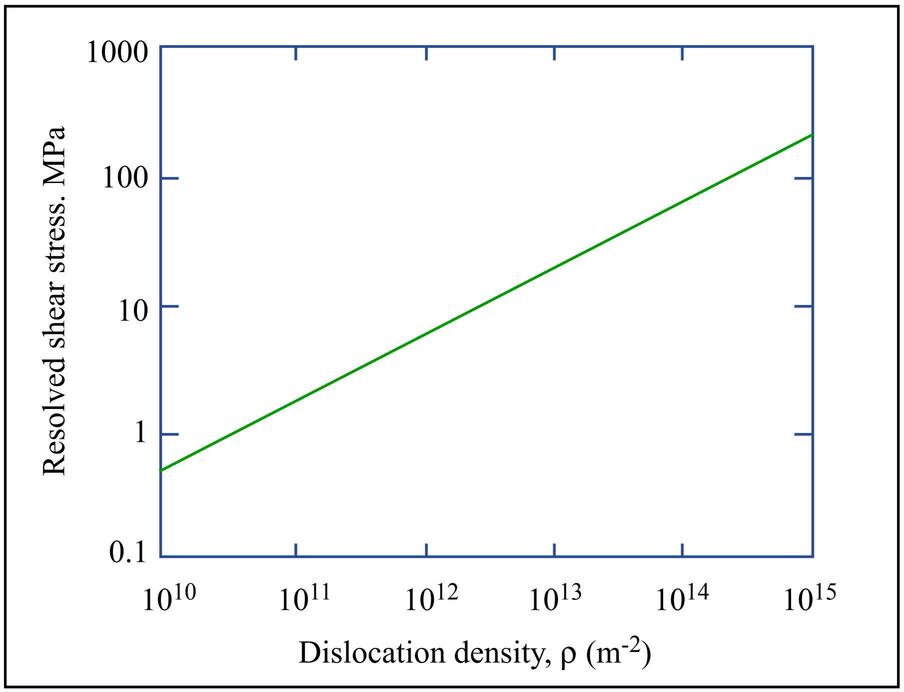
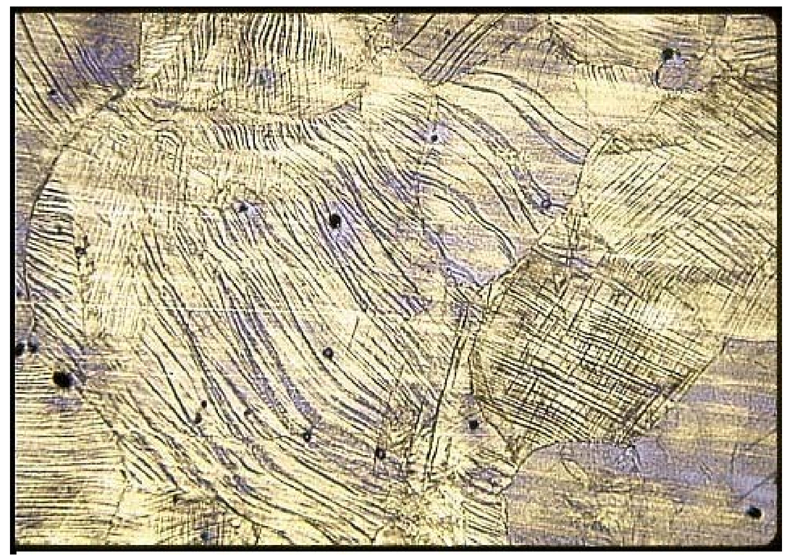


Figure by MIT OpenCourseWare.



Courtesy of George Langford. Used with permission.

Heavily Cold Worked Steel Microstructure

Microstructures, George Langford, MIT

Schematic of a Stress Strain Curve

http://en.wikipedia.org/wiki/File:Work_HArd.png

WORK HARDENING

- Holloman Power Law Hardening

$$\tau_y = K\gamma^n$$

- n – Strain Hardening Exponent
- K – Strength Coefficient

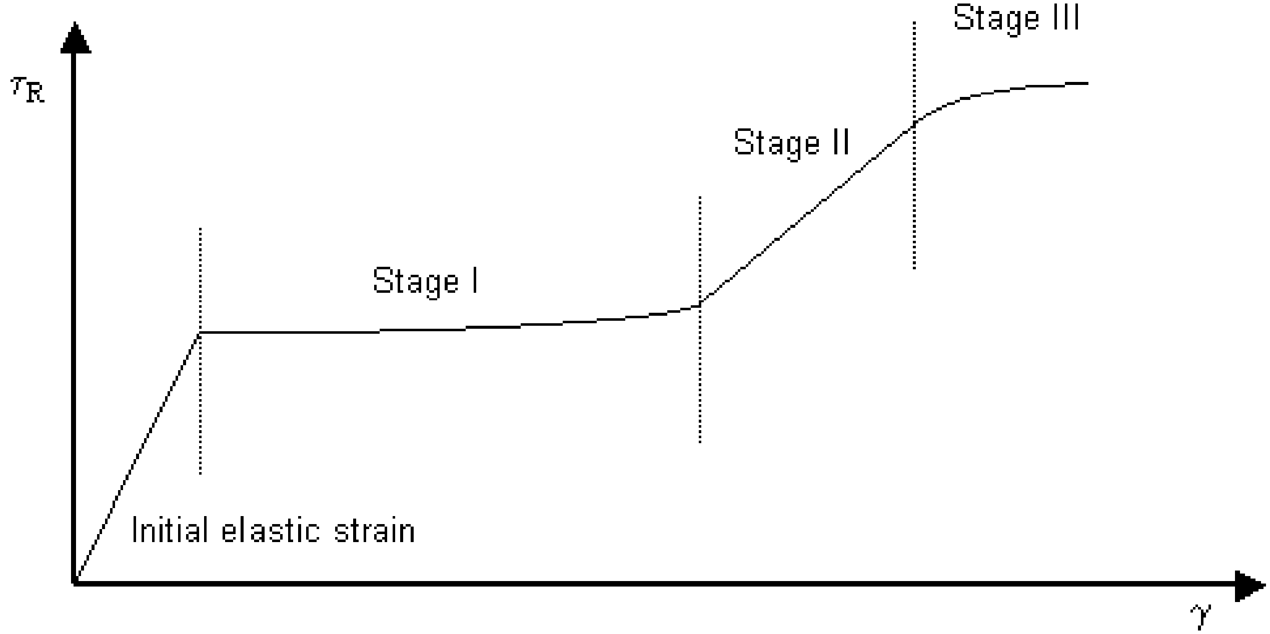
Table removed due to copyright restrictions.
Please see Table 9 in "Design for Deformation Processes." Ch. 11 in Dieter, George Ellwood, Howard A. Kuhn, and S. L. Semiatin. *Handbook of Workability and Process Design*. Materials Park, OH: ASM International, 2003.

Values of n and K for certain selected metals

Handbook of Workability and Process design, Dieter GE

WORK HARDENING

- Stages in a single crystal
  - Stage I : Single Slip
  - Stage II : Work Hardening Stage
  - Stage III : Saturation of Work Hardening



http://www.doitpoms.ac.uk/tlplib/slip/slip_in_ccp.php

POLYCRYSTAL DEFORMATION

- Multiple Slip Regime
  - Elastic Anisotropy
    - Local stress state is complicated
  - Accommodation of Plasticity
    - Shape compatibility must be satisfied
    - Nucleates "Geometrically Necessary Dislocations" to remove the incompatibility
    - Stage II is absent

Removal of Shape Incompatibilities during deformation

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QUESTIONS ?

3.40J / 22.71J / 3.14 Physical Metallurgy
Fall 2009