Dislocation energy

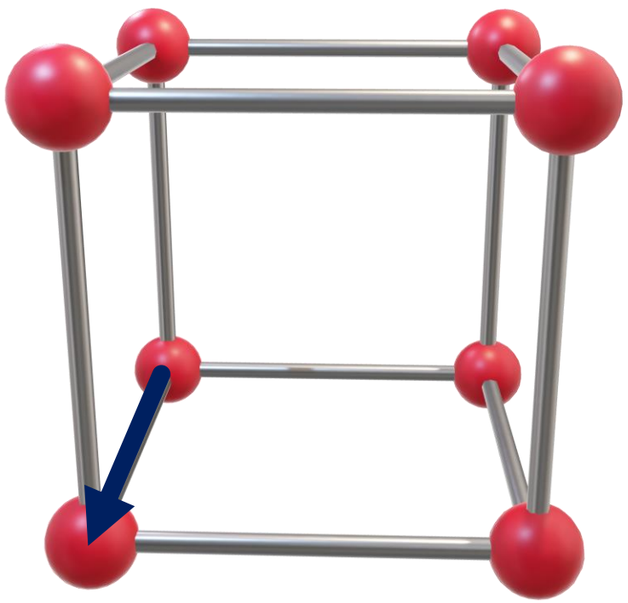
Thapar Institute of Engineering & Technology
(Deemed to be University)
Bhadson Road, Patiala, Punjab, Pin-147004
Contact No. : +91-175-2393201
Email : info@thapar.edu

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Burgers vector

The Burger vector b is the shortest lattice translation.

SC



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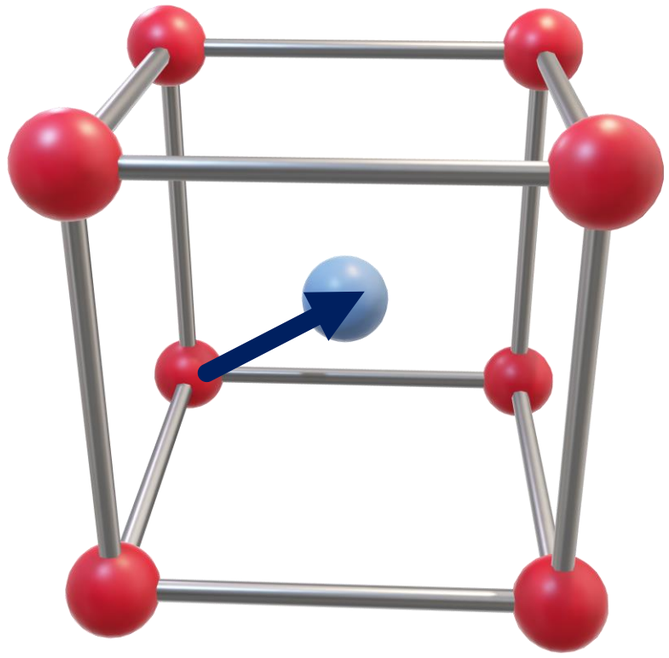

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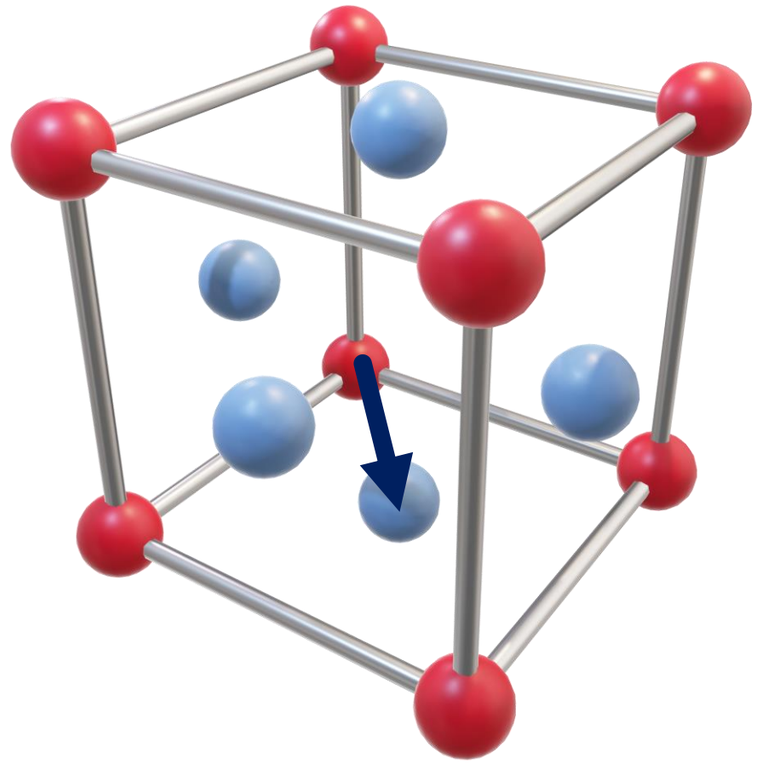
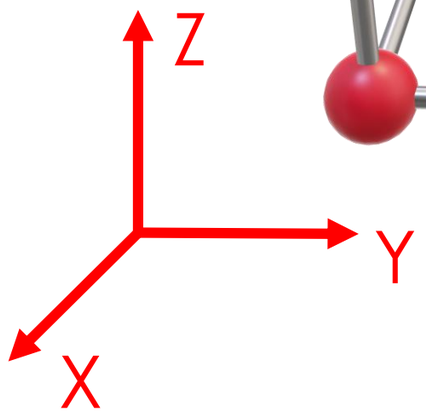
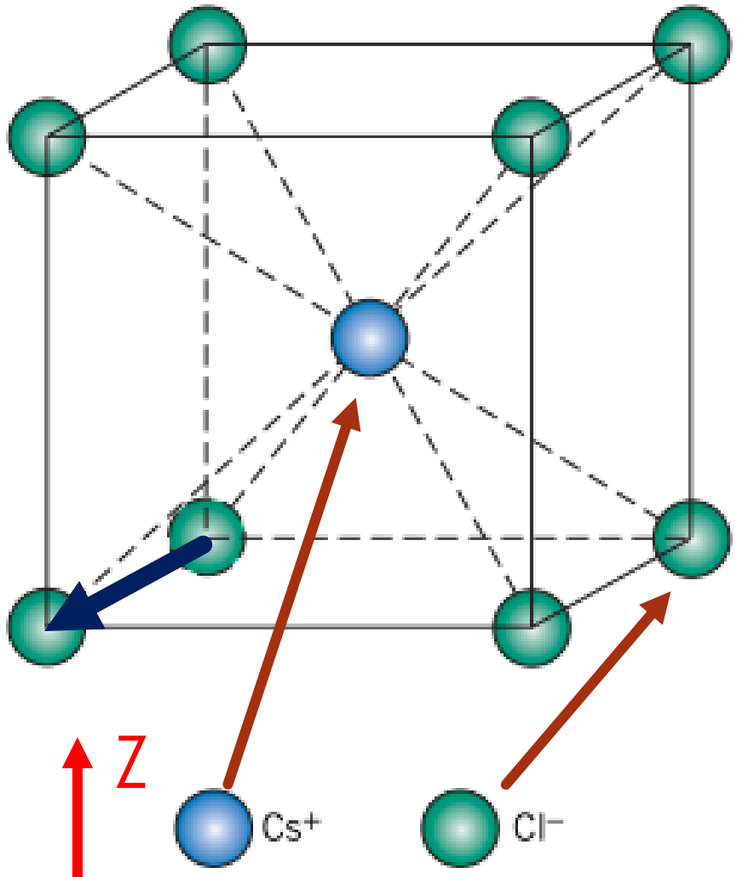


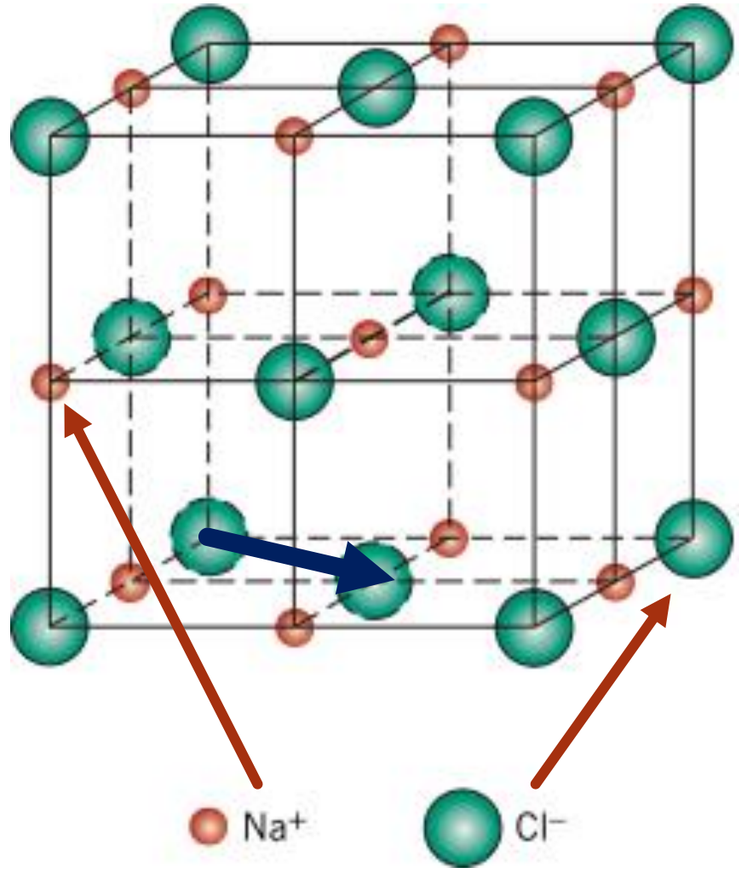


Burgers vector

CsCl



NaCl



Burgers Vector

The Burger vector b is the shortest lattice translation.

Crystal system	Direction of Burger vector
Monoatomic FCC	½<110>
Monoatomic BCC	½<111>
Monoatomic SC	<100>
NaCl type structure	½<110>
CsCl type structure	<100>
DC type structure	½<110>

Burgers Vector

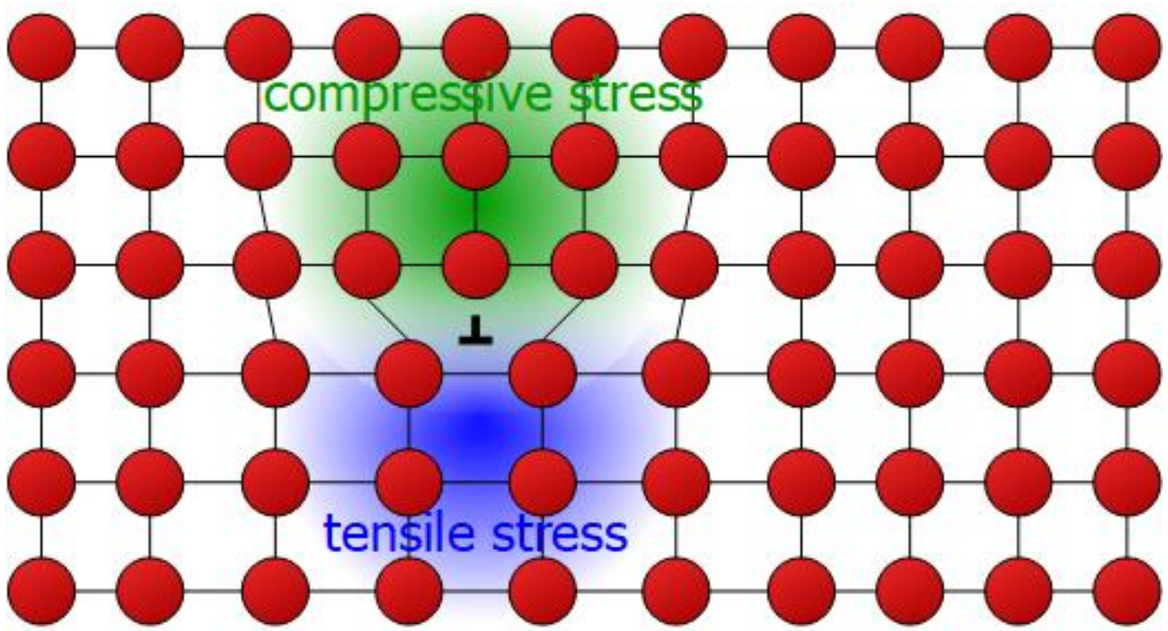
Why Burgers vector is large in ionic crystals?

- In ionic crystals if there is an extra half-plane of atoms contained only atoms of one type then the charge neutrality condition would be violated → this is an unstable condition.

- This implies that Burgers vector has to be a full lattice translation vector:
  CsCl → **b = <100>** *Cannot be ½<111>*
  NaCl → **b = ½ <110>** *Cannot be ½<100>.*

- This makes Burgers vector large in ionic crystals:
  Cu → $|\mathbf{b}| = 2.55$ Å
  NaCl → $|\mathbf{b}| = 3.95$ Å.

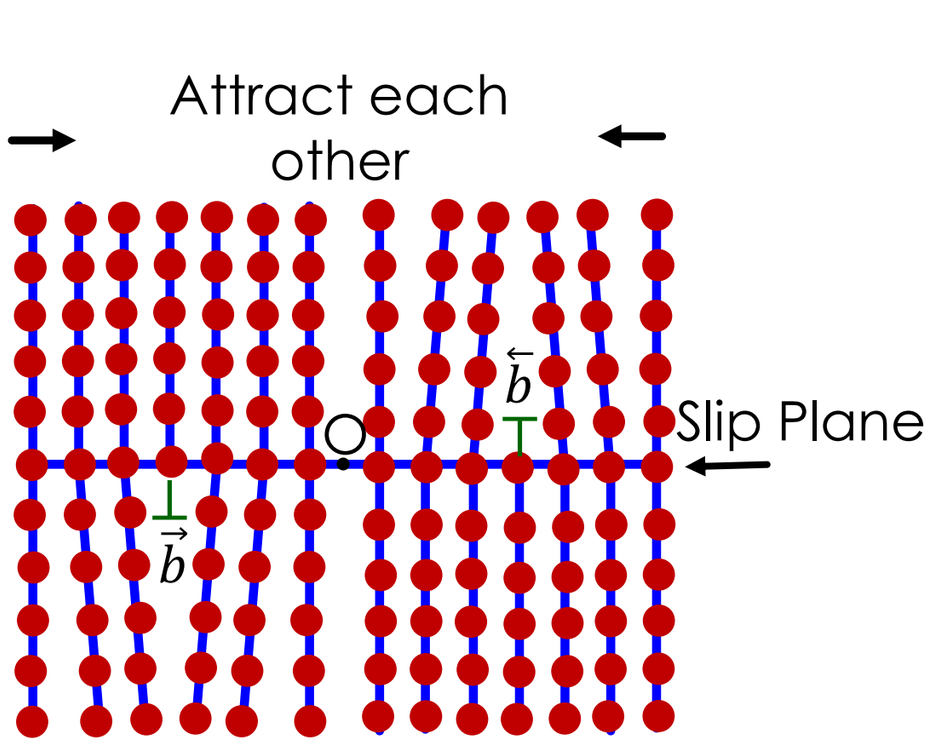
1 Dimensional dislocations

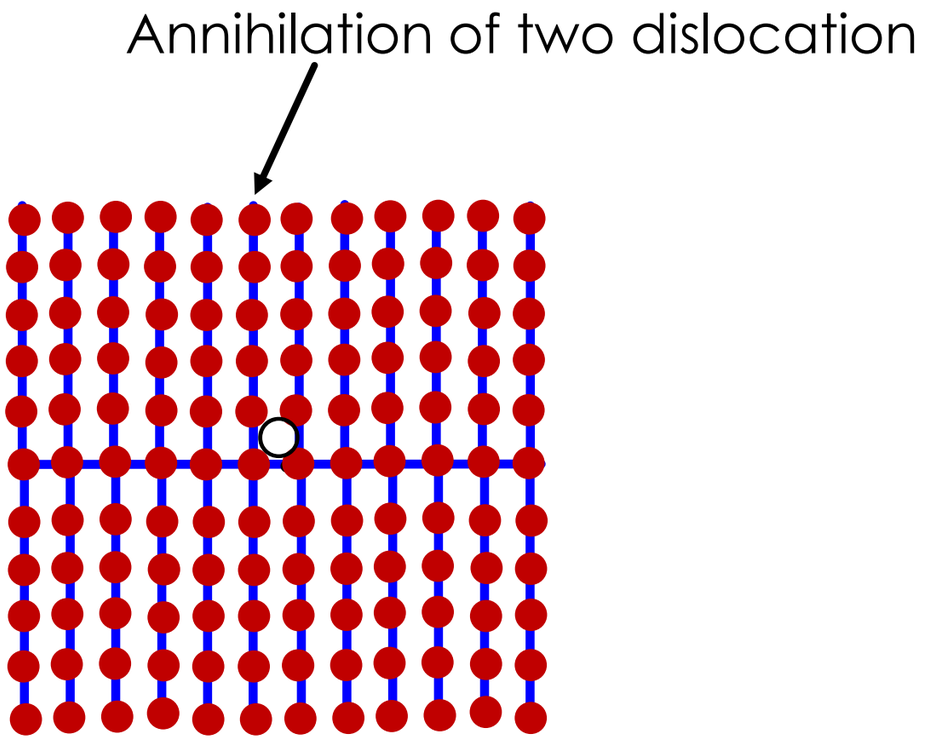


Forces between dislocations

1. Two dislocations of opposite sign (i.e. having equal but opposite Burgers vector) on the same plane, attracts each other.

When they combine , elimination of extra half plane atoms take place causing annihilation of the two dislocations to minimize the total energy of the system.

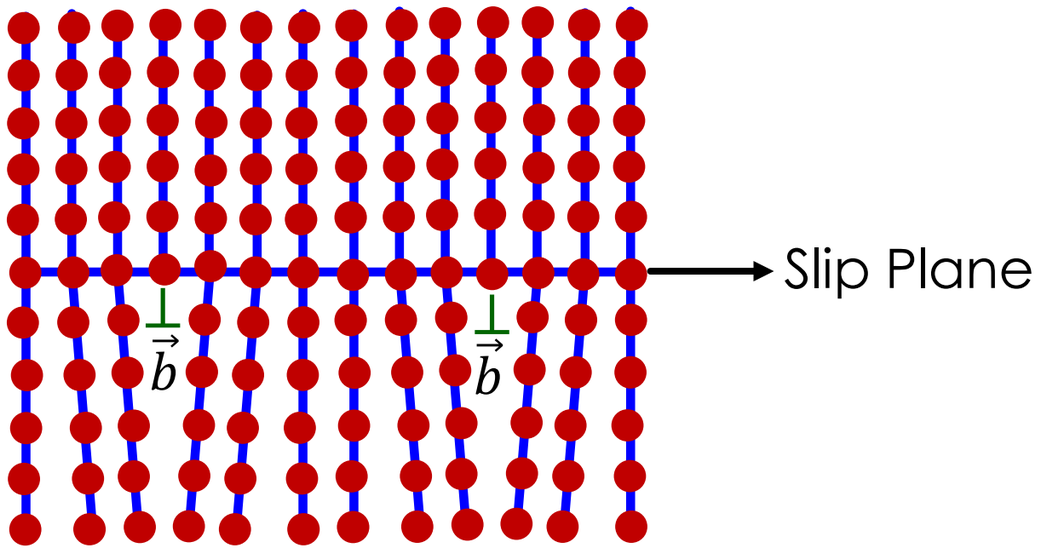


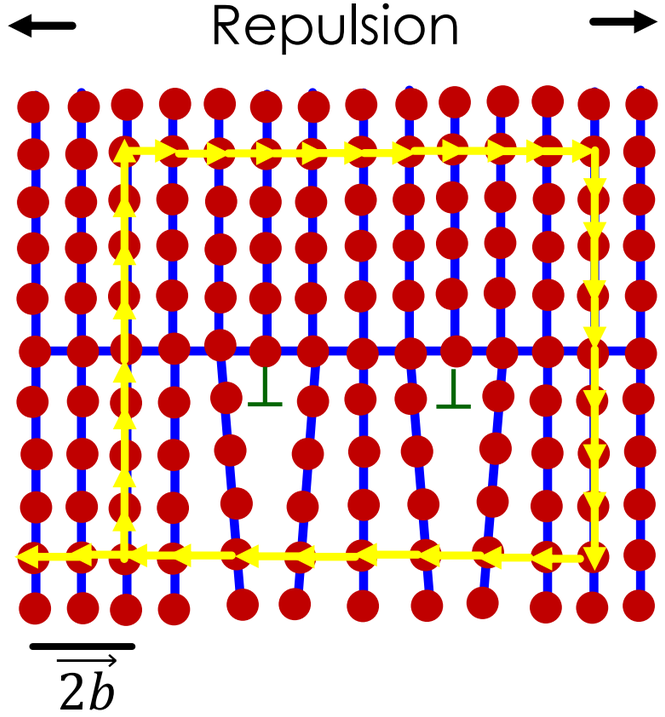


Forces between dislocations

2. Two parallel dislocations of similar sign on the same plane, repel each other.

   Because when they come closer, there takes place an increase of energy. Burgers vector has been drawn assuming the two as a single dislocation with Burgers vector $\overrightarrow{2b}$.

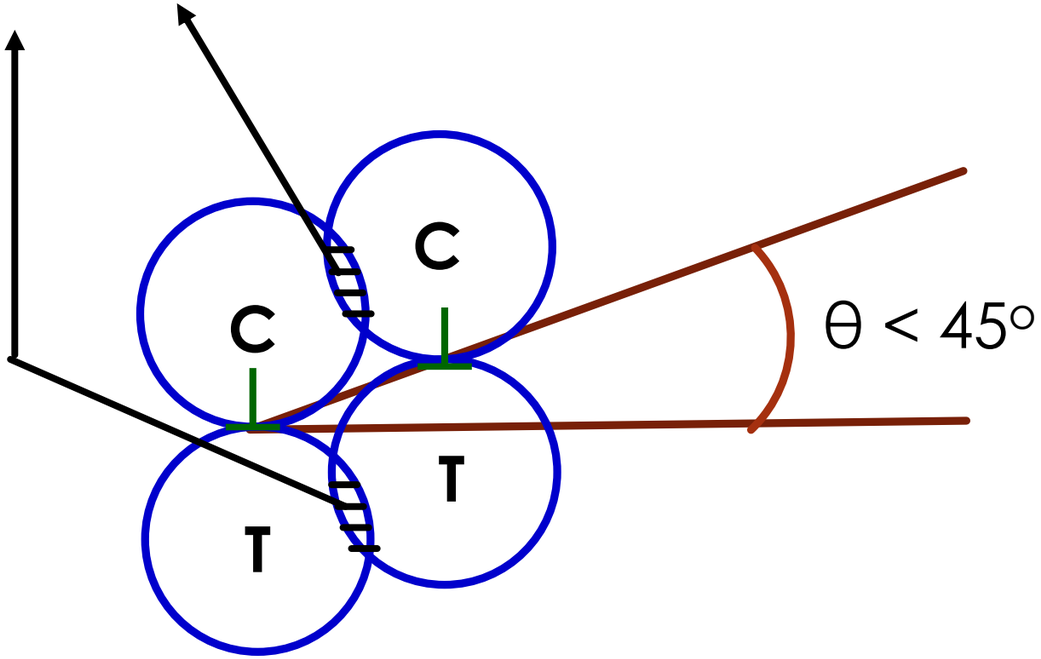




Forces between dislocations

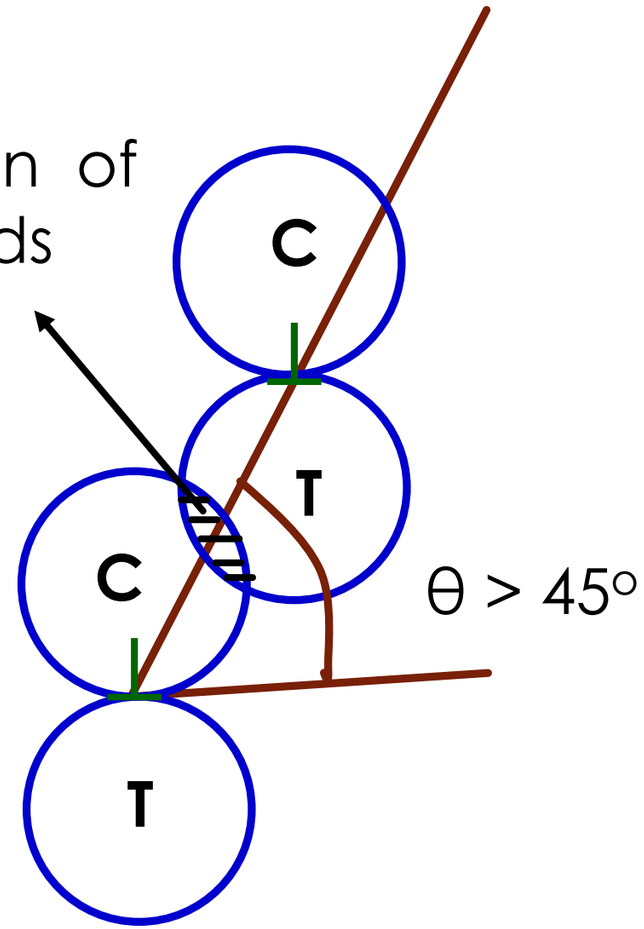
3. Two parallel edge dislocations of the same sign on different slip planes attract or repel reach other depending on the angle between the slip direction and the line joining them.

Reinforcement of stress fields



Repulsion

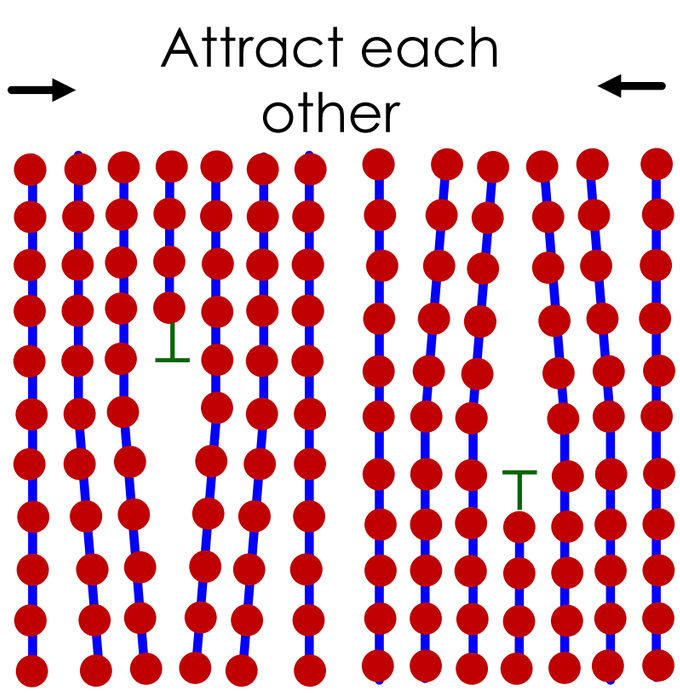
Cancellation of stress fields

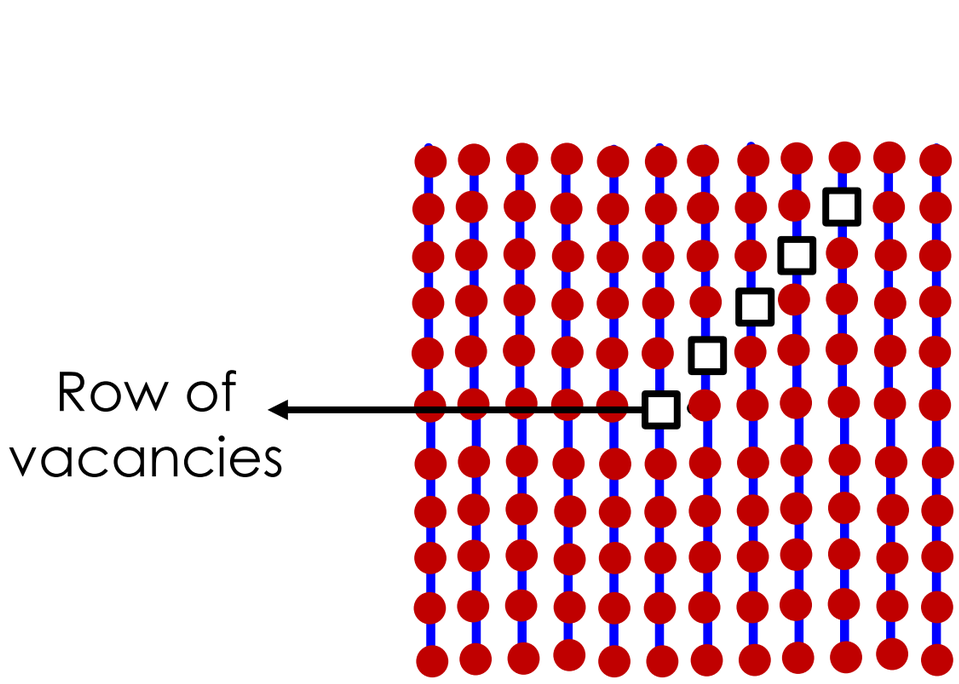


Attraction

Forces between dislocations

4. Two parallel edge dislocations of opposite signs on nearby planes attract each other and annihilate each other leaving behind a row of vacancies or a row of interstitialcy atoms.





Dislocation Energy

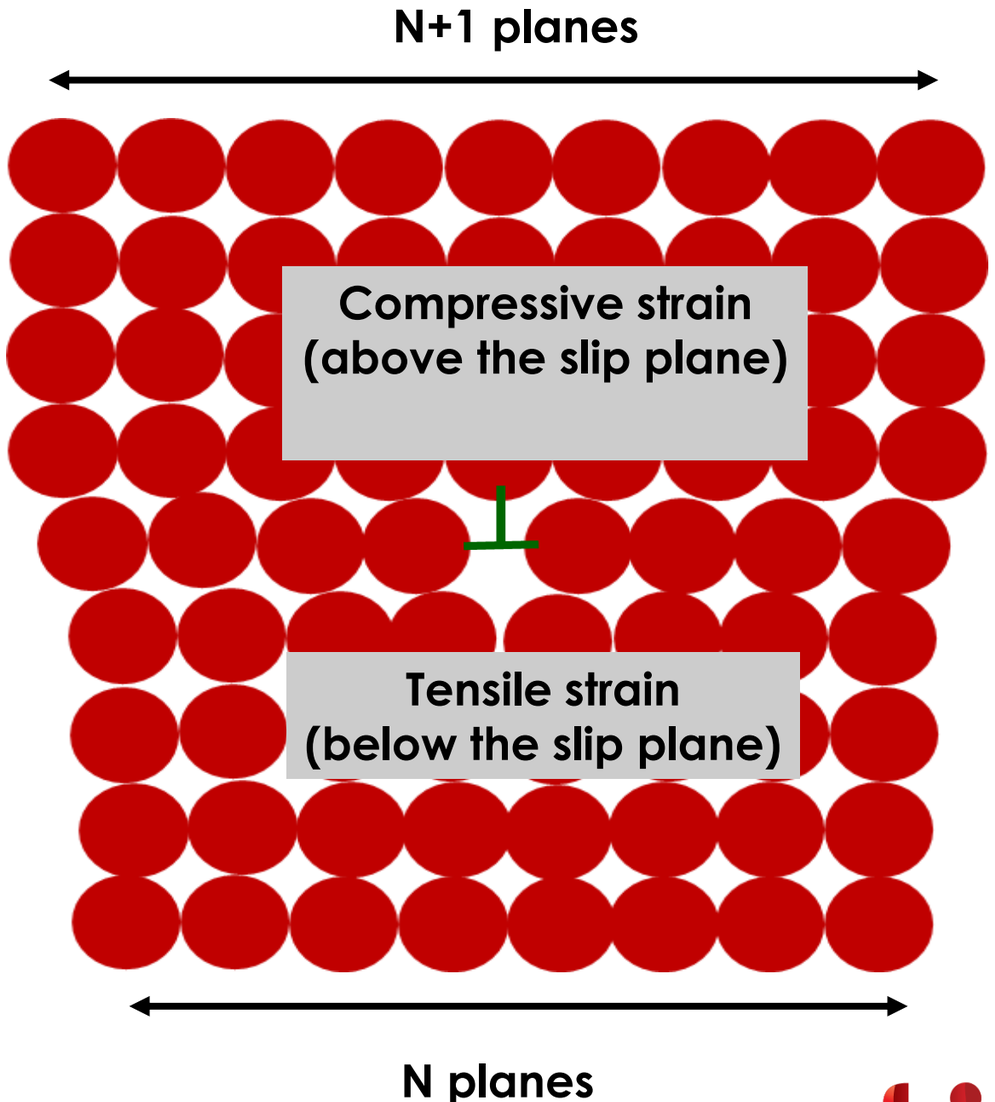
Dislocations have distortional energy associated with them as is evident from the compressive and the tensile strains around an edge dislocation or the shear strains around a screw dislocation.

The elastic strain energy *E* per unit length of a dislocation of Burgers vector b is

$$E = \frac{1}{2}\,\mu b^2$$

Where μ is shear modulus of the crystal and b is length of the Burgers vector.

Unit: J/m



Dislocation Energy

Dislocations tend to have as small as Burgers vector as possible.

How ??

$$\overrightarrow{2b} \rightarrow \vec{b} + \vec{b}$$

Elastic energy decreases by 50% during this breakup.

Dislocation density ρ measured in /m^2.
In annealed crystals 10^8 - 10^{10} /m^2

Summary

1. Dislocations of opposite signs in the same plane attract each other.
2. Dislocations with same sign in the same plane repels each other.
3. The dislocation energy is directly proportional to the square of the Burgers vector magnitude.
4. Ionic crystals have large Burgers vector as compared to metallic samples.

Assignment

1. An optical microscope can resolve a step of aluminum width 300 nm. A slip band was observed in a simple cubic crystal (a = 3 Å). How many (minimum) dislocations must have slipped out of the crystal?
2. An aluminum crystal has a dislocation density of 10^{10} m^{-2}. The sheer modulus of aluminum is GNm^{-2}. Calculate the elastic energy of line imperfections stored in the crystal.
3. The small angle boundary in FCC copper is due to extra (100) planes of atoms as edge dislocations. If the angle of disorientation is 1°, what is the distance between two neighboring edge dislocations? Given lattice parameter for Cu = 3.62 Å.