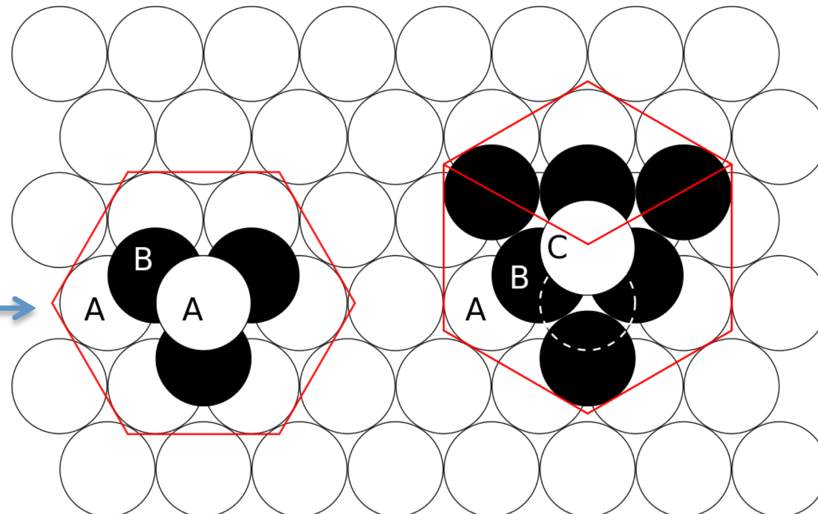
Partial Dislocations
Plastic Deformation in Crystalline Materials

Kamyar Davoudi

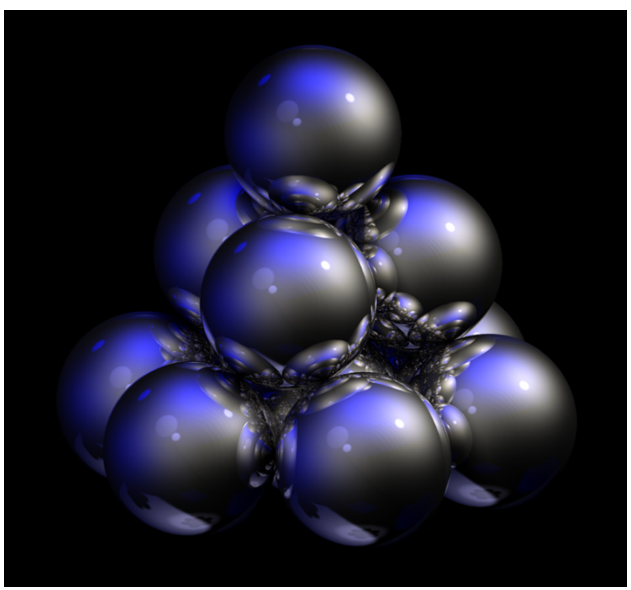
Fall 2015

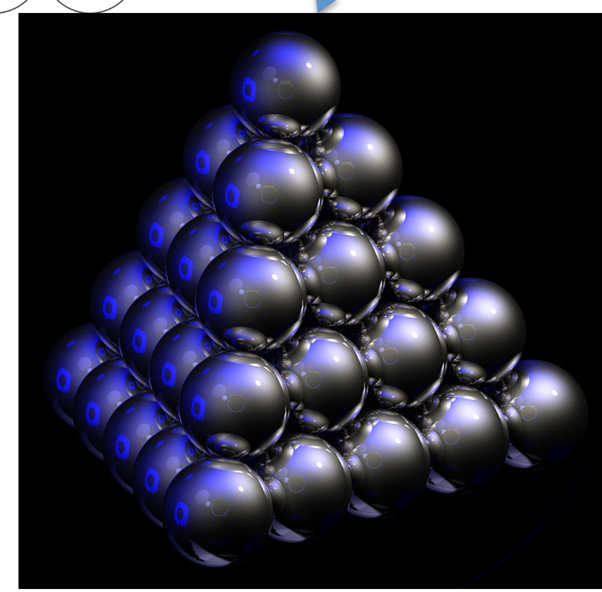
Perfect FCC and HCP Crystals

hcp

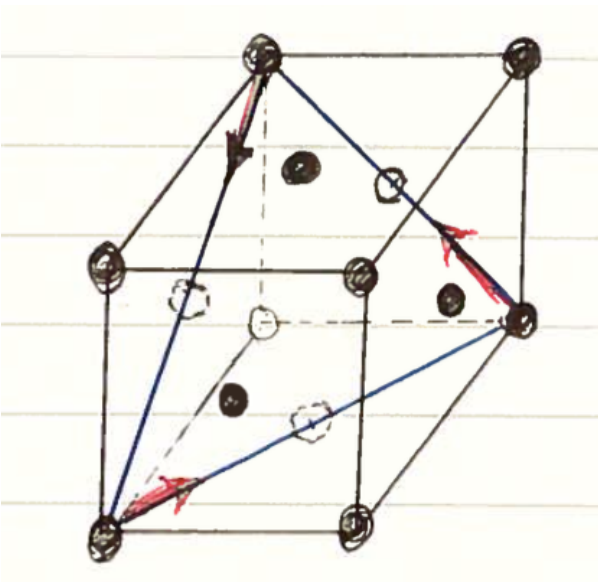


fcc
(also called ccp)





Burgers vector in fcc



- Each {111} plane contains three <110>.
- Each <110> lies on two {111} planes
- Shortest perfect dislocation slip vector:

$$\vec{b} = \frac{a}{2}[110]$$

- Magnitude of the Burgers vector

$$b = \frac{a}{\sqrt{2}}$$

Dislocations in FCC Structures

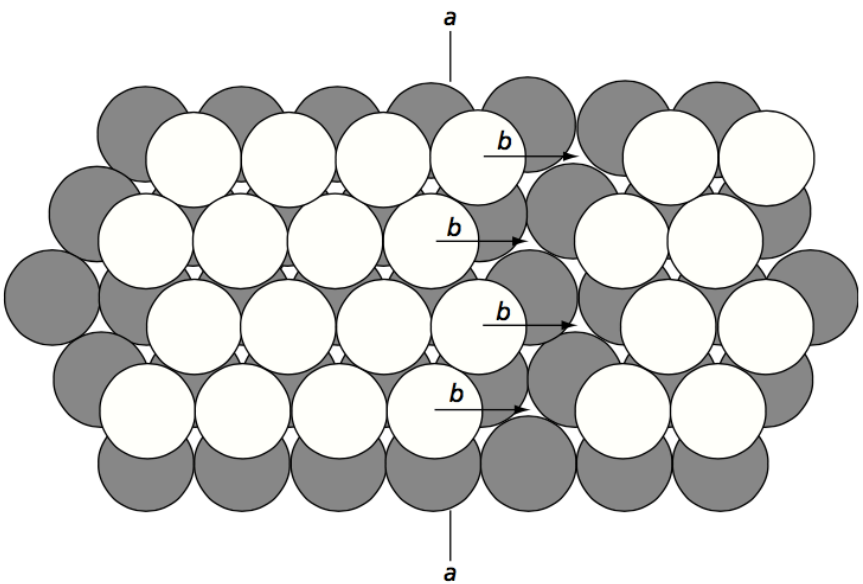


FIG. 4.22 A total dislocation (edge orientation) in a face-centered cubic lattice as viewed when looking down on the slip plane

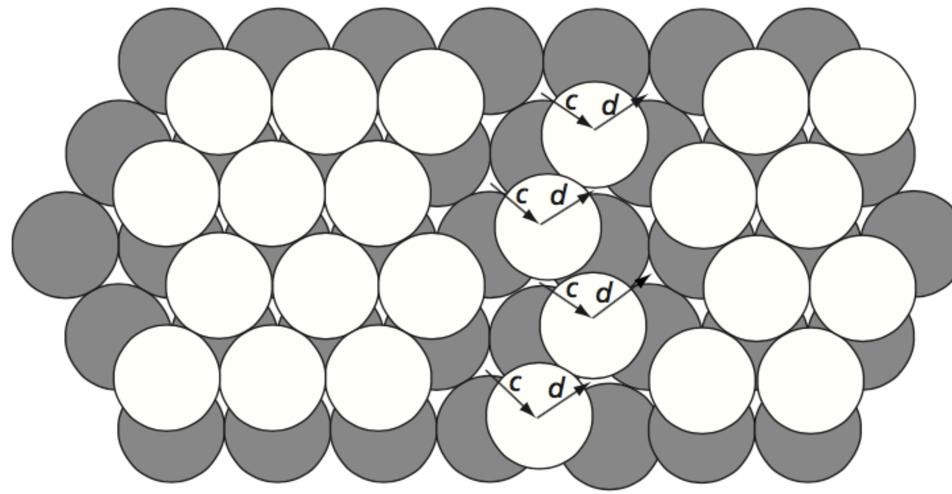
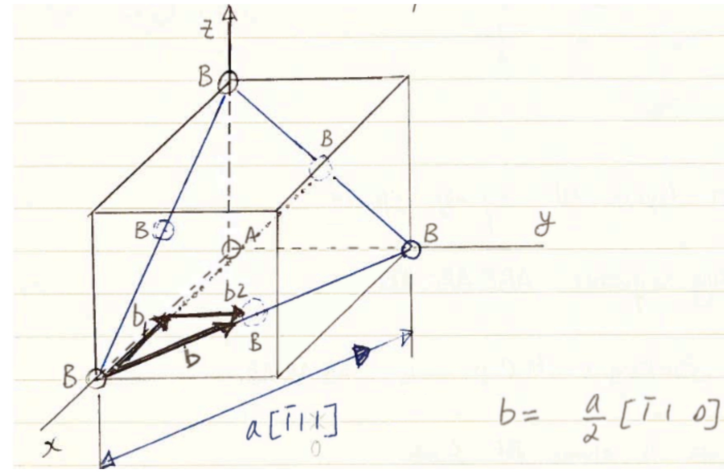


FIG. 4.23 Partial dislocation in a face-centered cubic lattice

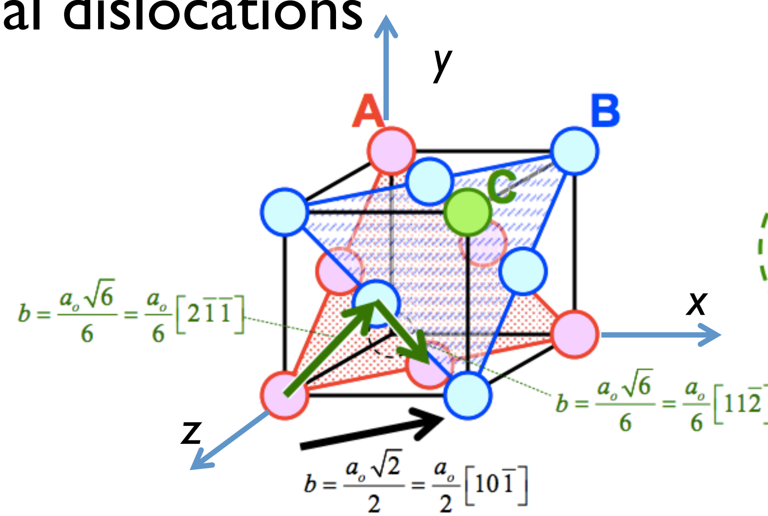
[Abbaschian, Abbaschian, Reed]

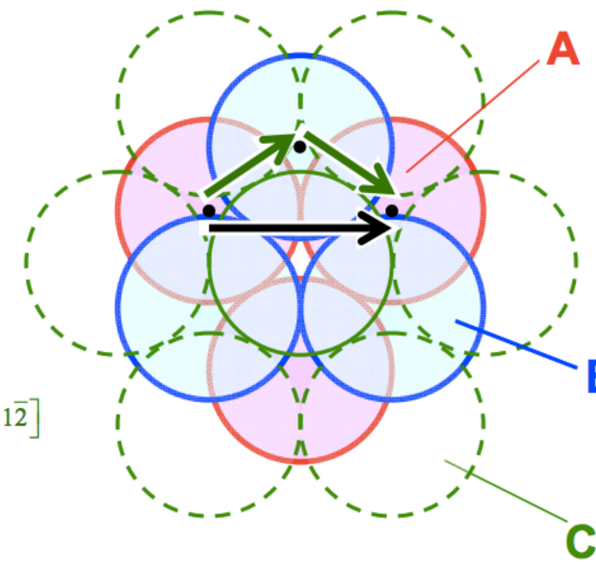
Shockley Partials

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



The Burgers vector dissociates into two Shockley partial dislocations





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

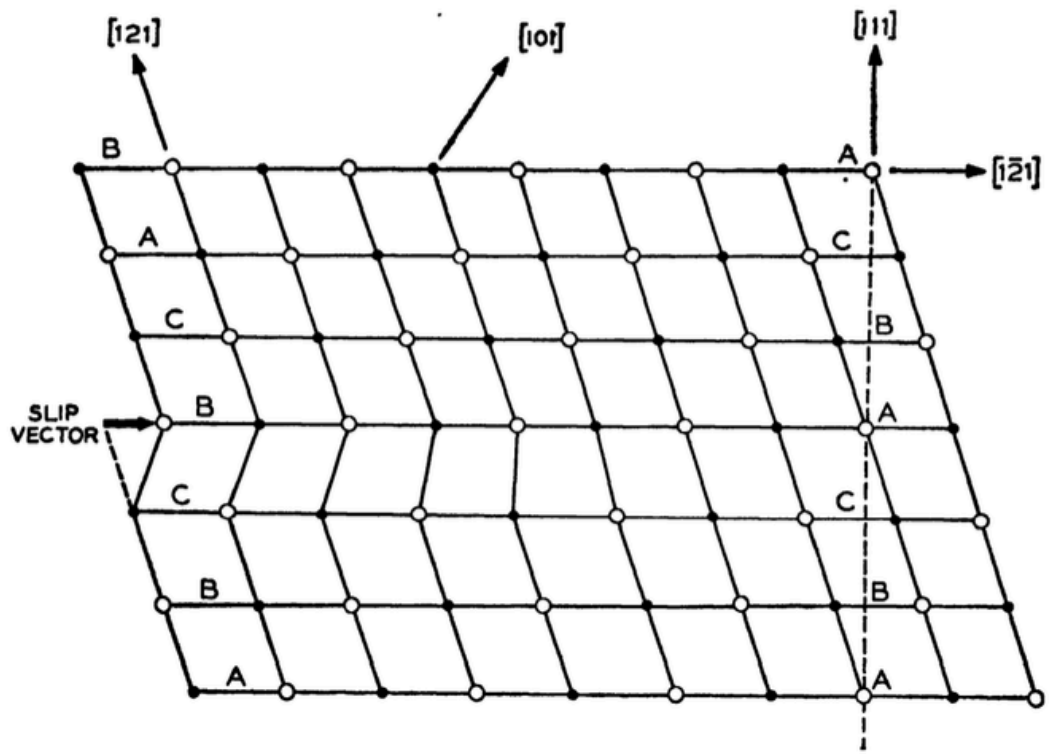


FIG. 7.2 A Shockley partial dislocation in the edge orientation in face-centered cubic. The plane of the figure ($\bar{1}01$) is normal to the dislocation. The slip vector $\frac{1}{6}[1\bar{2}1]$ is shown. Note the fault on the left of the partial dislocation. The open and solid circles represent atoms in different elevations.

[Read, *Dislocations in Crystals*, 1953]

Definition of Burgers Vector

- "Frank (1951): begin the Burgers circuit on the fault and go into good material, making a sequence of steps along **t** vectors such that the same sequence would close in a perfect crystal. Now however, the last step will not be an atom-to-atom step; in other words, the closure failure (= Burgers vector) is not a **t** vector."
[Read, 1953]

Remarks

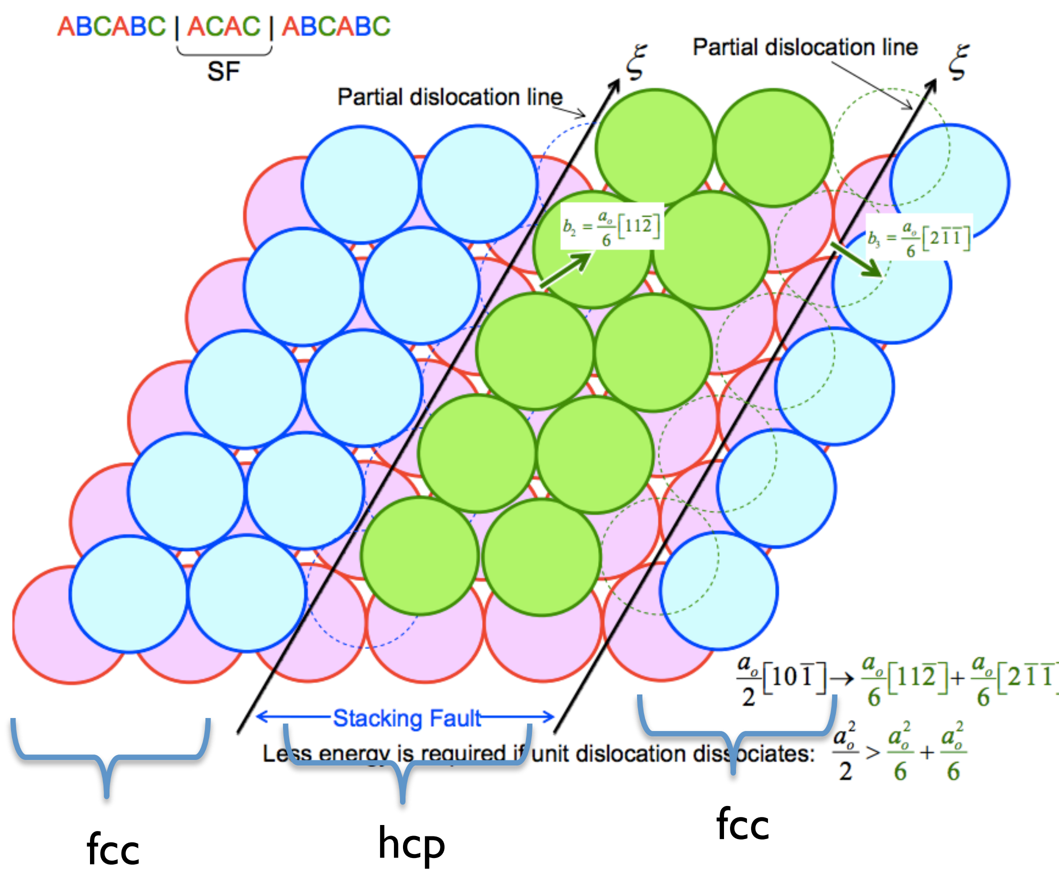
- Two criteria:

1. For any reaction, the sum of the Burgers vector on the both sides are the same.
2. Franks' energy criterion:
   Reaction takes place if energy is reduced
   $E = \alpha \mu b^2$

- Dissociation of a Burgers vector into two Shockley partials satisfies both criteria
- Both Shockley partials lie on the same plane where the Burgers vector lies (the partials are glissile, i.e. they can move)

Stacking Fault

- Stacking fault is a planar defect and as its name implies it is a local region in the crystal where the regular sequence has been interrupted



Stacking Fault Energy

- The two Shockley partials repel each other but the stacking fault posses a surface energy γ (also sometimes denoted by χ_{SF}) , which prevents the partials from separating too widely

- Aluminum has the lowest stacking fault energy and silver has the highest one.

TABLE 1.5. Stacking-fault energies in some close-packed materials (in mJ/m^2)[a]

Material	Type	χ_{sf}
Al	FCC	200 (HL)
Ag	FCC	17 (HL); 20 (C)
Au	FCC	55 (HL); 35 (C)
Be	HCP	>230 (F)
Cd	HCP	160 (F)
Cu	FCC	73 (HL)
Ge	Diamond cubic	75 (PH)
Mg	HCP	~125 (F)
Ni	FCC	400 (HL); 125 (C)
Pd	FCC	180 (HL)
Pt	FCC	95 (HL)
Rh	FCC	~750 (HL)
Si	Diamond cubic	69 (FC)
Th	FCC	~750 (HL)
Zn	HCP	~230 (F)

[a] References: HL, Hirth and Lothe (1982) (and references within); C, Coulomb (1978); F, Fleischer (1986); FC, Föll and Carter (1979); PH, Packeiser and Haasen (1977).

[Argon, Strengthening Mechanism in Crystal Plasticity, 2008]

γ Surface

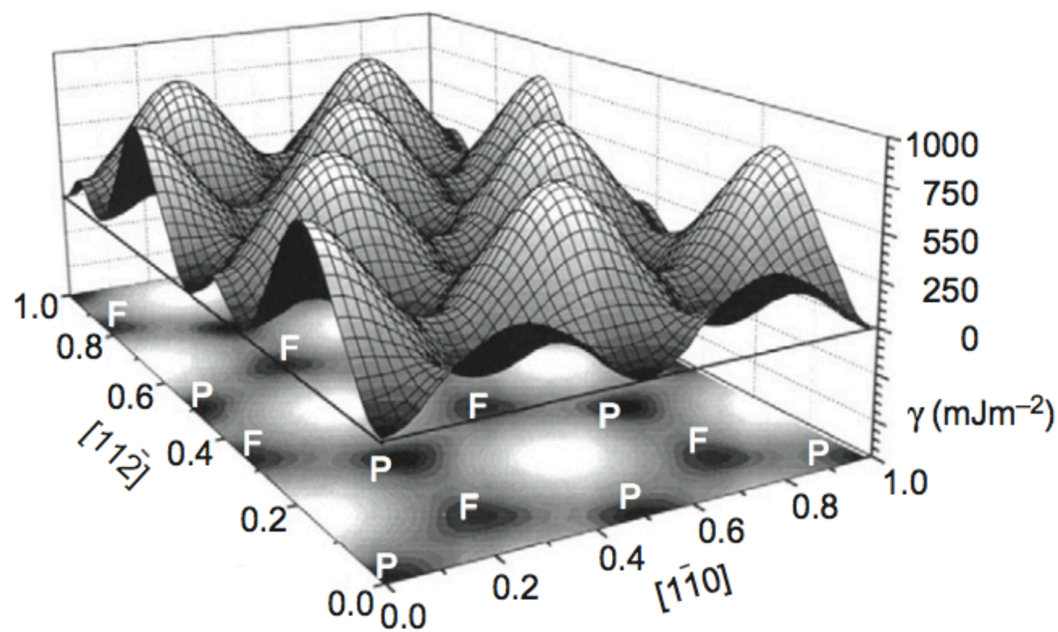
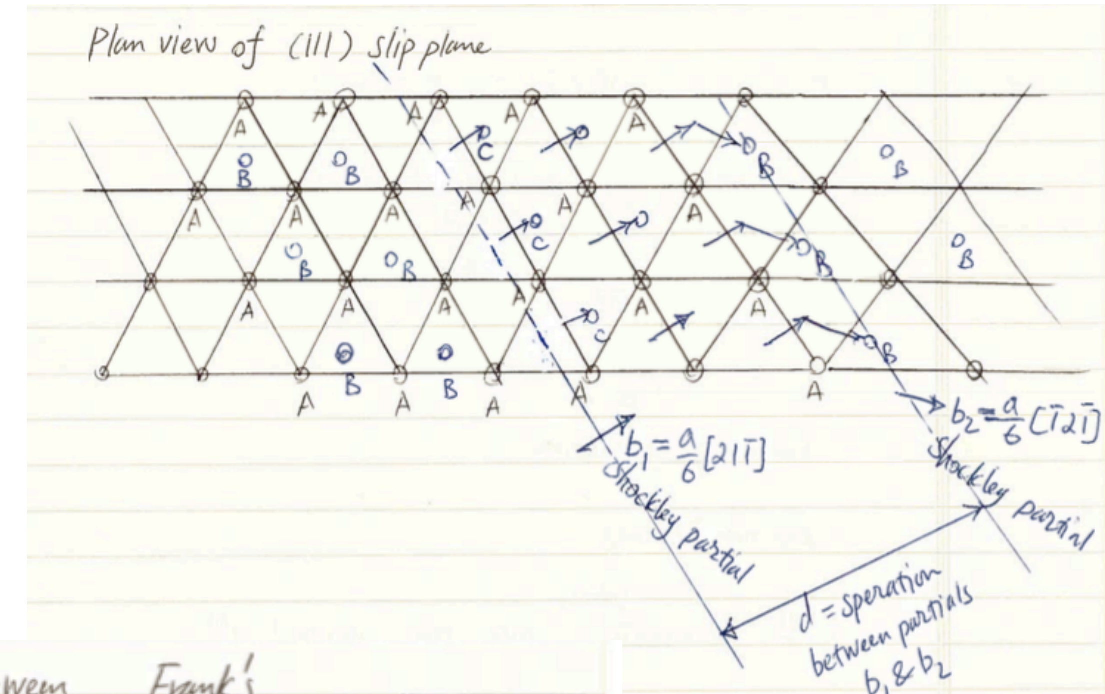


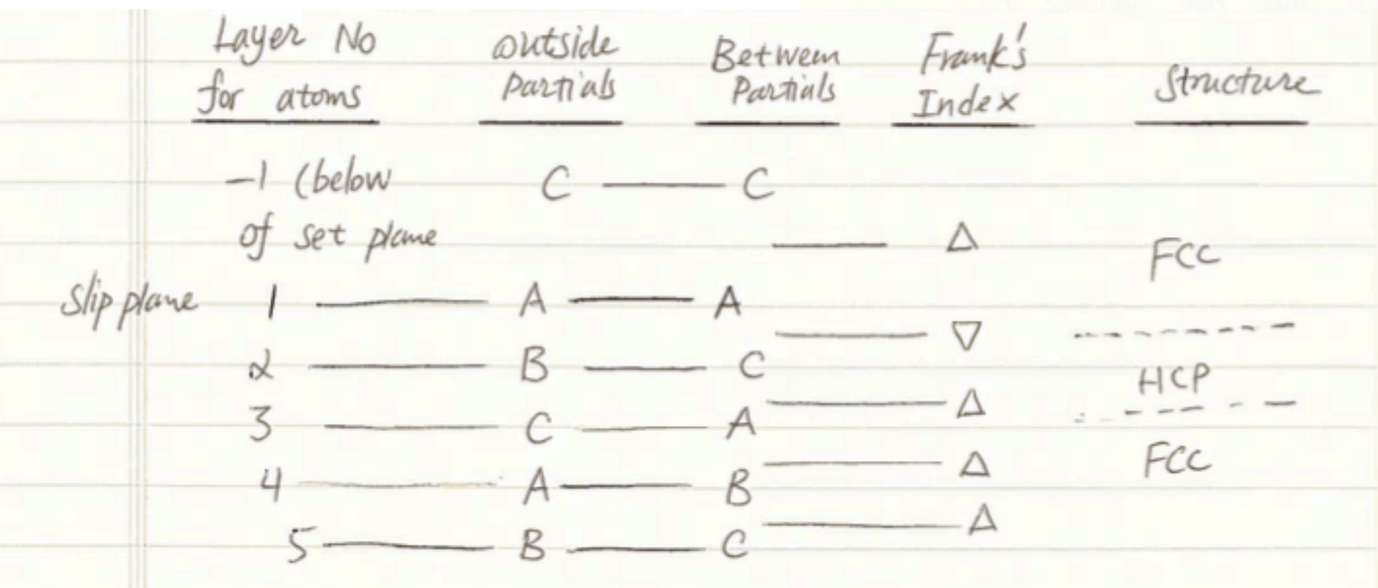
FIGURE 5.4

γ surface for the (111) plane of copper obtained by atomic-scale computer simulation. γ is zero for perfect stacking (P). Intrinsic fault (F) is metastable (with $\gamma \simeq 40$ mJ m^{-2}) and corresponds to fault vectors of the form $\frac{1}{6}\langle 112 \rangle$. *(Courtesy Yu. N. Osetsky.)*

Frank's Index

In fcc materials, the stacking fault is a region with two atomic layers having stacking similar to hcp.

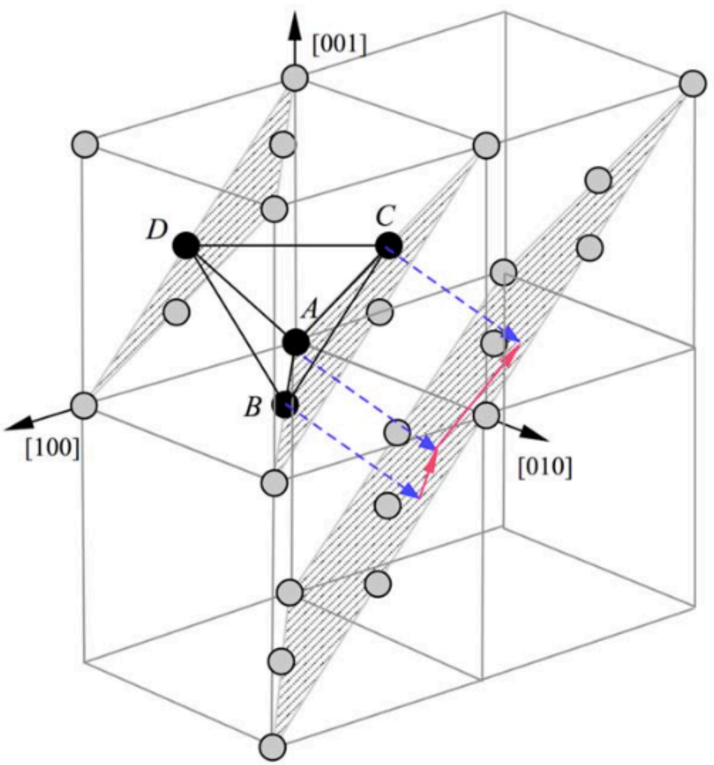


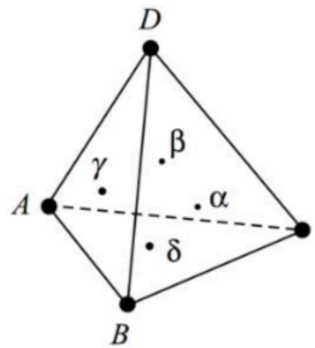


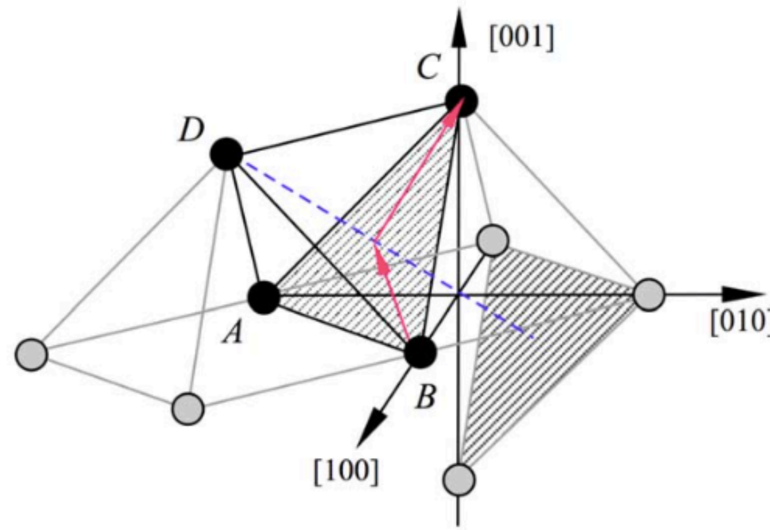
	Layer No for atoms	Outside Partials	Between Partials	Frank's Index	Structure
	-1 (below of set plane	C	C		
				Δ	FCC
Slip plane	1	A	A		
				∇	
	2	B	C		HCP
				Δ	
	3	C	A		
				Δ	FCC
	4	A	B		
				Δ	
	5	B	C		

Calculate Equilibrium Spacing Between Schockley Partials

Thompson Tetrahedron

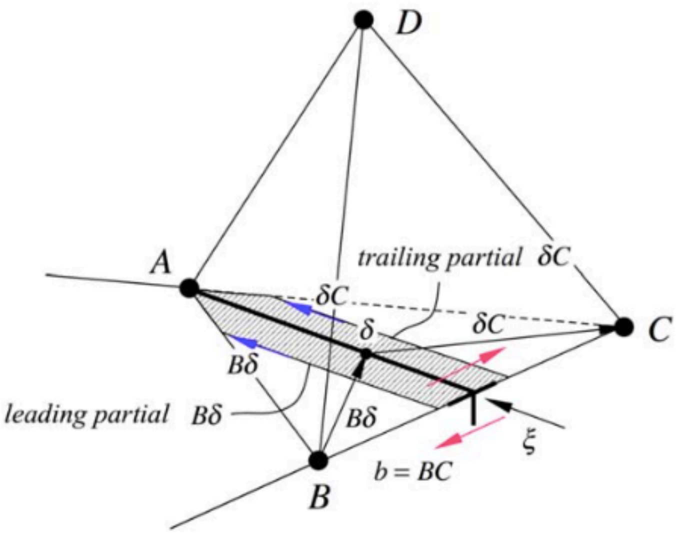




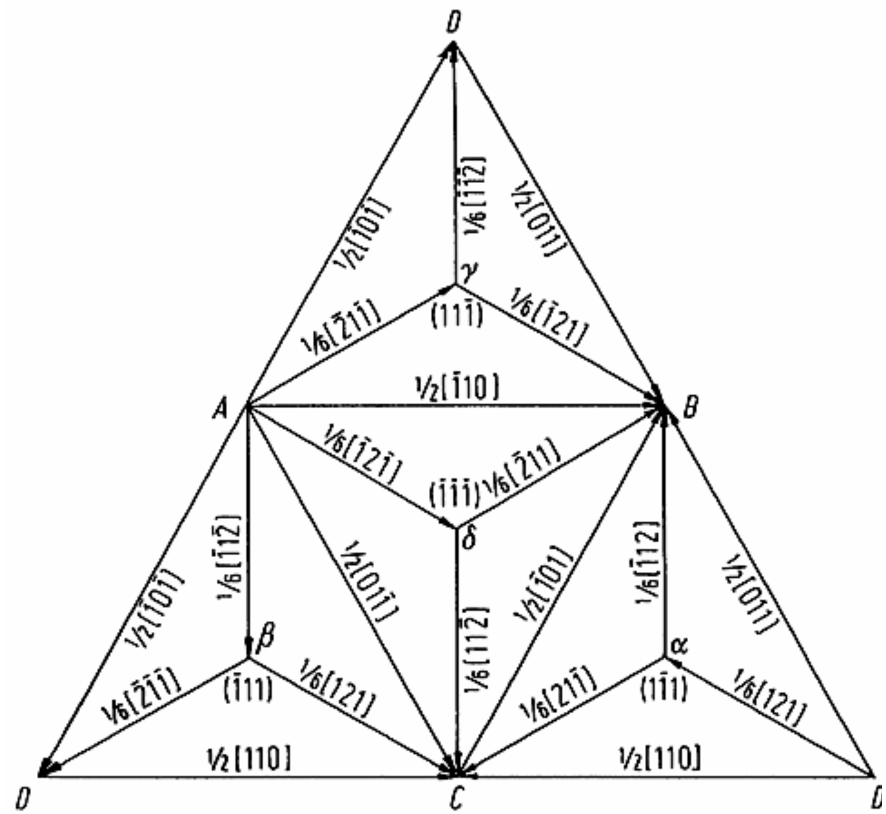


[Nix, Partial Dislocation Tutorial for FCC Metals]

Thompson Tetrahedron Example

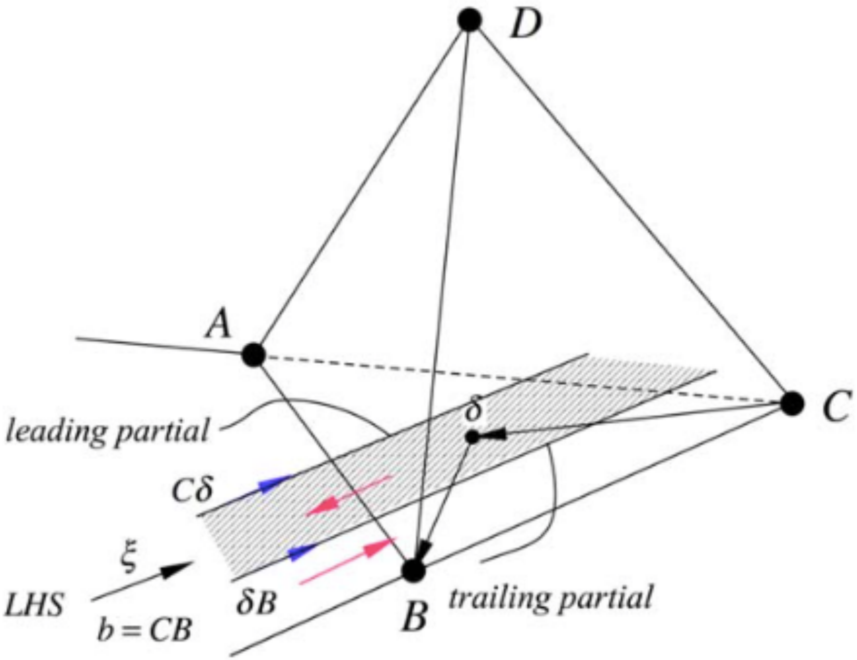


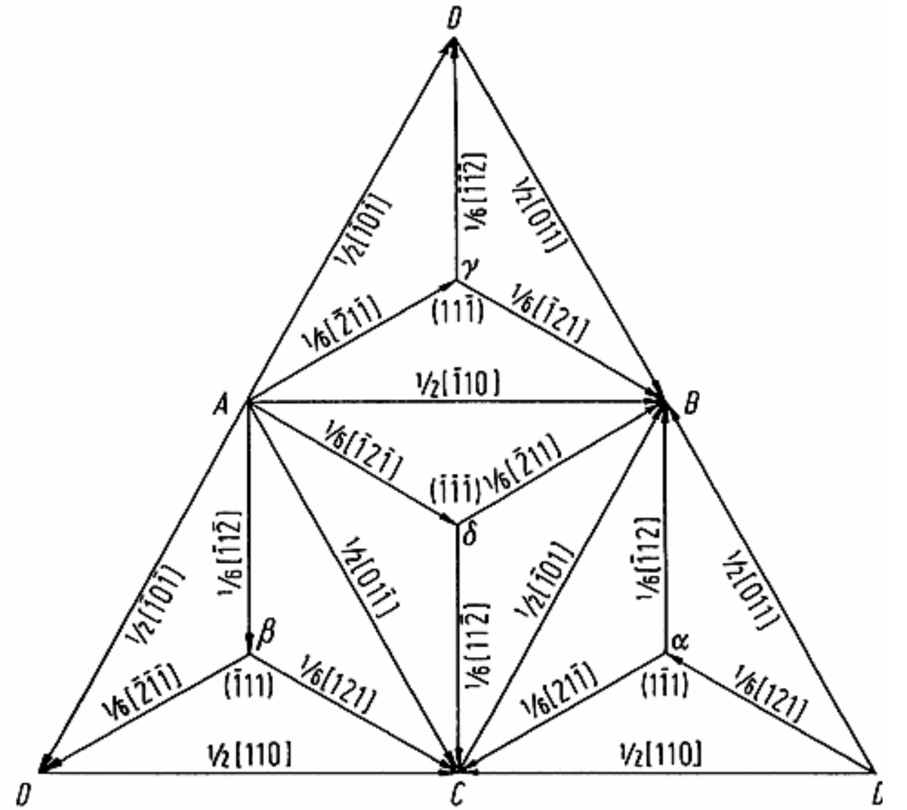
Glide of a negative edge dislocation.



[Nix, Partial Dislocation Tutorial for FCC Metals]

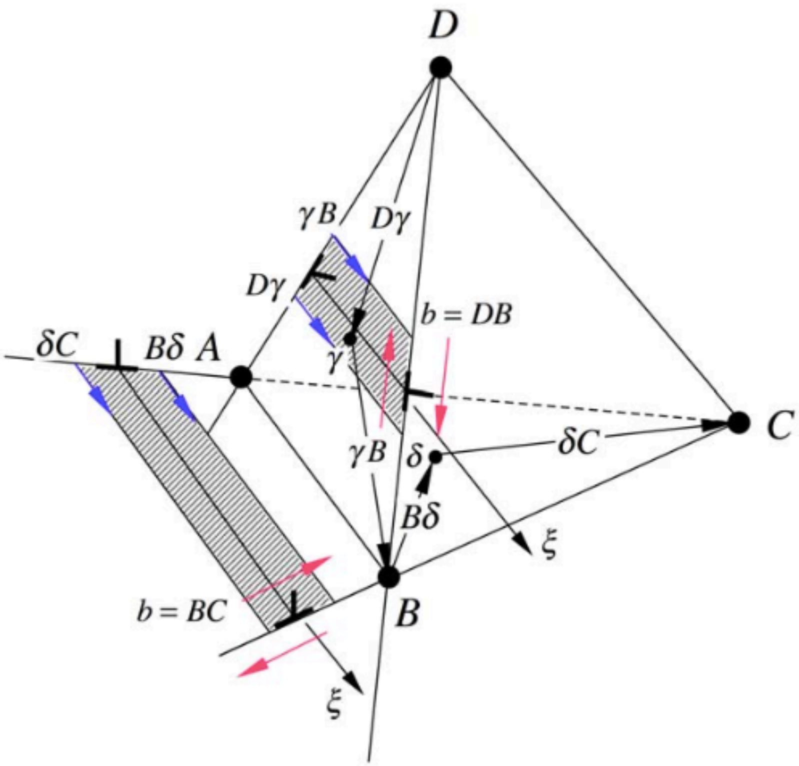
Another Example

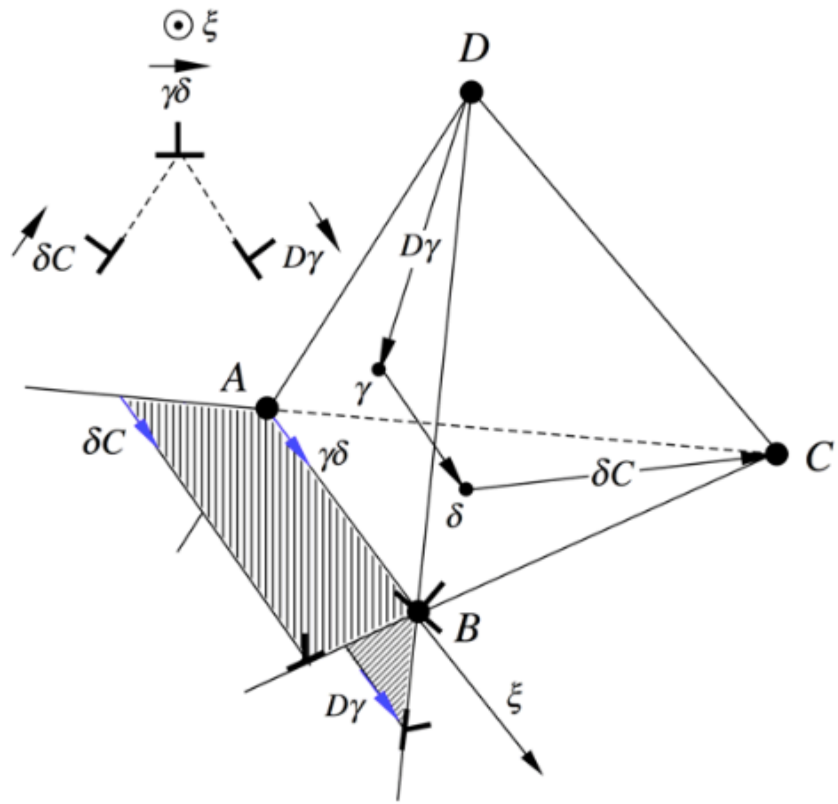




[Nix, Partial Dislocation Tutorial for FCC Metals]

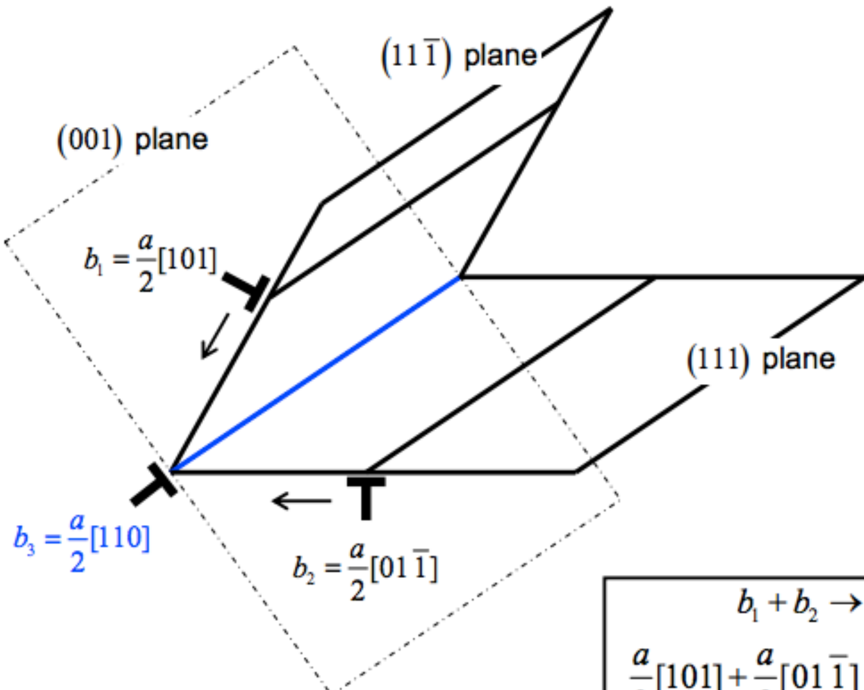
Lomer-Cottrell Lock



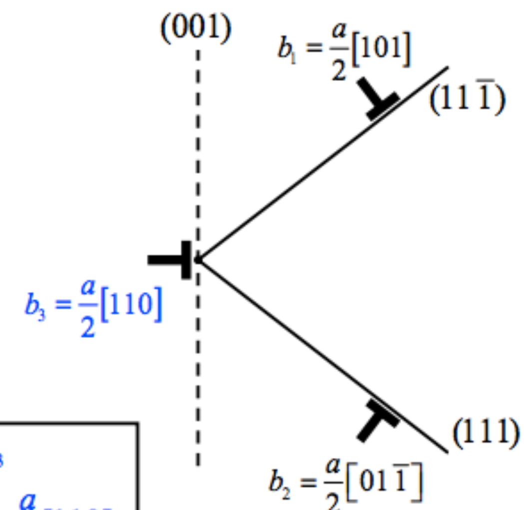


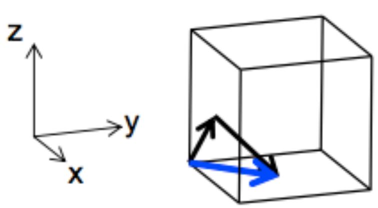
[Nix, Partial Dislocation Tutorial for FCC Metals]

Interaction of Dislocations on Intersecting Slip Planes



Lomer lock





$$b_1 + b_2 \rightarrow b_3$$

$$\frac{a}{2}[101] + \frac{a}{2}[01\bar{1}] \rightarrow \frac{a}{2}[110]$$

on $(11\bar{1})$, on (111), on (001)

$$b_1^2 + b_2^2 > b_3^2$$

$$\frac{a_o^2}{4} + \frac{a_o^2}{4} > \frac{a_o^2}{4}$$

Further Reading

- Abbaschian, A., Abbaschian, L., Reed-Hill, R., Physical Metallurgy Principles, 4th ed., Cengage Learning , 2009
- Hull, D., Bacon, J.D., Introduction to Dislocations, 5th ed., Elsevier, 2011.
- Nix, W., Partial Dislocation Tutorial for FCC Metals, imechanica.org, 2010. (http://imechanica.org/node/7334)
- Read, Dislocations in Crystals, McGraw Hill, 1953.