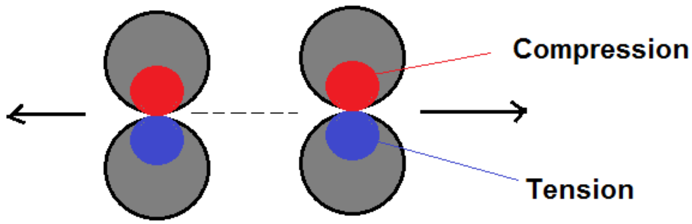
Forces between Dislocations

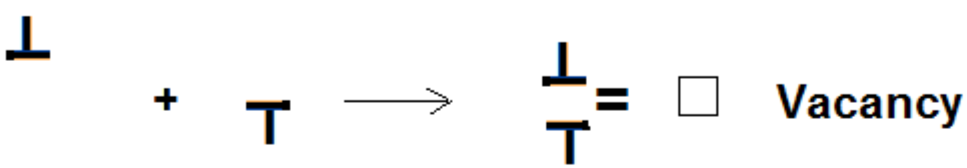
- Dislocation of like sign on the same plane repel each other.



Energy α Gb^2

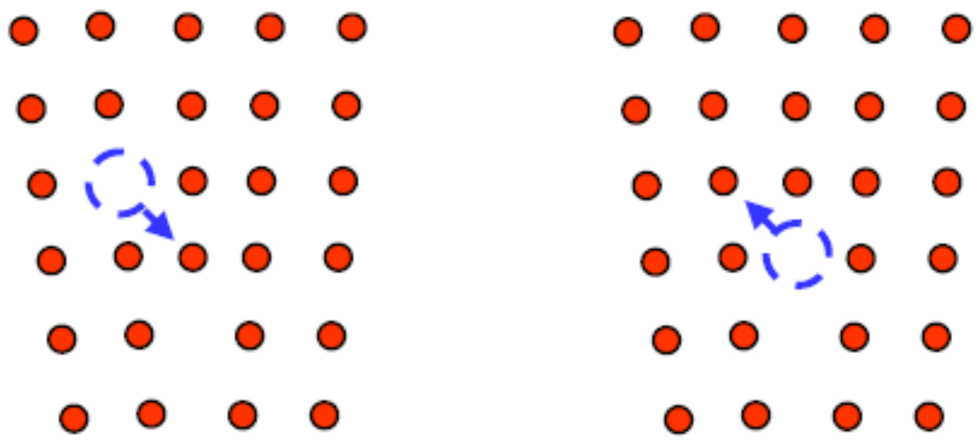
- Dislocation of opposite sign on the same plane would attract each other and annihilate themselves.

- If they are close to each other, they may produce a vacancy or interstitials.



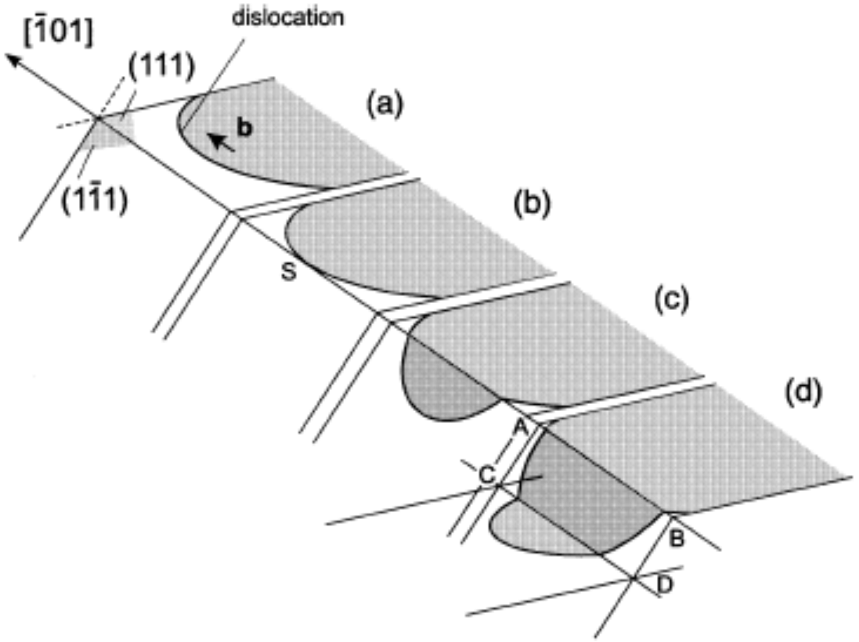
Dislocation Climb

- Edge dislocation glide in the slip plane containing dislocation line and Burgers vector.
- Edge dislocation can move out of its plane onto a parallel plane directly above or below the slip plane by a process called climb.
- Dislocation climb occurs by the diffusion of vacancies or interstitials to or from the site of dislocation .



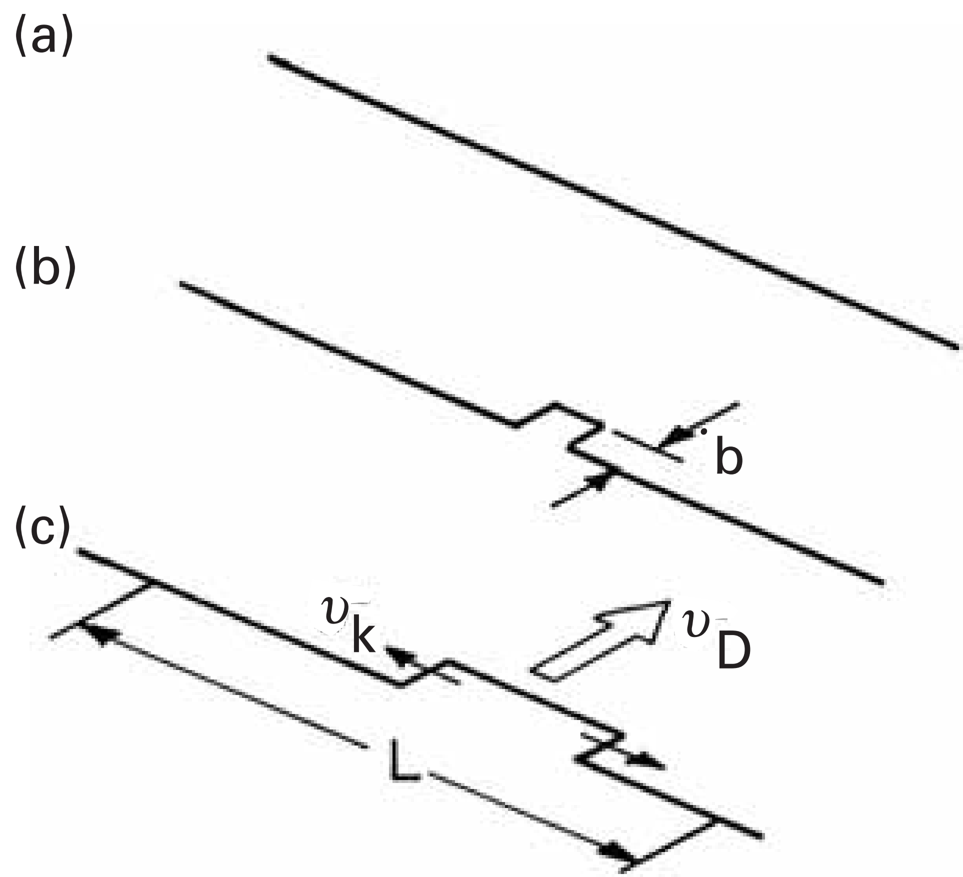
Dislocation Climb

- Edge dislocation move upward ⟶ positive climb
- Edge dislocation move downward ⟶ negative climb
- Climb is not possible with screw dislocation, since there is no extra half plane of atoms. However screw dislocation can easily change its plane via a process called cross-slip.

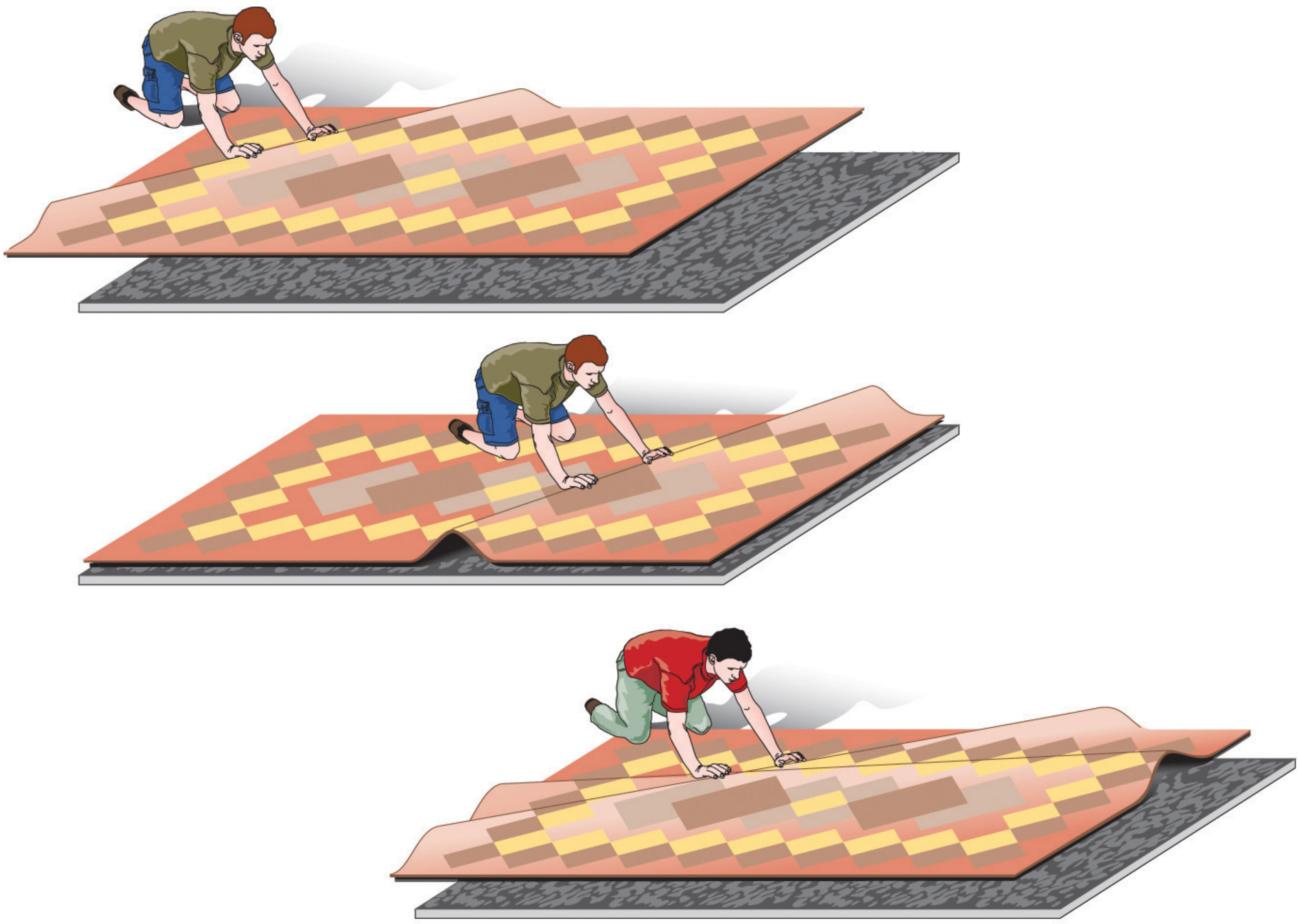


CROSS-SLIP OF A SCREW DISLOCATION

Mechanism of Cross-Slip (Seeger)



Intersection of Dislocations

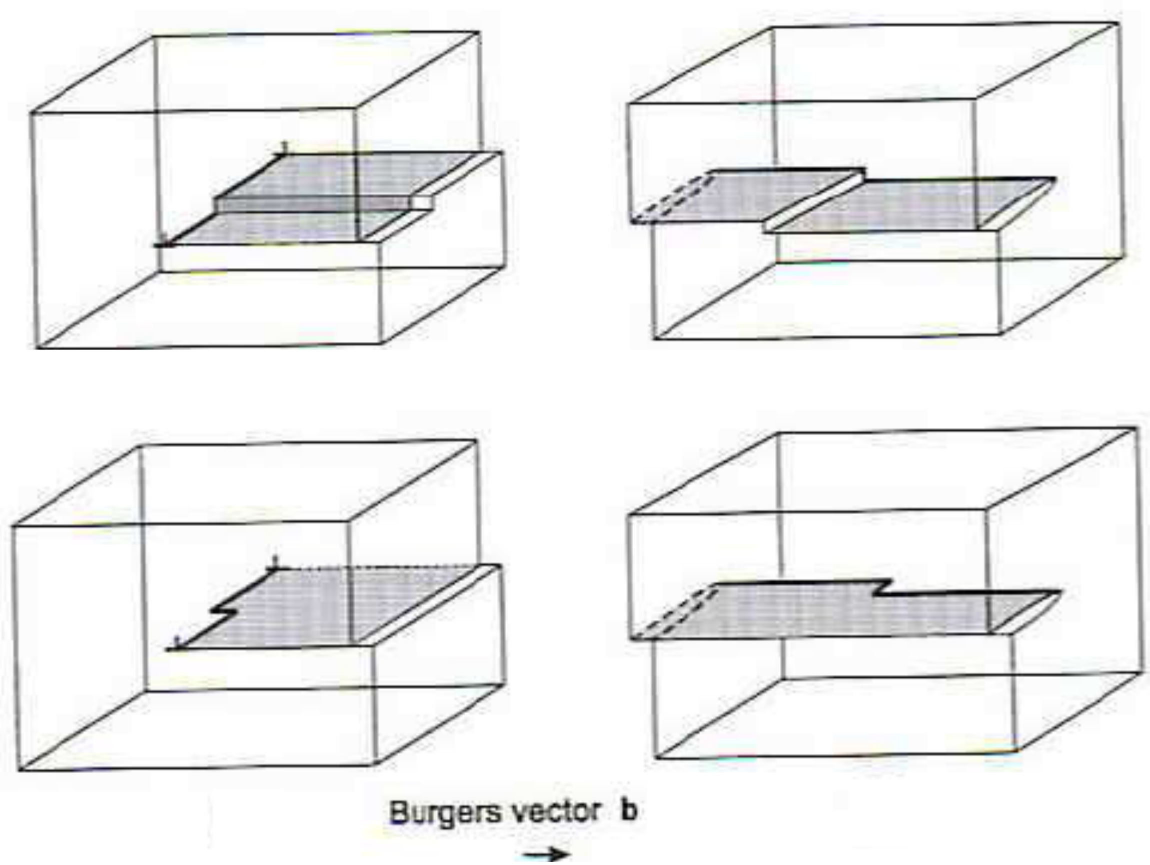


Intersection of Dislocations

- The intersection of two dislocations produces a sharp break (a few atom spacing in length) in dislocation line.

➢ Jog: a sharp break in the dislocation line moving it out of the slip plane.

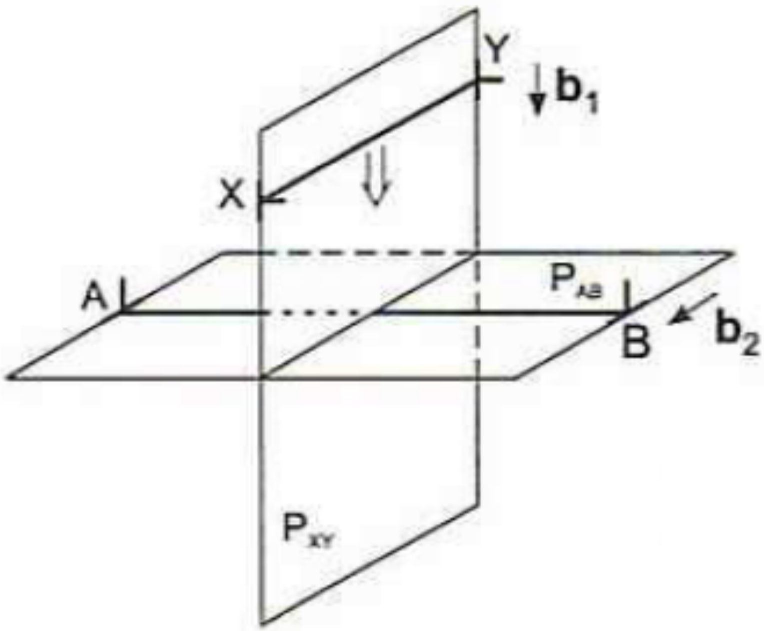
➢ Kink: a sharp break in the dislocation line which remains in the slip plane.

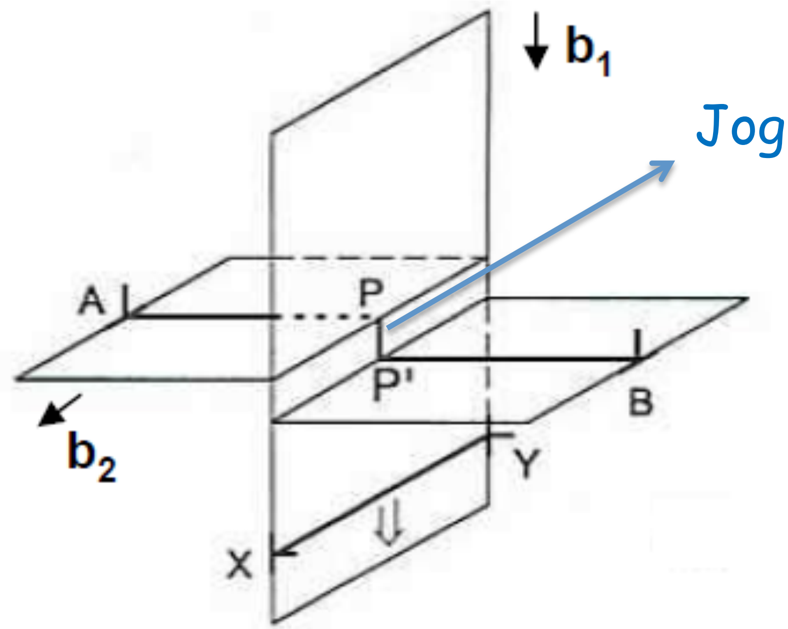


Intersection of Dislocations

- An edge dislocation XY with Burgers vector b_1 cuts through edge dislocation AB with Burgers vector b_2.

$$b_1 \perp b_2$$

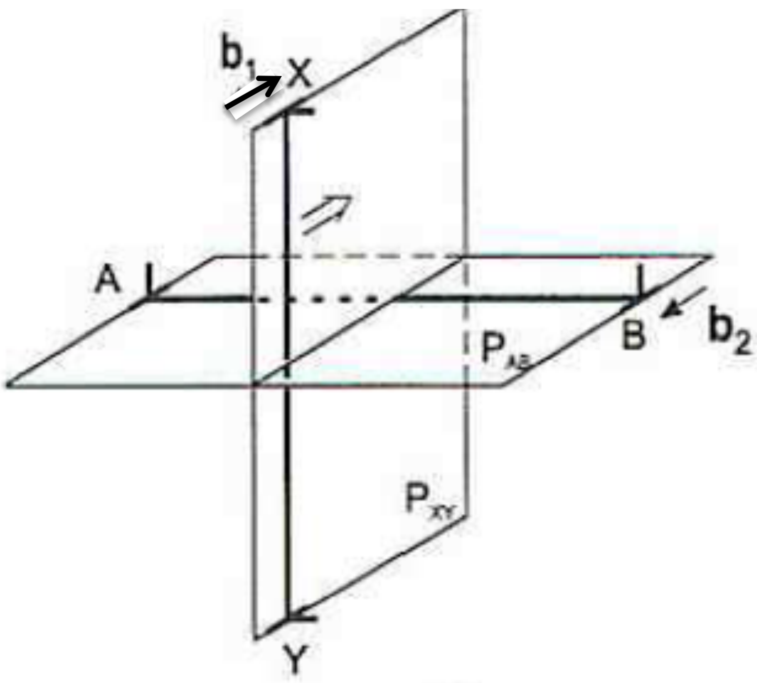


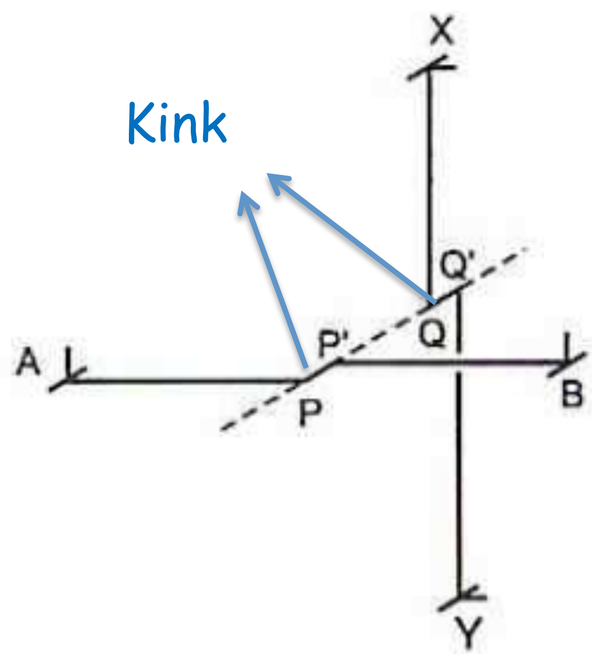


Intersection of Dislocations

- An edge dislocation XY with Burgers vector b_1 cuts through edge dislocation AB with Burgers vector b_2.

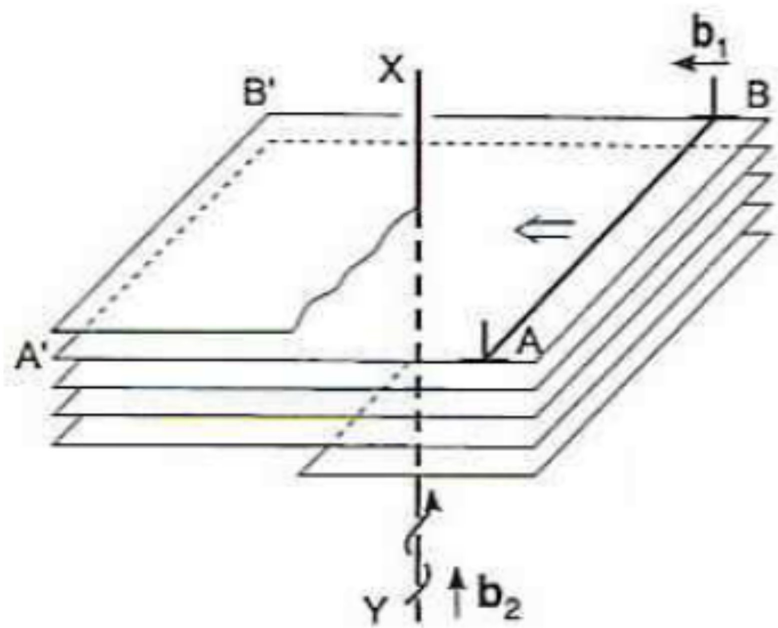
$$b_1 \parallel b_2$$

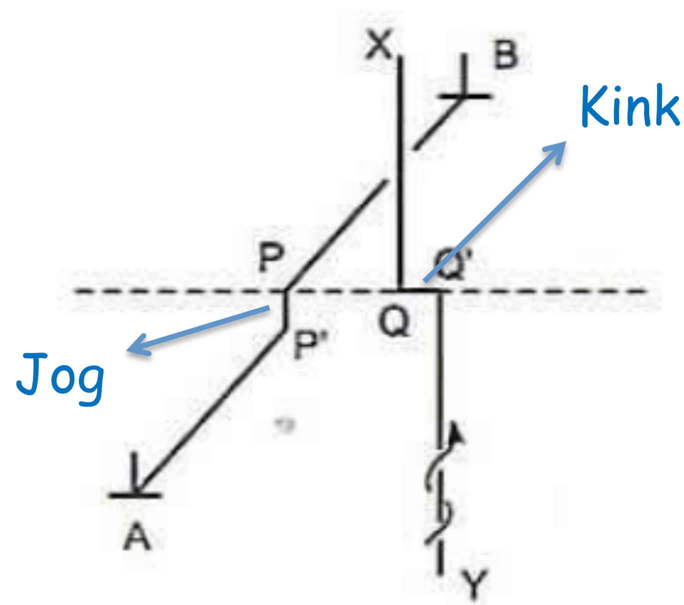




Intersection of Dislocations

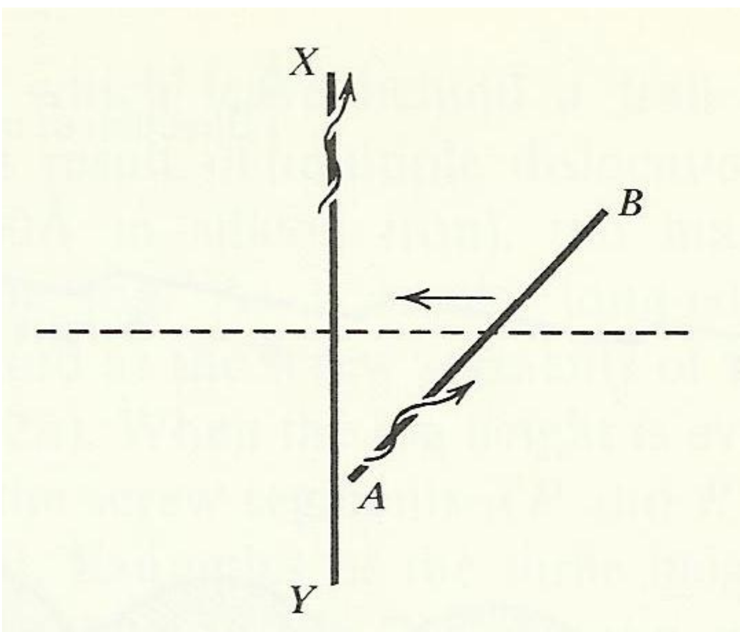
- An edge dislocation AB with Burgers vector b_1 cuts through screw dislocation AB with Burgers vector b_2.

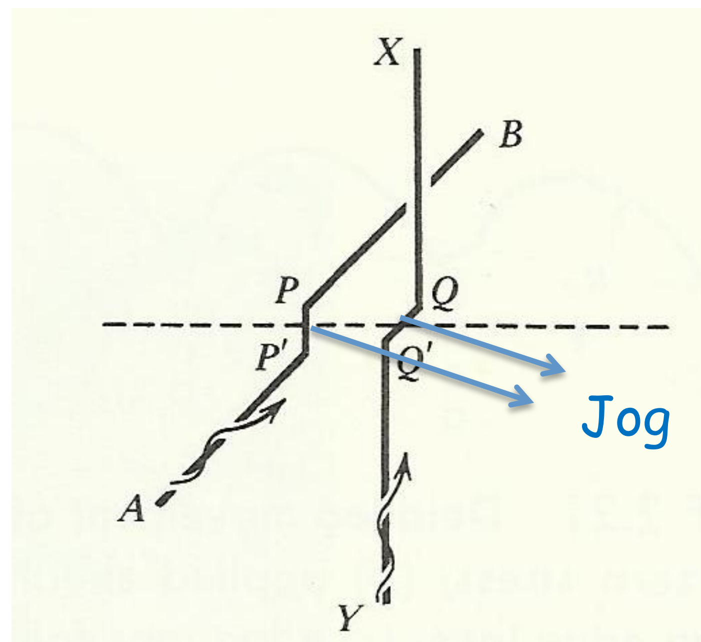




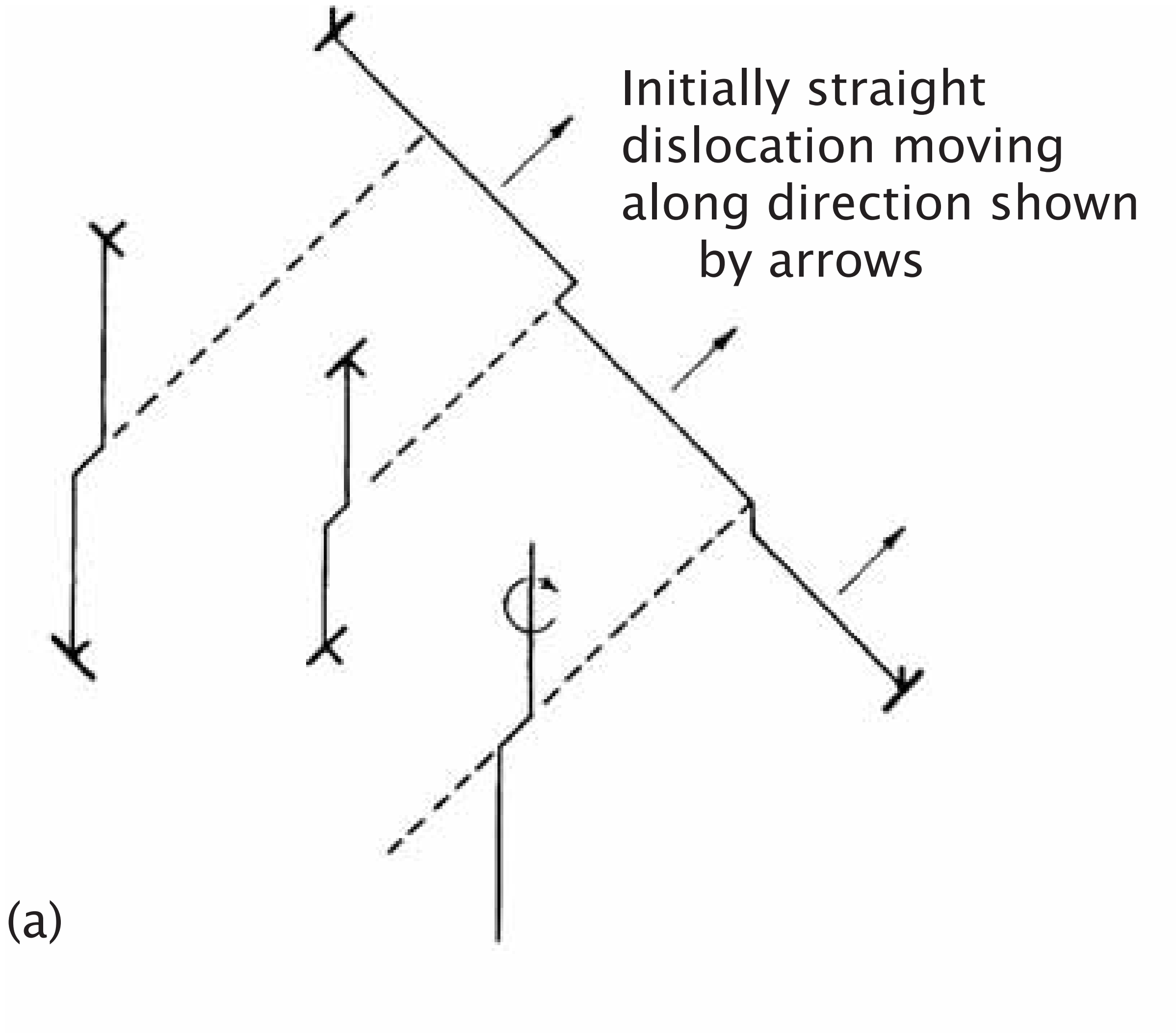
Intersection of Dislocations

- A screw dislocation AB with Burgers vector b_1 cuts through screw dislocation AB with Burgers vector b_2.

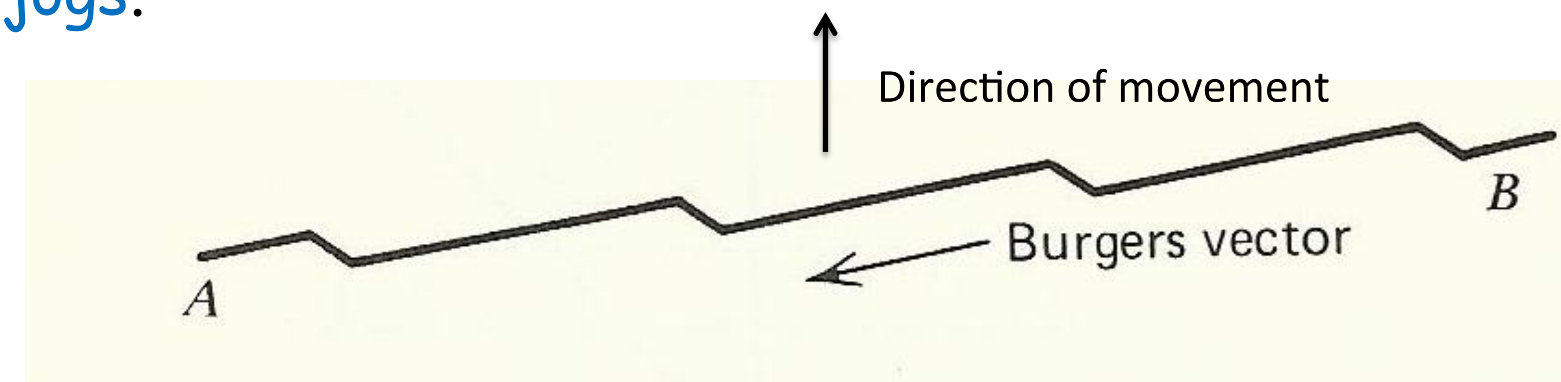




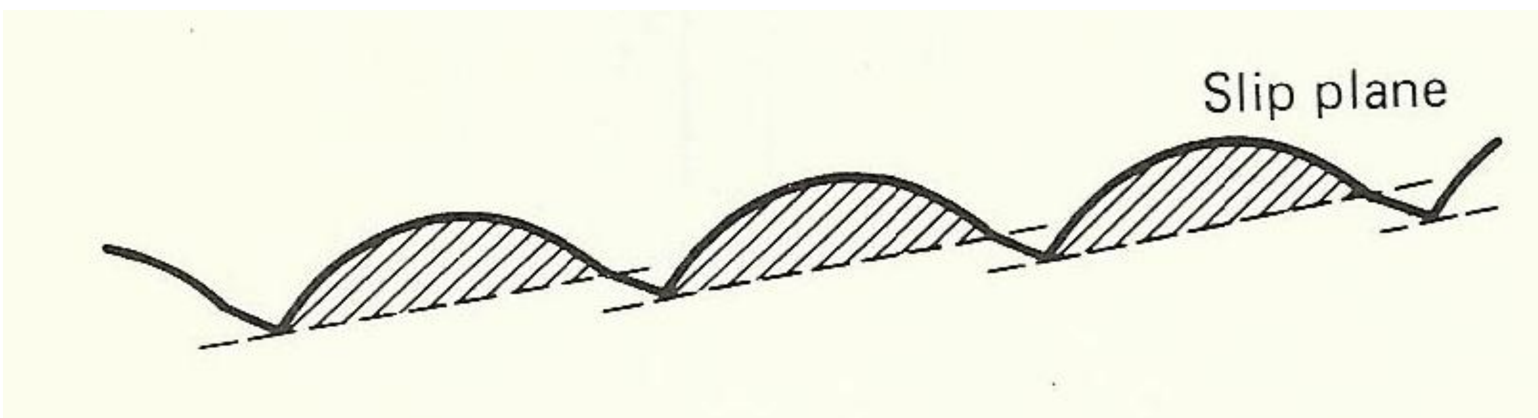
Intersection of Dislocations



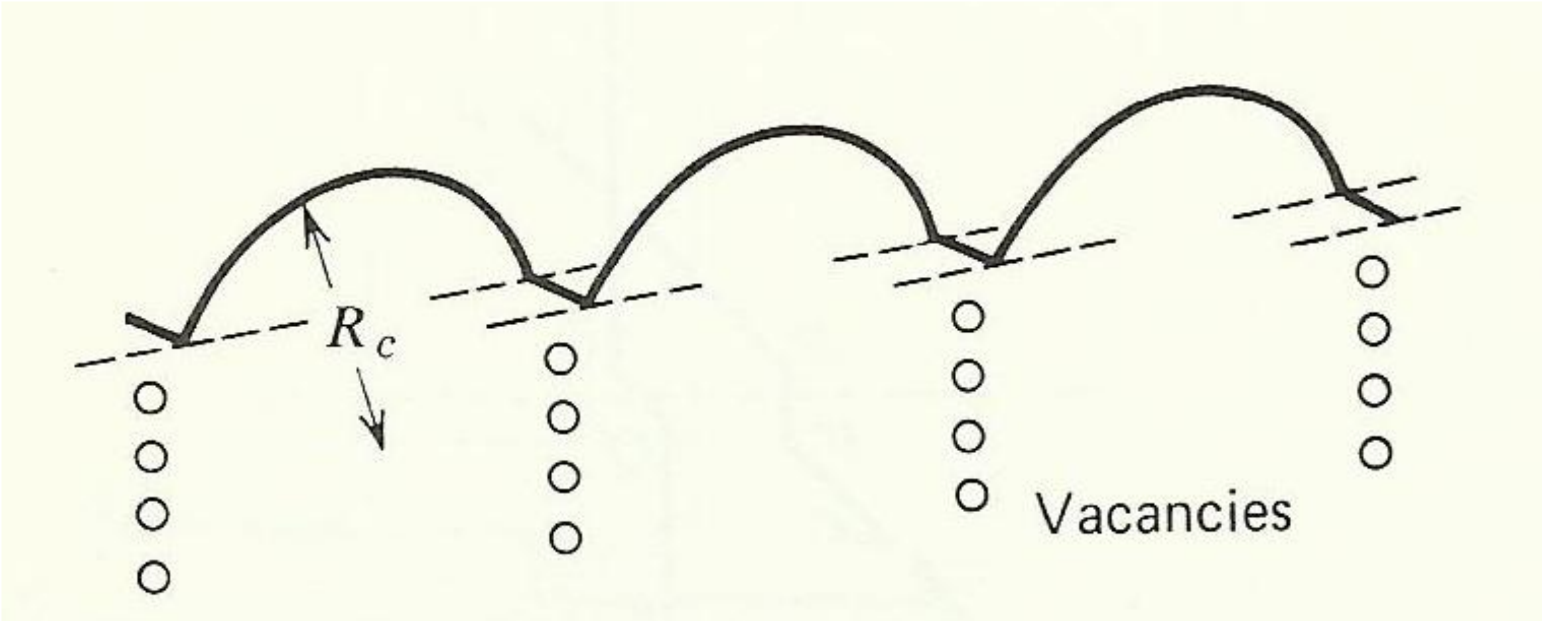
- Many intersections occur when a screw dislocation encounter a forest of screw dislocations, producing jogs.



- Jogs act as pinning points and cause dislocations to bow out when the shear stress is applied.

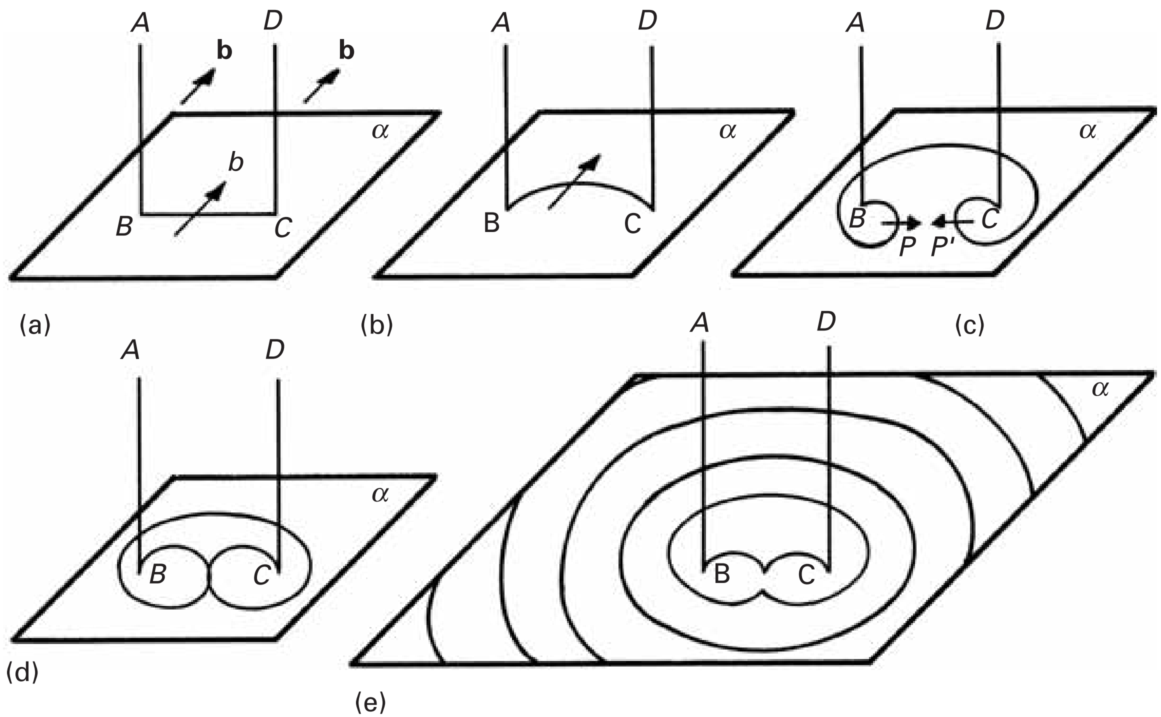


- At some critical radius R_c, the shear stress required to further decrease R is greater than the stress needed to climb.
- Then the dislocation will move forward leaving a trail of vacancies (or interstitials) behind each jog.



Multiplication of Dislocations (Frank & Read)

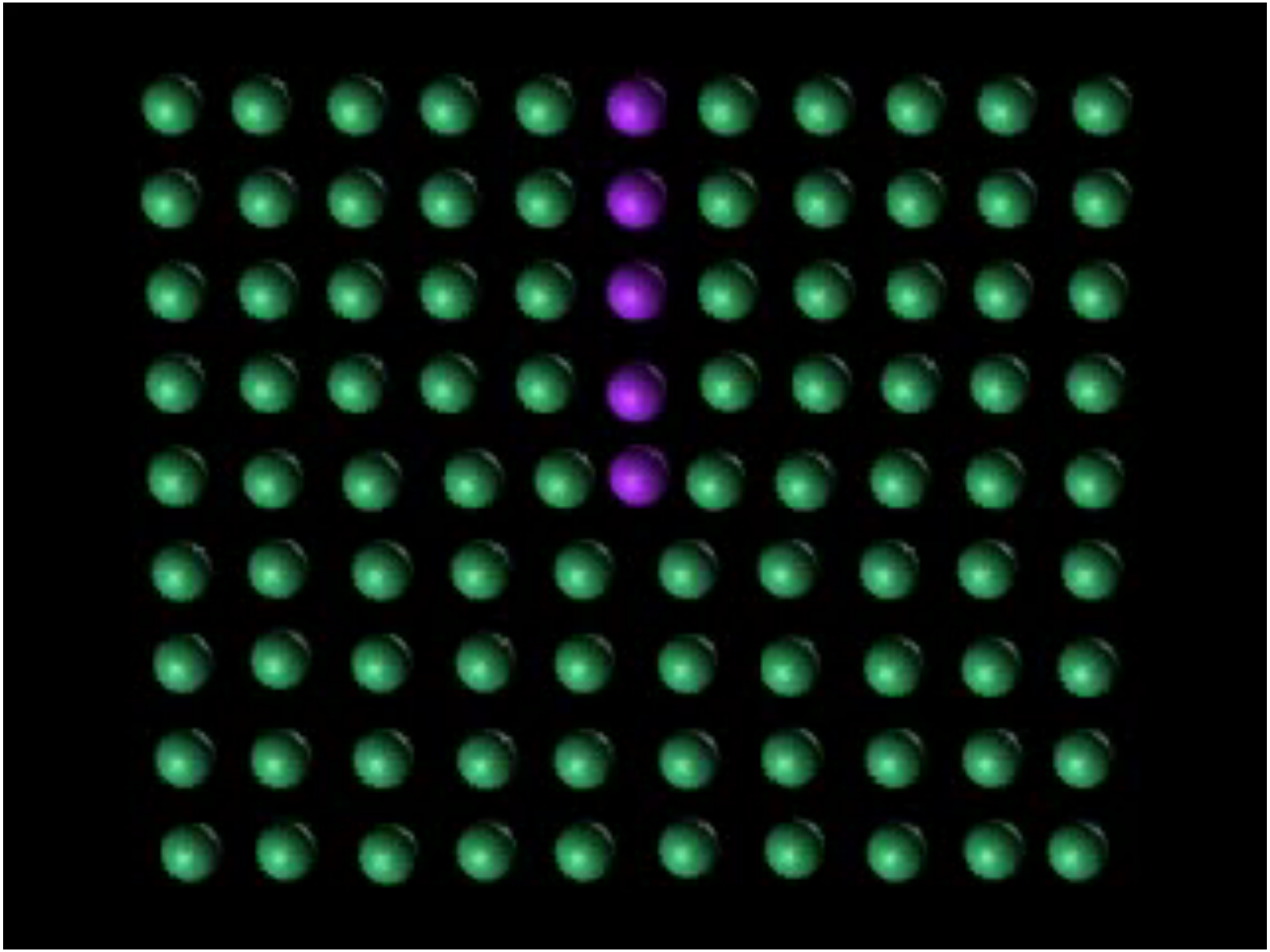
- The dislocation line AB bulges out (b) as the shear stress is applied.
- Beyond the maximum bulging point (c), the dislocation loop continues to expand till parts P and P' meet and annihilate each other to form a large loop and a new dislocation (e).



FRANK READ SOURCE

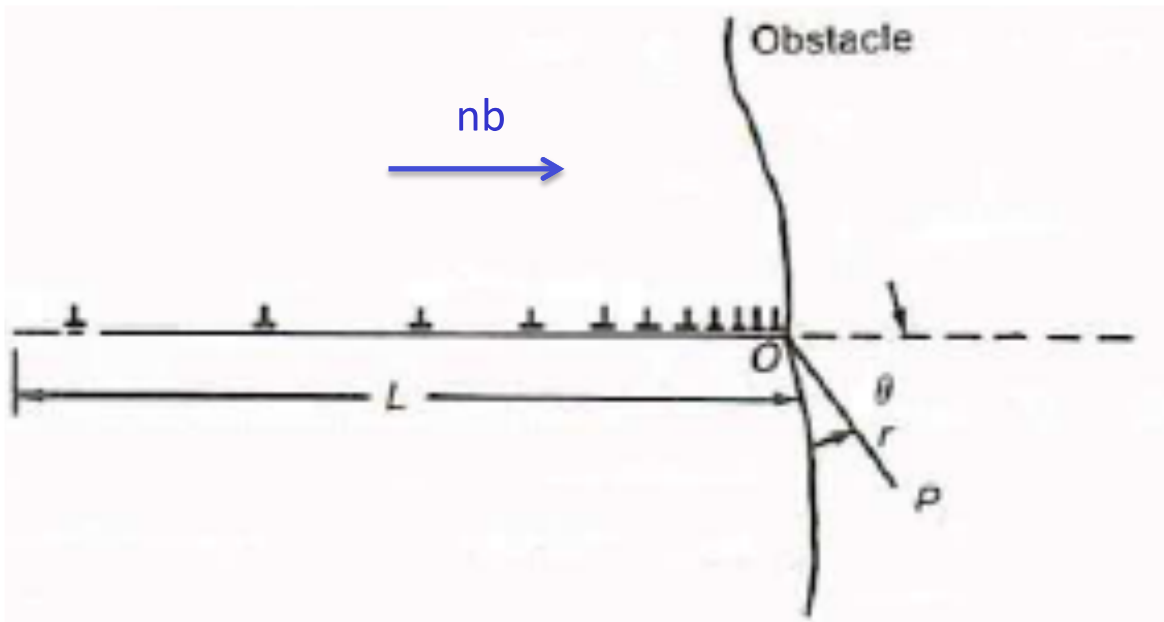
Dislocation-Point Defect Interaction

- solute atom > solvent atom:
  - Atom will be attracted to the tension side.
- solute atom < the solvent atom:
  - Atom will be attracted to the compression side.
- Vacancies will be attracted to regions of compression.
- Interstitials will be collected at regions of tension.

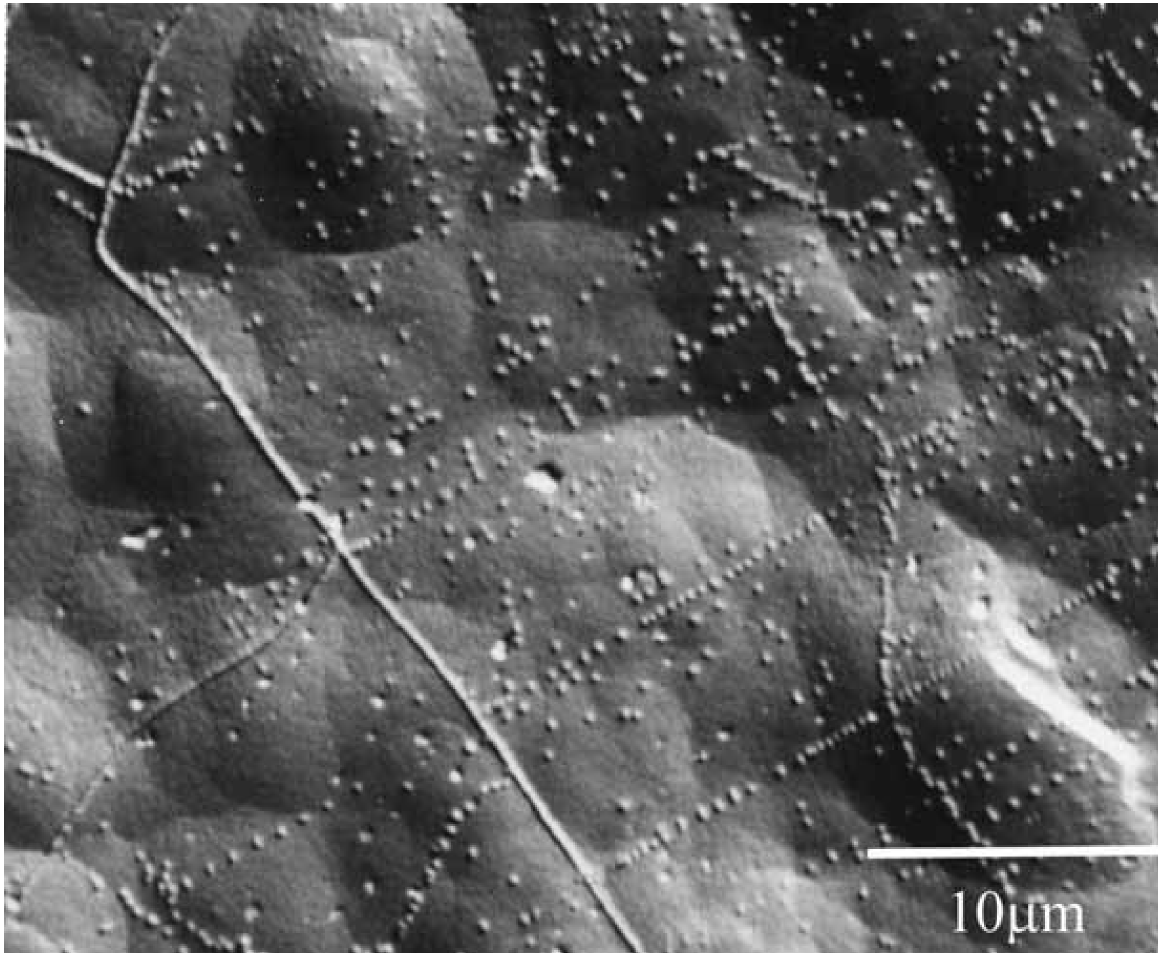


Dislocation Pile-Up

Dislocations often pile-up on slip planes at barriers i.e., grain boundaries or second phase particles.



Dislocation Pile-Up

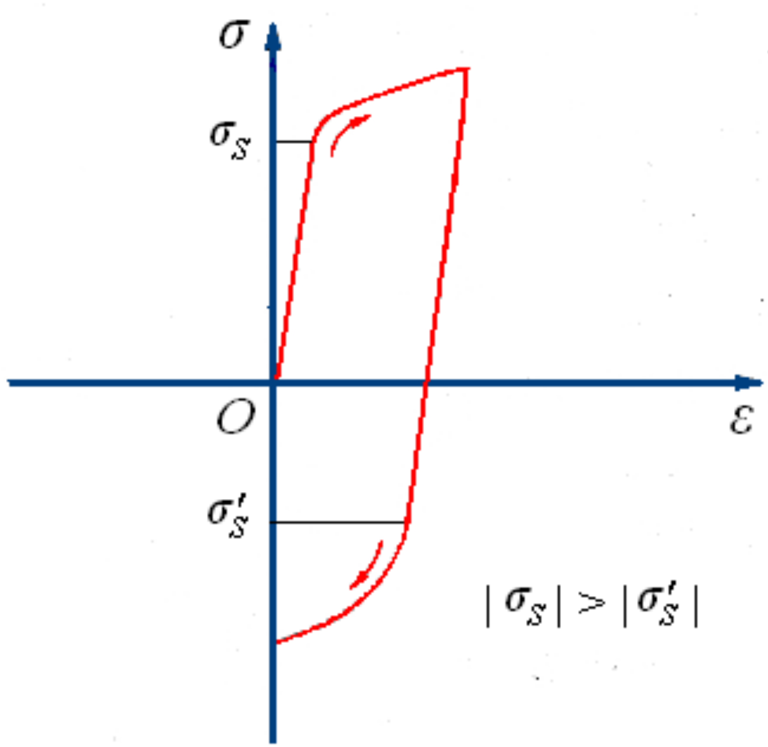


Dislocation Pile-Up

- The number of dislocations which can be supported by an obstacle will depend on
  - type of barrier,
  - orientation relationship between the slip plane and the structural features at the barrier,
  - material,
  - temperature.
- Breakdown of a barrier can occur by
  - slip on a new plane,
  - climb of dislocations around the barrier,
  - the generation of high enough tensile stresses to produce a crack.

Bauschinger Effect

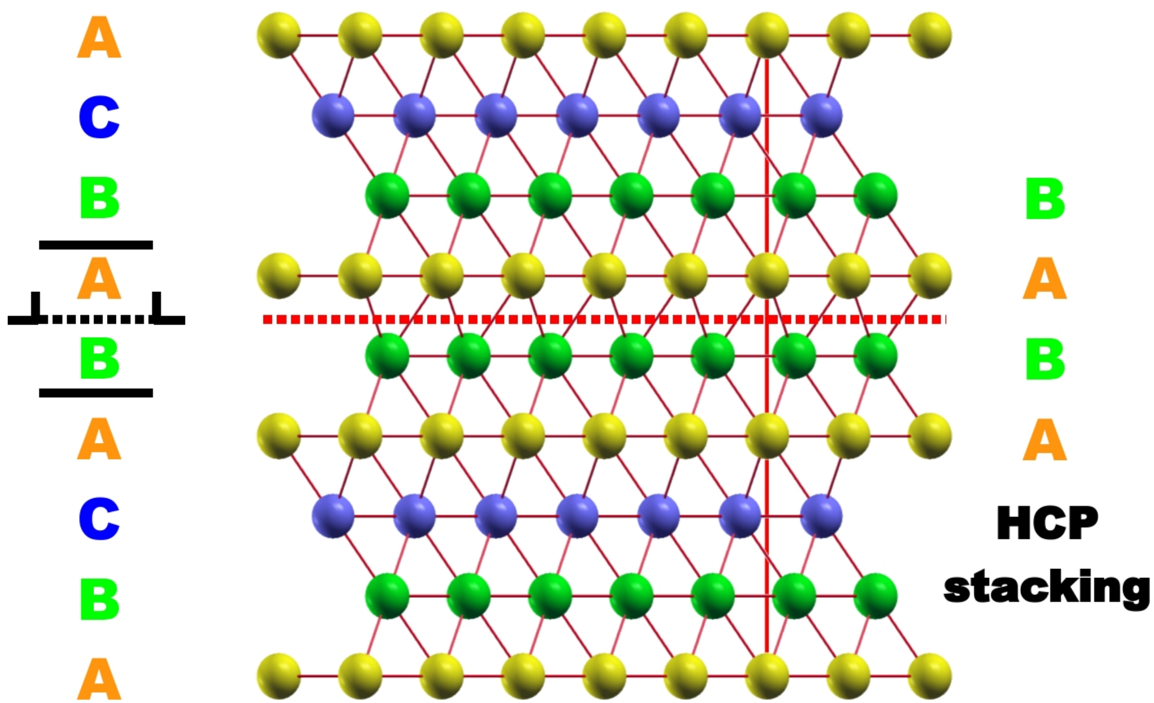
The lowering of the yield stress when deformation in one direction is followed by deformation in the opposite direction is called the Bauschinger effect.



- Back stress
- Creation of dislocations with opposite sign

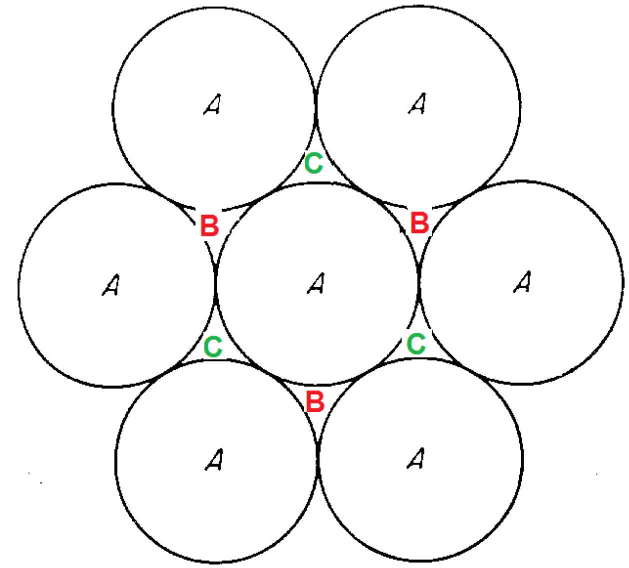
Stacking Faults

Errors, or faults, in the stacking sequence can be produced in most metals by plastic deformation.



Slip on the {111} plane in an fcc lattice produces a deformation stacking fault

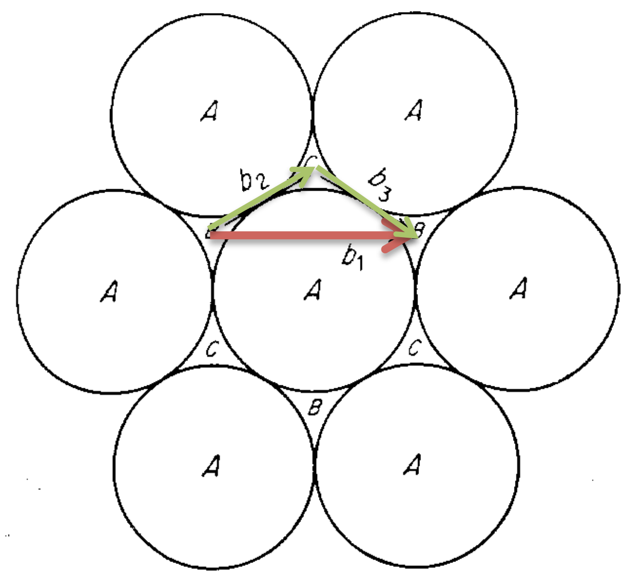
The {111} planes of FCC lattice are stacked on a close packed sequence ABCABC

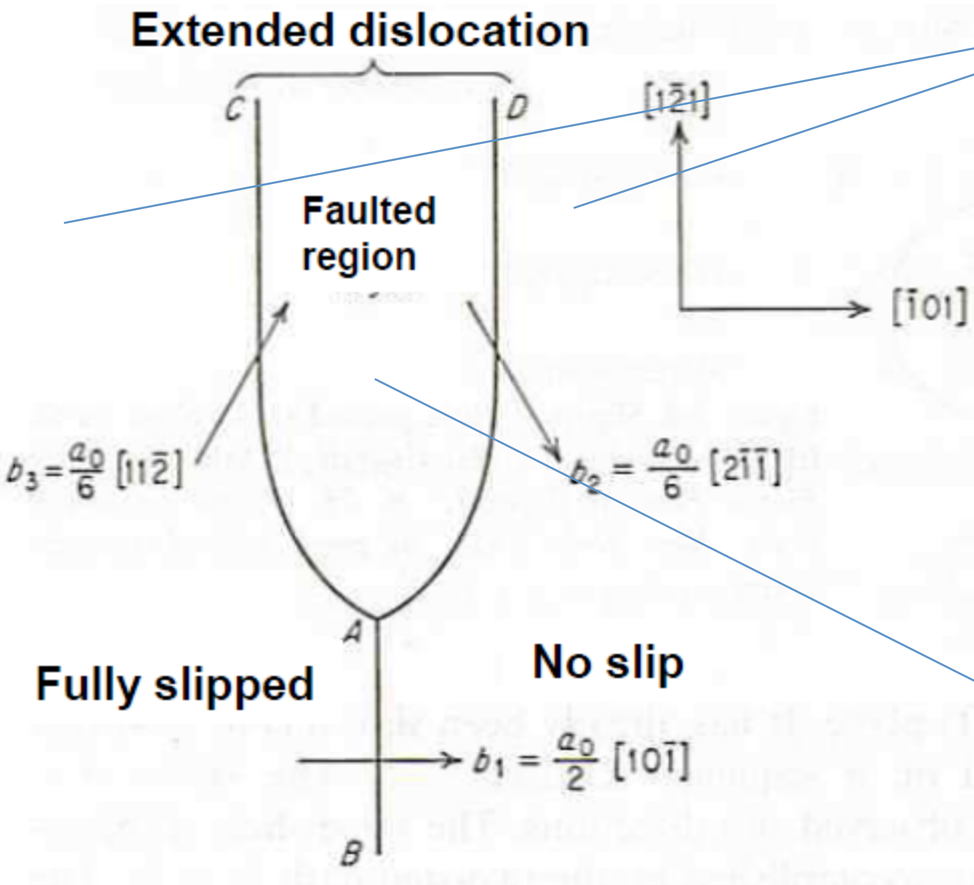


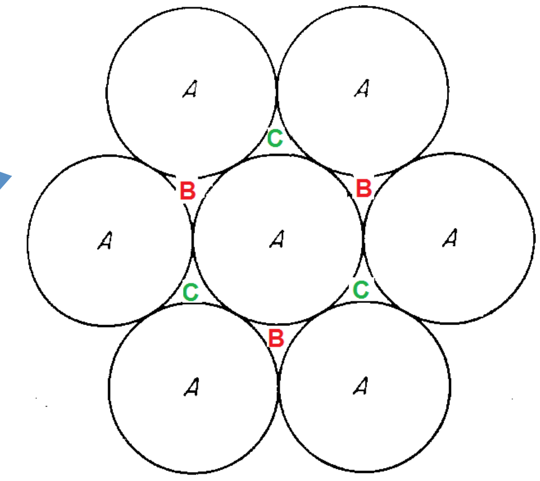
Perfect dislocation with b = $(a_0/2)$ [101] can decompose into two partial dislocations.

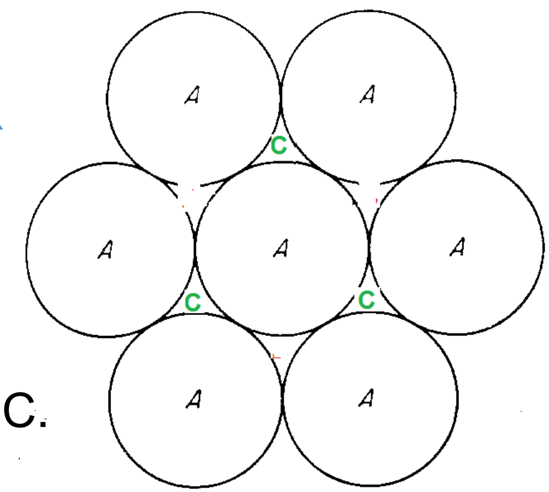
$$b_1 \rightarrow b_2 + b_3$$

$$\frac{a_o}{2}[10\bar{1}] \rightarrow \frac{a_o}{6}[2\bar{1}\bar{1}] + \frac{a_o}{6}[11\bar{2}]$$





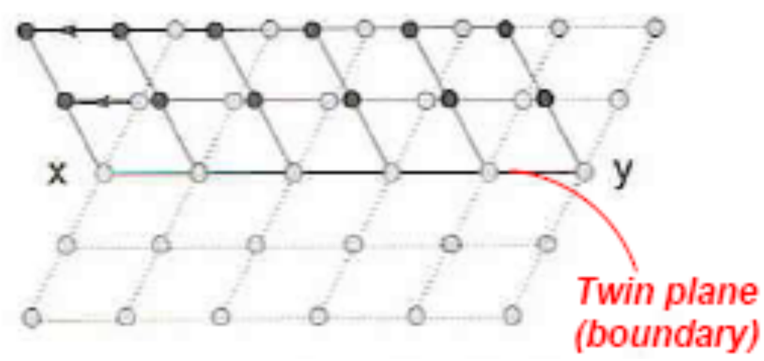




This Shockley partials creates a stacking fault ABCAC/ABC.

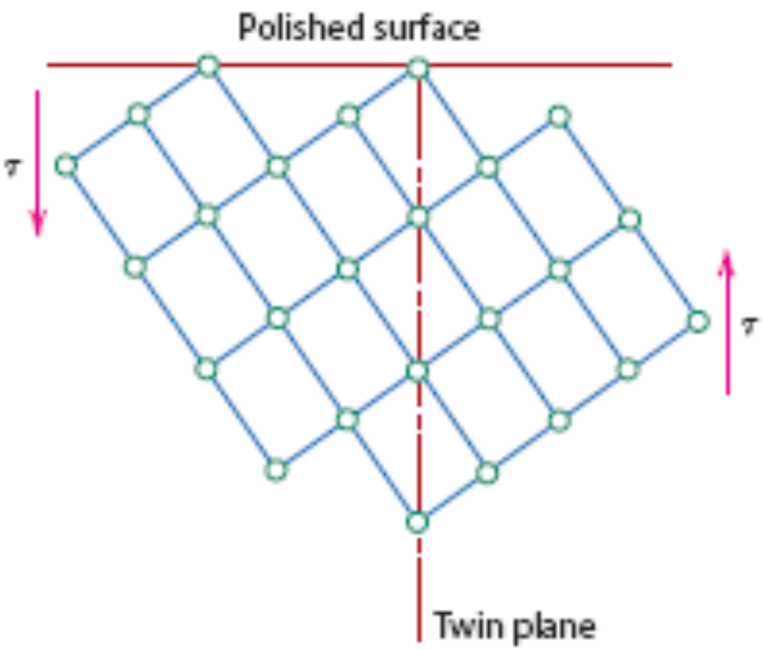
Deformation by Twinning

- Twinning occurs as atoms on one side of the boundary (plane) are located in mirror image positions of the atoms on the other side. The boundary is called twinning boundary.
  - Mechanical Twin (BCC, HCP): rapid rate of loading (shock loading) and decreased temperature.
  - Annealing Twin (FCC): Occurs during annealing heat treatment.

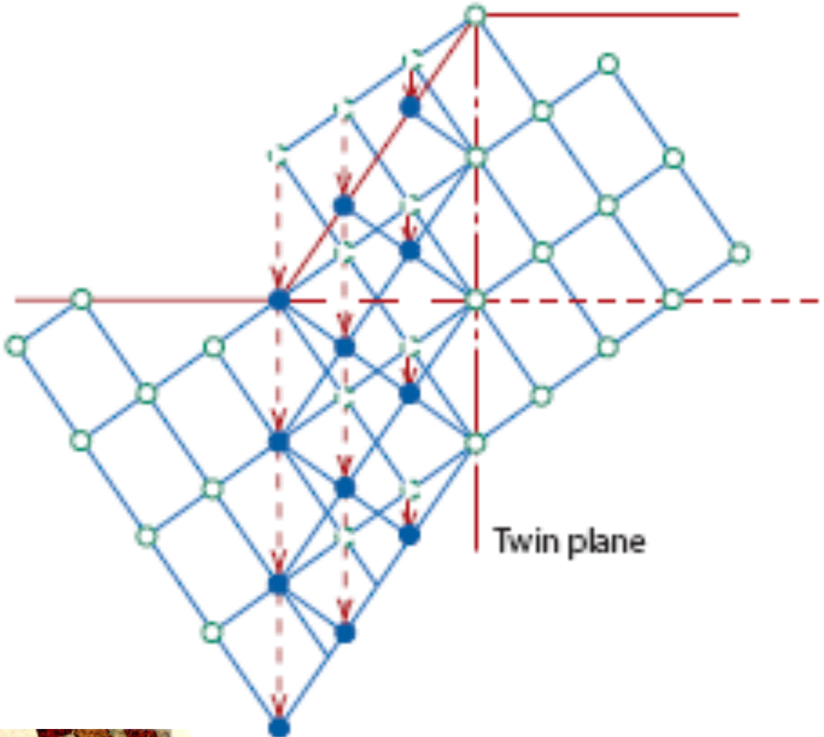


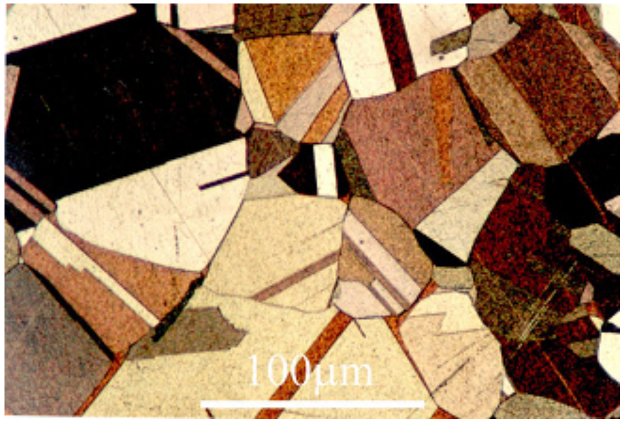
- Twinning normally occurs when slip systems are restricted.

Before deformation



After deformation





Deformation by Twinning

- The driving force: applied shear stress.
- Atom movements << atomic distance.
- small lattice strain ➔ no large deformation
- Twins do not extends beyond grain boundaries.

Twinning changes orientation

⬇

new slip systems in a favorable orientation

⬇

additional slip can take place