
3.40 Lecture Summary
09/28/09

1. Interactions between dislocations :

❖ **General rule :**

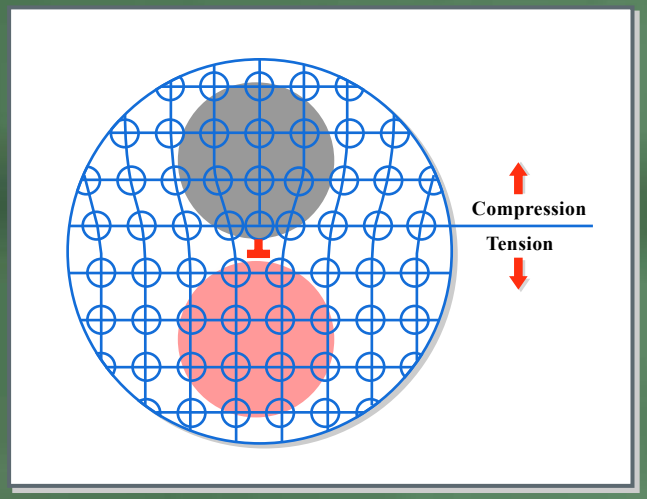
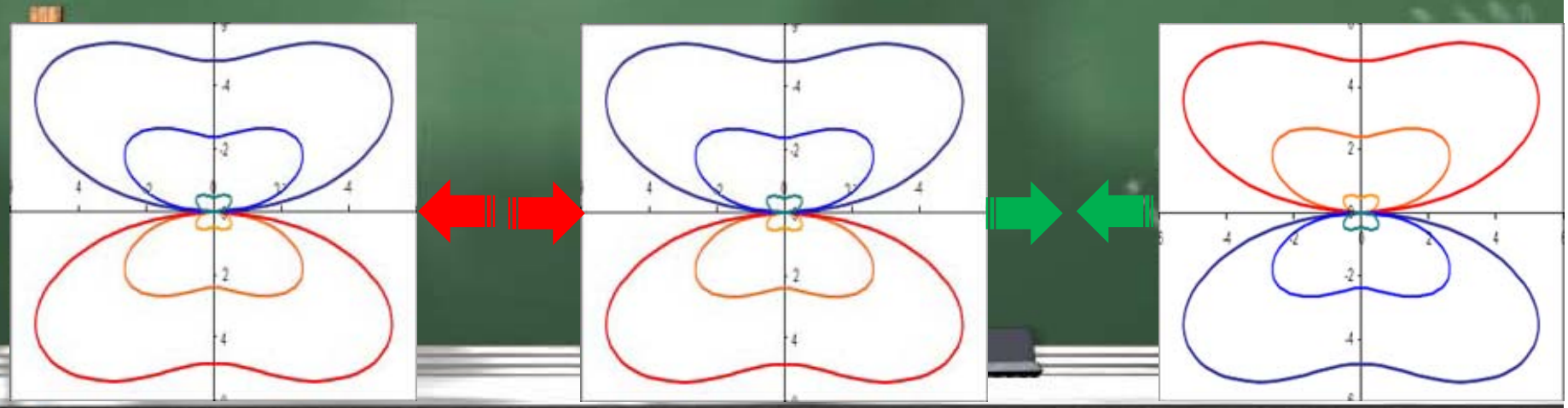


Figure by MIT OpenCourseWare.

Peach-Koehler equation :

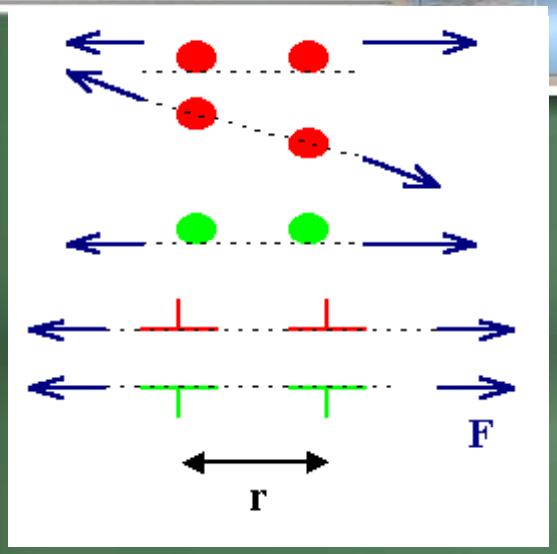
$$F_x = b_x\sigma_{xy} + b_y\sigma_{yy} + b_z\sigma_{zy}$$

$$F_y = -(b_x\sigma_{xx} + b_y\sigma_{xy} + b_z\sigma_{xz})$$



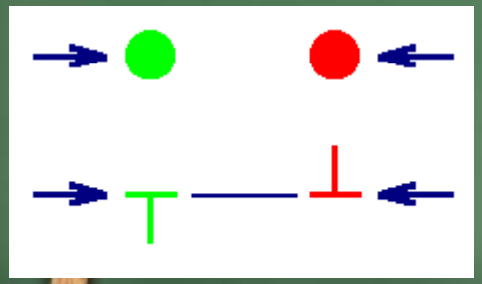
http://www.soton.ac.uk/~engmats/xtal/deformation/dislocation.html

❖ Main results :



⇨ **Repulsion F ~ b^2/r**

Courtesy of Helmut Föll. Used with permission.



⇨ **Attraction F ~ - b^2/r**

Courtesy of Helmut Föll. Used with permission.

T

⇨ **No interaction**

http://www.tf.uni-kiel.de/matwis/amat/

2. Effects on material behavior:

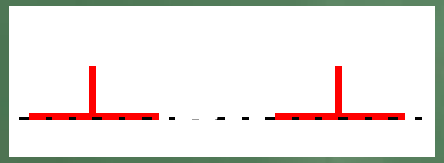
- ❖ Same plane, same sign ⇒ PILE UP

Please see videos of pileup and annihilation from Groupe Matériaux Cristallins sous sous Contrainte, CNRS.

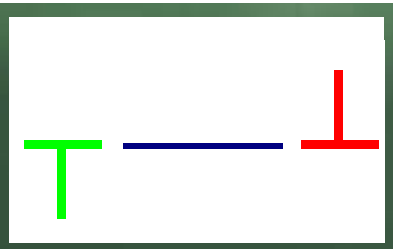
- ❖ Same plane, opposite sign ⇒ ANNIHILATION

Frank's rule :

$$\overline{b_3} = \overline{b_1} + \overline{b_2}$$



⇒ 2b



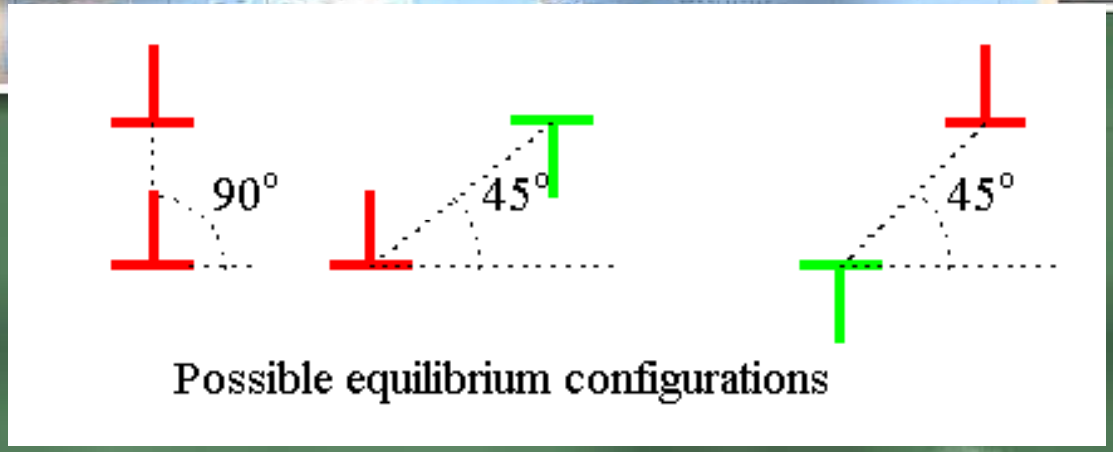
⇒ 0

Courtesy of Helmut Föll. Used with permission.

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

❖ Low energy configurations:

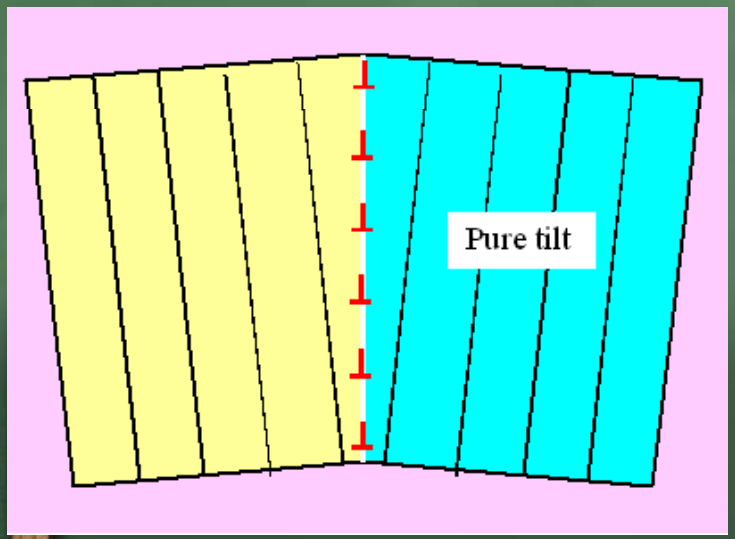
Dislocation dipole :

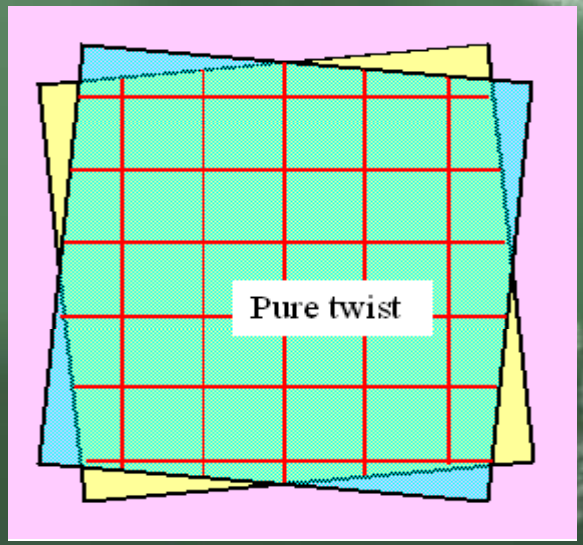


Possible equilibrium configurations

Courtesy of Helmut Föll. Used with permission.

Grain boundaries :

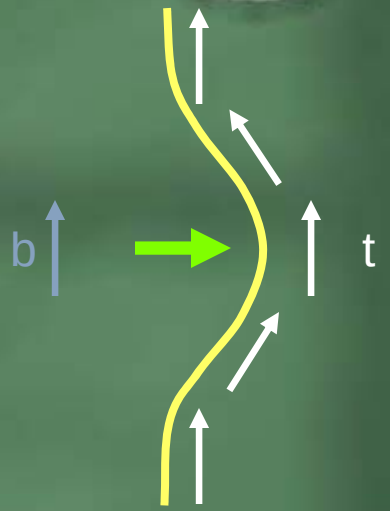


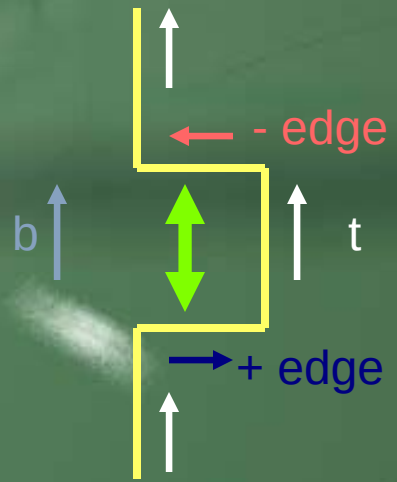


$$D = \frac{b}{\theta}$$

Courtesy of Helmut Föll. Used with permission.

3. Line Tension

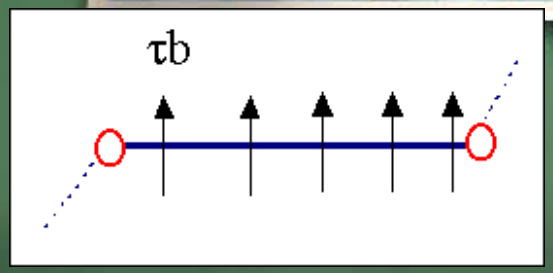


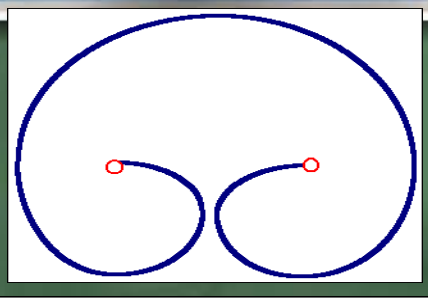


- Restoring force promotes straight dislocations
- Sharp bends are not favorable

4. Dislocation Multiplication

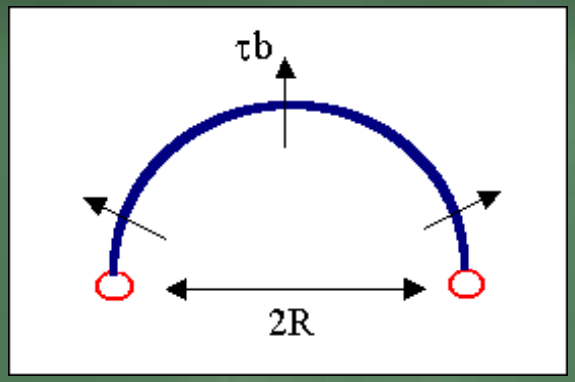
Pinned ends
Shear stress

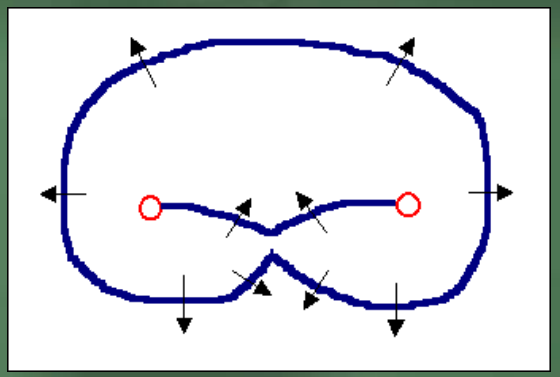




Two opposite segments meet and annihilate

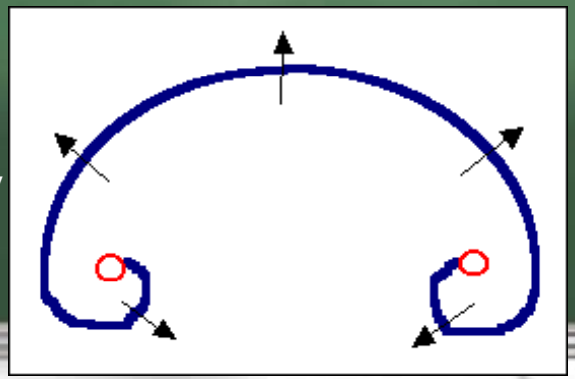
Dislocation bows out

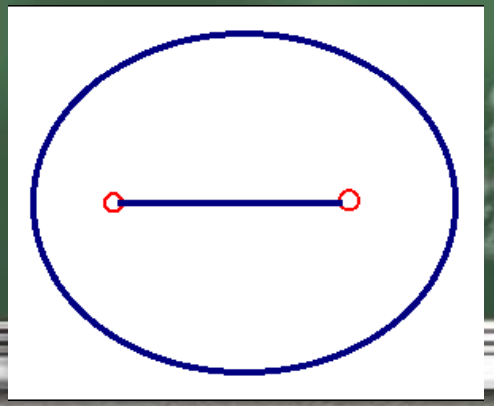




Loop and segment separate

Dislocation spontaneously grows





Loop expands

Line straightens

http://www.tf.uni-kiel.de/matwis/amat/def_en/kap_5/backbone/r5_3_2.html

Frank-Read Source

- Dislocation is pinned at both ends
- Shear stress is exerted on slip plane
- Force causes dislocation to lengthen and bend
- Dislocation spontaneously grows when
  - Shear stress overcomes restoring force
  - Past the semicircular equilibrium state
- Generate many dislocations on slip planes

Image removed due to copyright restrictions.
Please see http://commons.wikimedia.org/wiki/File:Frank-Read_Source.png

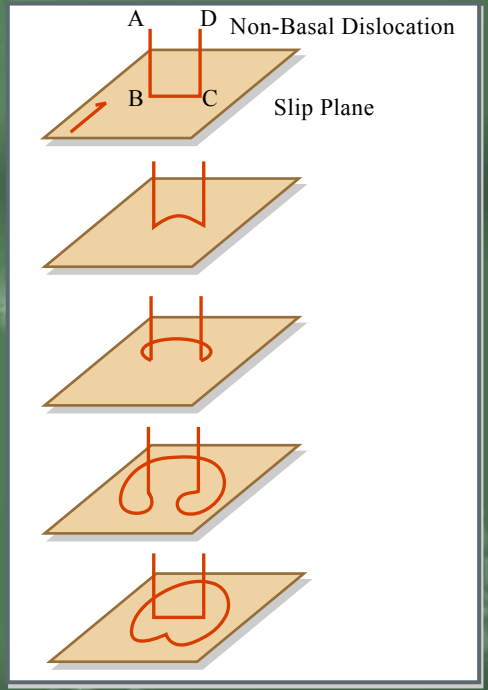


Figure by MIT OpenCourseWare.

http://web.earthsci.unimelb.edu.au/wilson/ice1/generations.html
http://en.wikipedia.org/wiki/Frank-Read_Source

Frank-Read Source

Image removed. Please see http://www.fml.t.u-tokyo.ac.jp/research/DD/ani/FR.html

http://www.fml.t.u-tokyo.ac.jp/research/DD/index.html

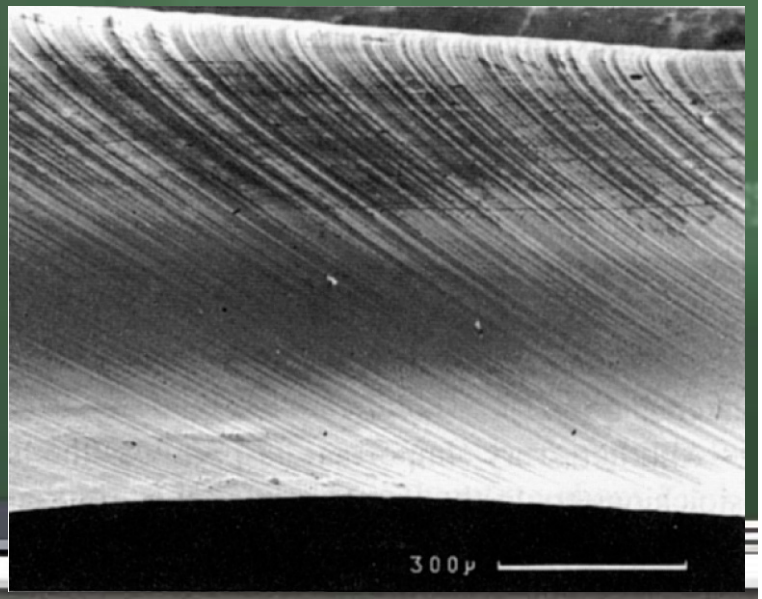
Frank-Read Source

Image removed. Please see http://www.fml.t.u-tokyo.ac.jp/research/DD/ani/2FR.html

http://www.fml.t.u-tokyo.ac.jp/research/DD/index.html

5. Dislocation Observation

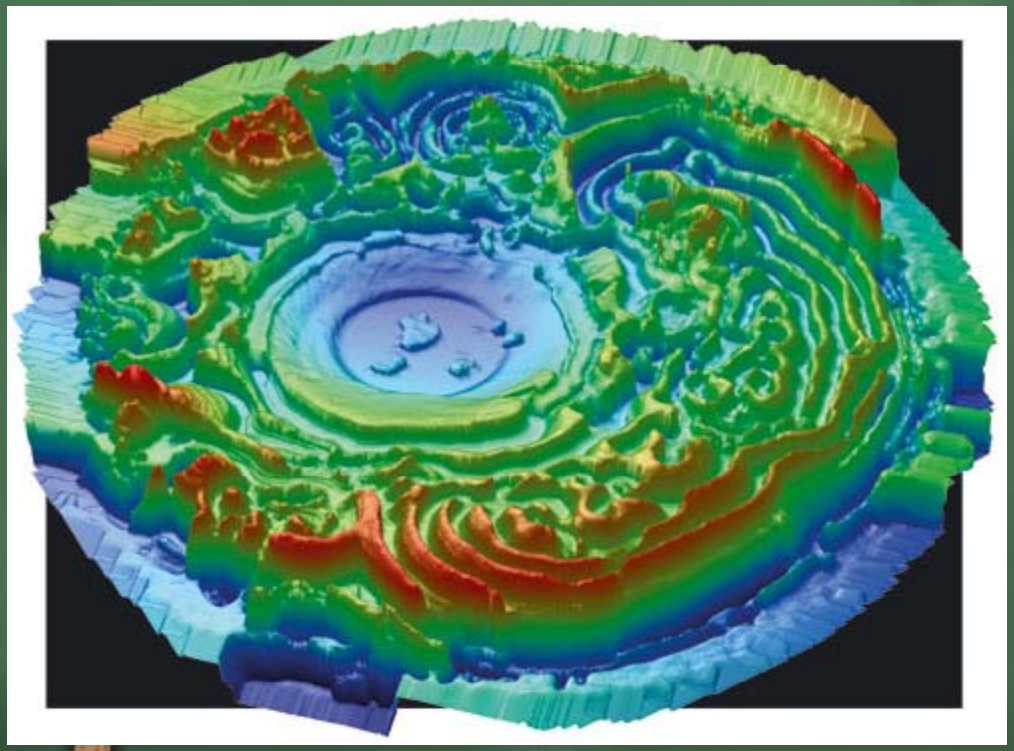
- Dislocations are sub-nm features
- Frank-read source generates many dislocations in one plane
- Therefore, it allows macroscopic observation of dislocations
  - Slip steps



Courtesy of DoITPoMS, University of Cambridge. Used with permission.

http://www.msm.cam.ac.uk/doitpoms/tlplib/miller_indices/printall.php

Dislocation Observation



Courtesy of Elsevier, Inc., http://www.sciencedirect.com. Used with permission.

- White light interferometer image from an optical profiler
- Partially decomposed crystalline GaN around a Ga droplet
- characteristics suggestive of a Frank-Read dislocation source
- Millimeter scale feature

http://materialstoday.com/covercomp2008.html


Questions?

3.40J / 22.71J / 3.14 Physical Metallurgy

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