재료의 기계적 거동
(Mechanical Behavior of Materials)

Lecture 11 – Dislocations
(Intersection and Origin of Dislocations)

Heung Nam Han
Professor
Department of Materials Science & Engineering
College of Engineering
Seoul National University
Seoul 151-744, Korea
Tel : +82-2-880-9240
Fax : +82-2-885-9647
email : hnhan@snu.ac.kr
Office hours : Tuesday, Thursday 16:45~17:30
Homepage : http://mmmpdl.snu.ac.kr

Intersection of Dislocations

Intersection of Two Edge Disl. with Perpendicular Burgers Vectors

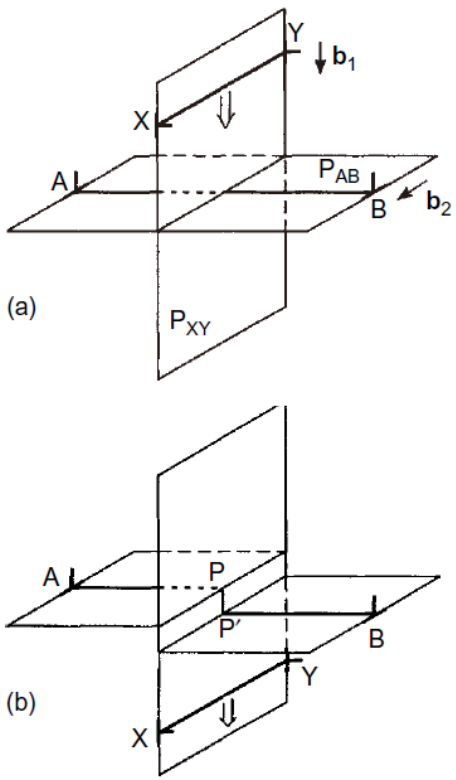


FIGURE 7.1
Intersection of edge dislocations with Burgers vectors at right angles to each other. (a) A dislocation *XY* moving on its slip plane P_{XY} is about to cut the dislocation *AB* lying in plane P_{AB}. (b) *XY* has cut through *AB* and produced a jog *PP′* in *AB*.

Edge Disl. XY : No change

Edge Disl. AB : Formation of jog (PP')
Small edge disl. , Burges vector : b_2,
Direction and magnitude : b_1

Intersection of Dislocations

Intersection of Two Edge Disl. with Parallel Burgers Vector

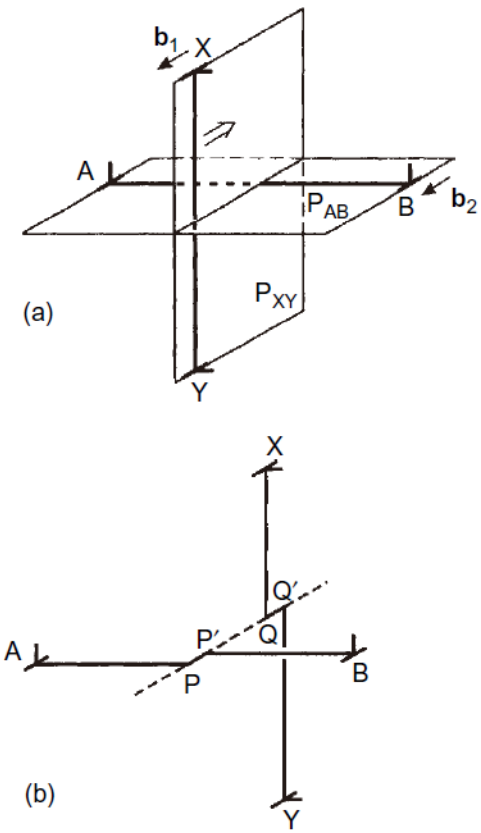


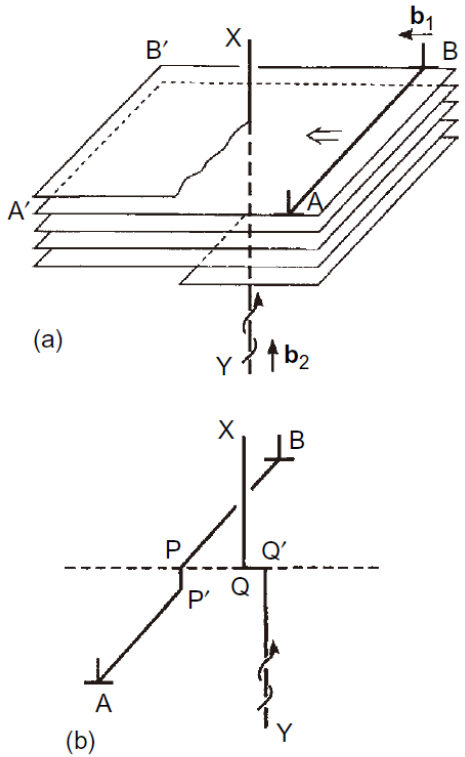
FIGURE 7.2
Intersection of edge dislocations with parallel Burgers vectors. (a) Before intersection. (b) After intersection.

Edge Disl. XY : Formation of kink (QQ') - length b_2

Edge Disl. AB : Formation of kink (PP') - length b_1

Intersection of Dislocations

Intersection of Edge Disl. with Perpendicular Screw Disl.



Edge Disl. AB : Formation of jog(PP')

Screw Disl. XY: Formation of kink(QQ') or jog(QQ')
If QQ' have same slip plane with screw, QQ' is kink.
If QQ' have different slip plane with screw, QQ' is jog.

FIGURE 7.3
Intersection of an edge dislocation *AB* with a right-handed screw dislocation *XY*. (a) *AB* moving in its slip plane is about to cut *XY*. Planes threaded by *XY* form a single spiral surface. *AB* glides over this surface and after crossing to *A′B′* the ends do not lie on the same plane. Thus the dislocation must contain a jog *PP′* as shown in (b).

Intersection of Dislocations

Intersection of Two Perpendicular Screw Disl.

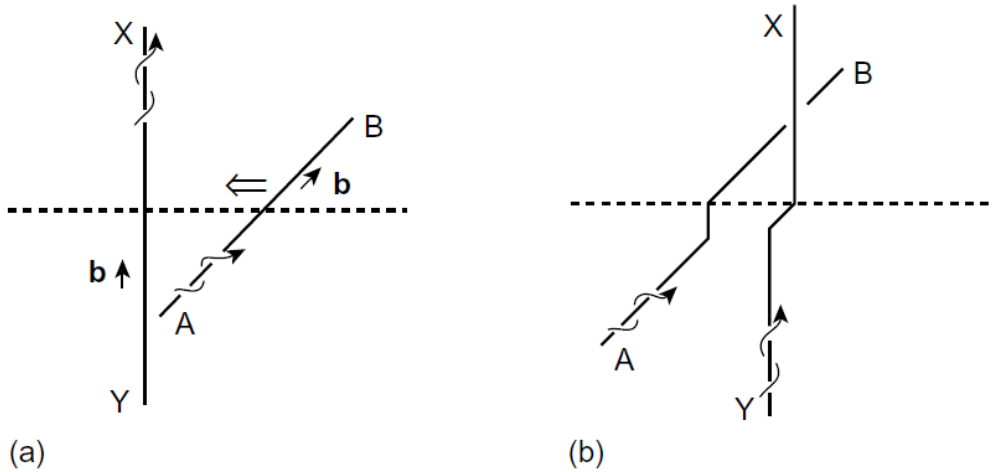


FIGURE 7.4
Intersection of screw dislocations. (a) Before intersection. (b) After intersection.

Screw Disl. AB : Formation of jog or kink
Screw Disl. XY : Formation of jog or kink

-Elementary Jog (or Unit Jog): Length of jog is equal to one Burgers vector.
-Superjog : Length of jog is multiples of Burgers vector.

Movement of Dislocation containing Jogs and Kinks

1. Edge Disl. with Jog

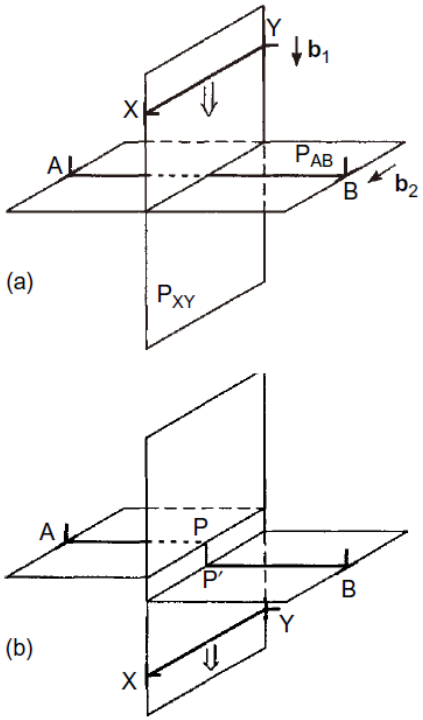


FIGURE 7.1
Intersection of edge dislocations with Burgers vectors at right angles to each other. (a) A dislocation *XY* moving on its slip plane P_{XY} is about to cut the dislocation *AB* lying in plane P_{AB}. (b) *XY* has cut through *AB* and produced a jog *PP′* in *AB*.

Jog PP' : small edge disl.

Jog in edge disl. does not affect the glide of edge disl.

Movement of Dislocation containing Jogs and Kinks

2. Edge Disl. with Kink

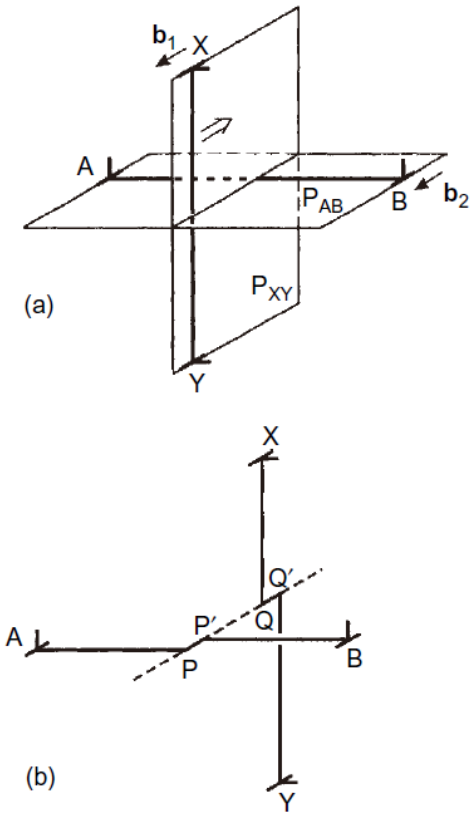


FIGURE 7.2
Intersection of edge dislocations with parallel Burgers vectors. (a) Before intersection. (b) After intersection.

Kink PP' : small screw disl.

Kink in edge disl. does not resist the glide of edge disl., in fact, the kink assists the glide of edge disl.

Movement of Dislocation containing Jogs and Kinks

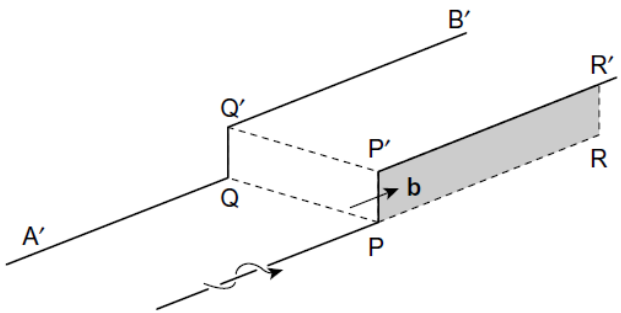


FIGURE 7.5
Movement of a jog on a screw dislocation. Jog *PP′* has a Burgers vector normal to *PP′* and is, therefore, a short length of edge dislocation. The plane defined by *PP′* and its Burgers vector is *PP′RR′* and is the plane in which *PP′* can glide. Movement of the screw dislocation to *A′QQ′B′* would require climb of the jog from *PP′* to *QQ′*.

3. Screw Disl. with Kink

PP' : small edge disl.
Slip plane of kink PP'(P'PRR') is same with slip plane.
Kink does not affect the glide of screw disl.

4. Screw Disl. with Jog

Slip plane of jog PP'(P'PRR') is different from slip plane of screw disl.(Q'P'R'B').
As screw disl. glide, jog can move only by climb(PP' QQ').

Movement of Screw Disl. with Jogs

Jog resists the movement of screw disl. and the climb process requires thermal activation thus the movement of the screw disl. will be temperature dependent.

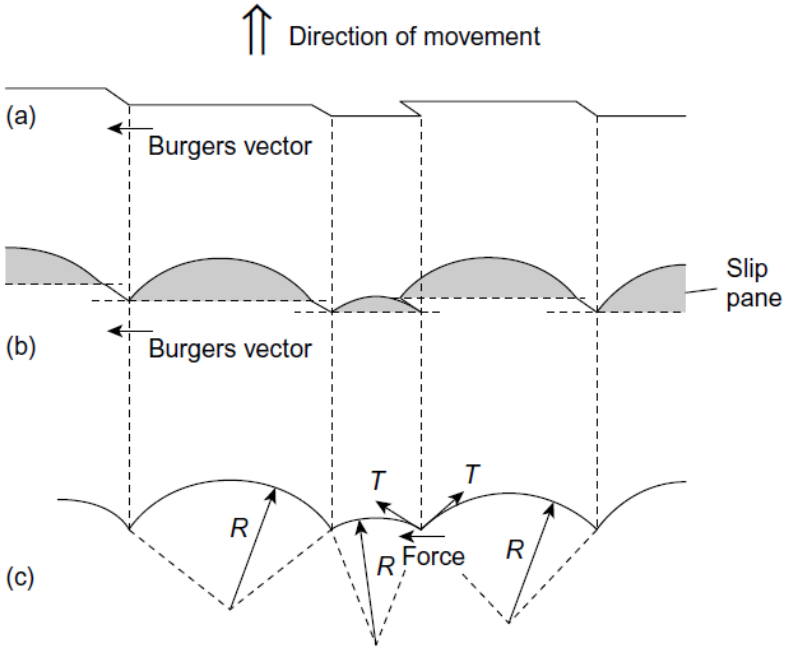


FIGURE 7.6
Movement of a jogged screw dislocation. (a) Dislocation with no applied stress. (b) Dislocation segments pinned by jogs bowing under stress to radius of curvature *R*. (c) Projection in slip plane showing force on jog due to unbalanced sideways components of line tension *T*.

Screw disl. glide
→ Screw disl. bows out between the jogs to a radius of curvature $R = \alpha G b / \tau$
→ Induce glide force on the jogs due to the difference in line tension
→ Two relatively close-spaced jogs glide together and resulting in annihilation or formation of a superjog
→ The remaining jogs will be of approximately uniform spacing, x

Motion of Screw Disl. with Superjogs

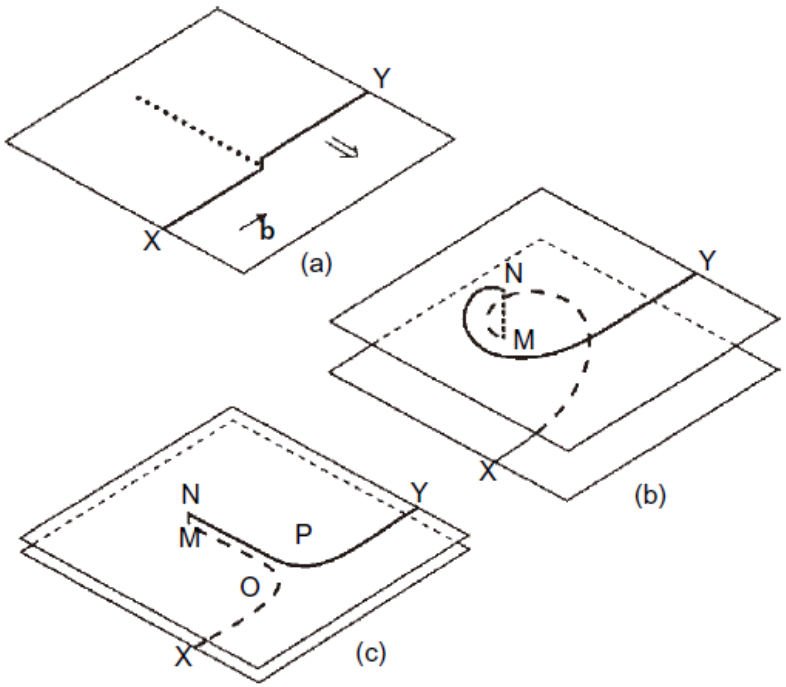
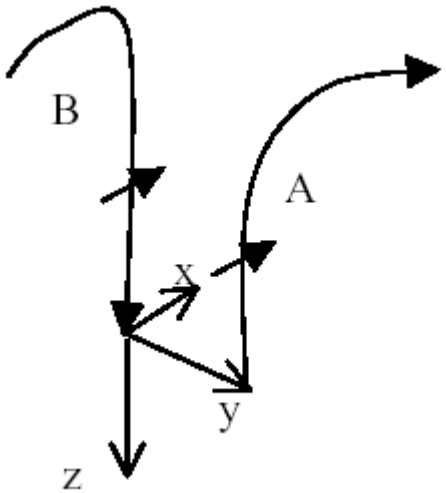


FIGURE 7.8
Behavior of jogs with different heights on a screw dislocation moving in the direction shown by the double arrow. (a) Small jog is dragged along, creating point defects as it moves. (b) Very large jog — the dislocations *NY* and *XM* move independently. (c) Intermediate jog — the dislocations *NP* and *MO* interact and cannot pass by one another except at a high stress. *(After Gilman and Johnston,* Solid State Physics, *13, 147, 1962.)*



Dislocation dipole

Origin of Dislocations

In fleshly grown crystal

1. **Dislocations and defects in seed crystal**

2. **Nucleation of dislocation during crystal growth**
   - **Heterogeneous nucleation of dislocation due to internal stress generated by impurity particles. If local internal stress > critical stress, → "Nucleation of dislocation"**
   - **Impingement of different parts of growing interfaces. "Misfit dislocation"**
   - **Formation of dislocation loop by the coalescence of vacancies.**

Multiplication of Dislocations (Frank-Read Source)

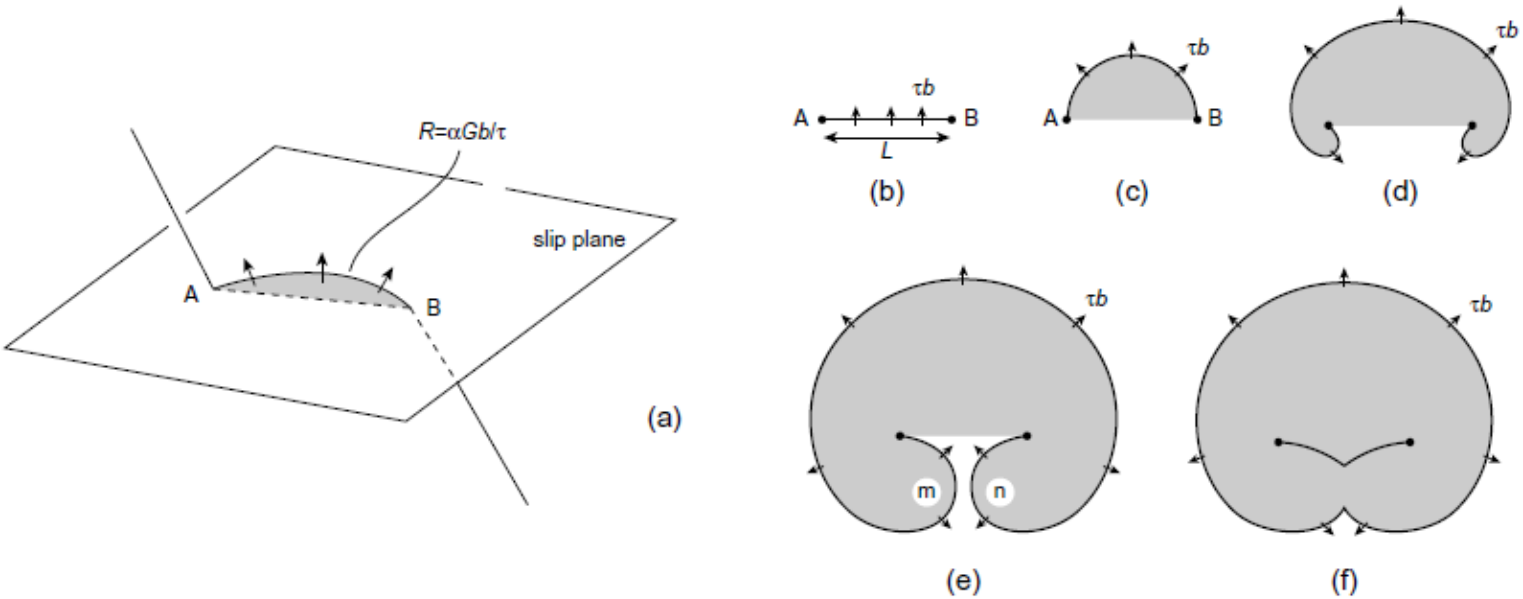
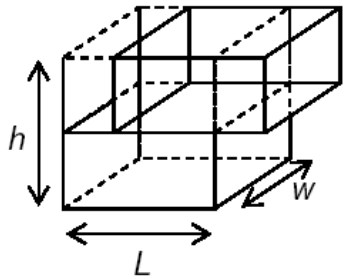


FIGURE 8.5

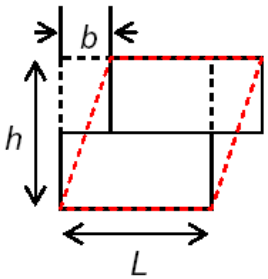
Diagrammatic representation of the dislocation movement in the Frank—Read source. Unit slip has occurred in the shaded area. *(After Read (1953),* Dislocations in Crystals, *McGraw-Hill.)*

How much strain is caused by dislocation motion?

- If a single dislocation passes through the crystal, what will be the resulting strain?



3-D



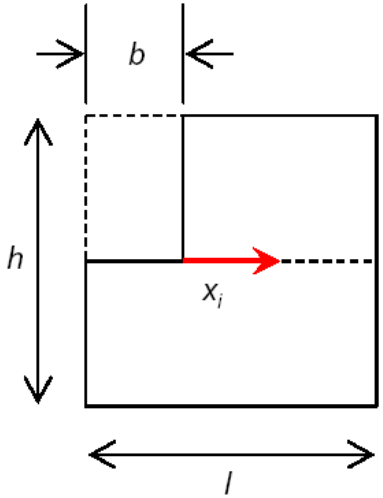
2-D

Cubic crystal after passage of a single dislocation

First we recognize that the shear strain is simply defined by the equation:

$$\text{shear strain} = \gamma = \frac{b}{h}$$

How much strain is caused by dislocation motion?



– Single dislocation:

$$\gamma = \frac{x_i}{l}\frac{b}{h}$$

– Multiple dislocations:

$$\gamma = \frac{1}{l}\frac{b}{h}\sum_{1}^{N} x_i$$

If N dislocations move an average distance $\bar{x}$ then,

$$\gamma = \frac{N\bar{x}}{l}\frac{b}{h} \text{ for multiple dislocations}$$

$$l \times h = \text{area of the end of the crystal}$$

$$\text{dislocation density} = \rho_{\perp} = \frac{N}{lh} \equiv \frac{\#\ \perp\ \text{lines}}{\text{area}}$$

$$\therefore$$

$$\boxed{\gamma = \rho_{\perp} b \bar{x}}$$

How much strain is caused by dislocation motion?

The shear strain rate associated with this type of motion is:

$$\dot{\gamma} = \frac{d\gamma}{dt} = \rho_{\perp} b \frac{dx}{dt} = \rho_{\perp} b \dot{x} \text{ or } \boxed{\dot{\gamma} = \rho_{\perp} b v}$$

where v is the dislocation velocity.

This is the Taylor-Orowan relation, which relates dislocation motion to strain rate.

How much strain is caused by dislocation motion?

Typical Dislocation Densities Encountered in a Parallepiped Sample $(3 * 3 * 8\ \mathrm{mm})$[a]

Sample History	Dislocation Density ρ (m^{-2})	Length of Dislocation Line per Sample (km)	Mean Distance D between Dislocations (μm)
As grown	10^{10}	100	10
As grown and annealed	10^{8}	1	100
Strained	$10^{13} \sim 10^{15}$	$10^{5} \sim 10^{8}$	0.1

[a] Dimensions are $3 * 3 * 8\ \mathrm{mm}^3$ (which is adequate for a compression test), depending on prior thermomechanical history. In fact, such dislocation densities, which may appear surprisingly large when scaled with sample dimensions, make sense when considering that dislocations are defects at the atomic scale (i.e., the number of atoms located in the immediate vicinity of a dislocation line is many orders of magnitude less than the total number of atoms in the sample).