Unit II

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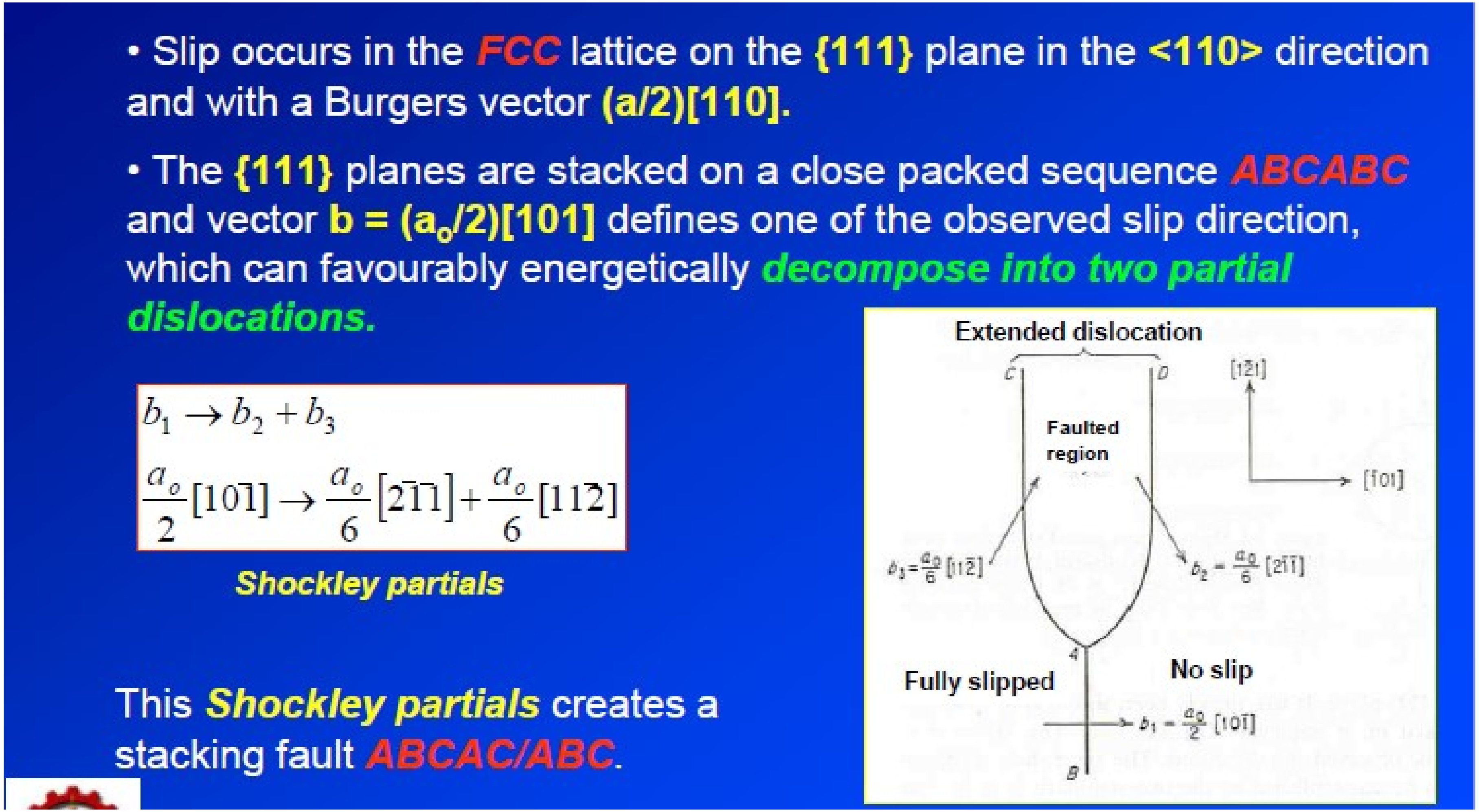
Dislocation in FCC lattice



- Slip occurs in the ***FCC*** lattice on the **{111}** plane in the **<110>** direction and with a Burgers vector **(a/2)[110].**
- The **{111}** planes are stacked on a close packed sequence ***ABCABC*** and vector **b = (a$_o$/2)[101]** defines one of the observed slip direction, which can favourably energetically ***decompose into two partial dislocations.***

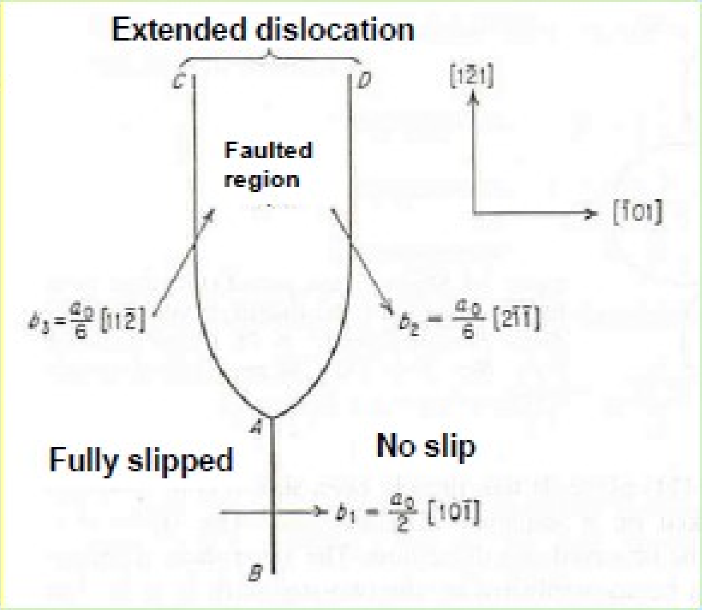
$$\boxed{\begin{aligned} &b_1 \rightarrow b_2 + b_3 \\ &\frac{a_o}{2}[10\bar{1}] \rightarrow \frac{a_o}{6}\left[2\bar{1}\bar{1}\right] + \frac{a_o}{6}[11\bar{2}] \end{aligned}}$$

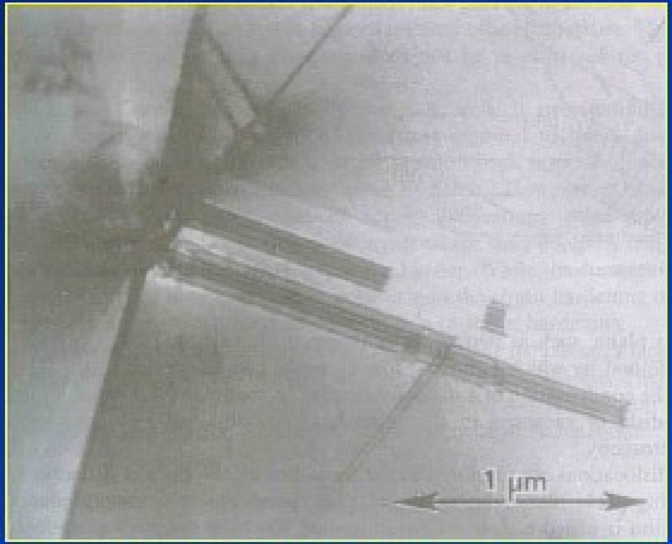
Shockley partials

This ***Shockley partials*** creates a stacking fault ***ABCAC/ABC***.

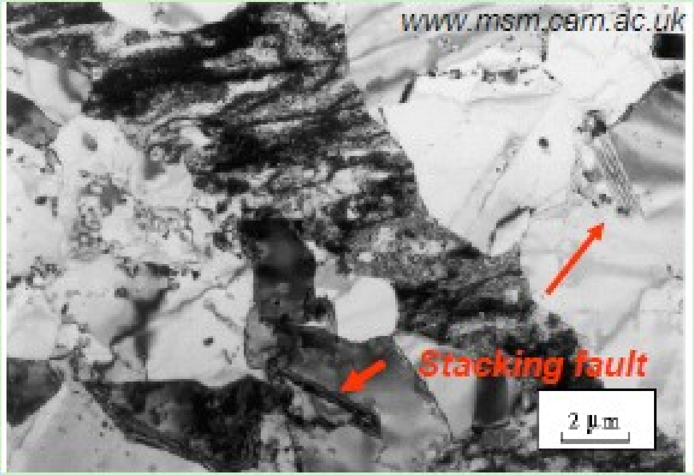
Dissociation of a dislocation into two partial dislocations

- The combination of the two partials **AC** and **AD** is known as an ***extended dislocation***.
- The region between them is a ***stacking fault*** which has undergone slip.
- The equilibrium of these partial dislocations depends on the stacking fault energy.



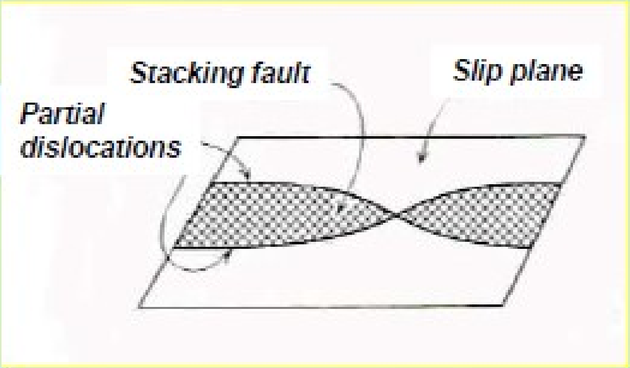


Group of stacking fault in 302 stainless steel stopped at boundary



Stacking faults

The wider region between partial dislocation, the lower stacking fault energy



Model of a stacking fault.

- ***Characteristics of metals with low SPF;***
  1) Easy to strain harden
  2) Easy for twin annealing to occur
  3) Temperature dependent flow stress

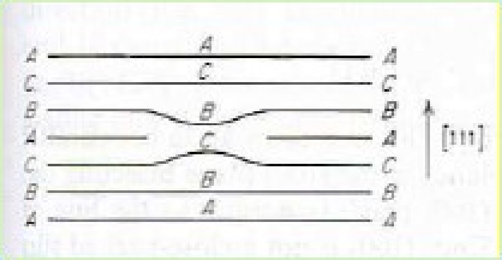
- **Aluminium** – high stacking fault energy → more likely to cross slip.
- **Copper** – lower stacking fault energy → cross slip is not prevalent.

Typical values of stacking fault energy

Metal	Stacking fault energy (mJ m^{-2})
Brass	<10
303 stainless steel	8
304 stainless steel	20
310 stainless steel	45
Silver	~25
Gold	~50
Copper	~80
Nickel	~150
Aluminium	~200

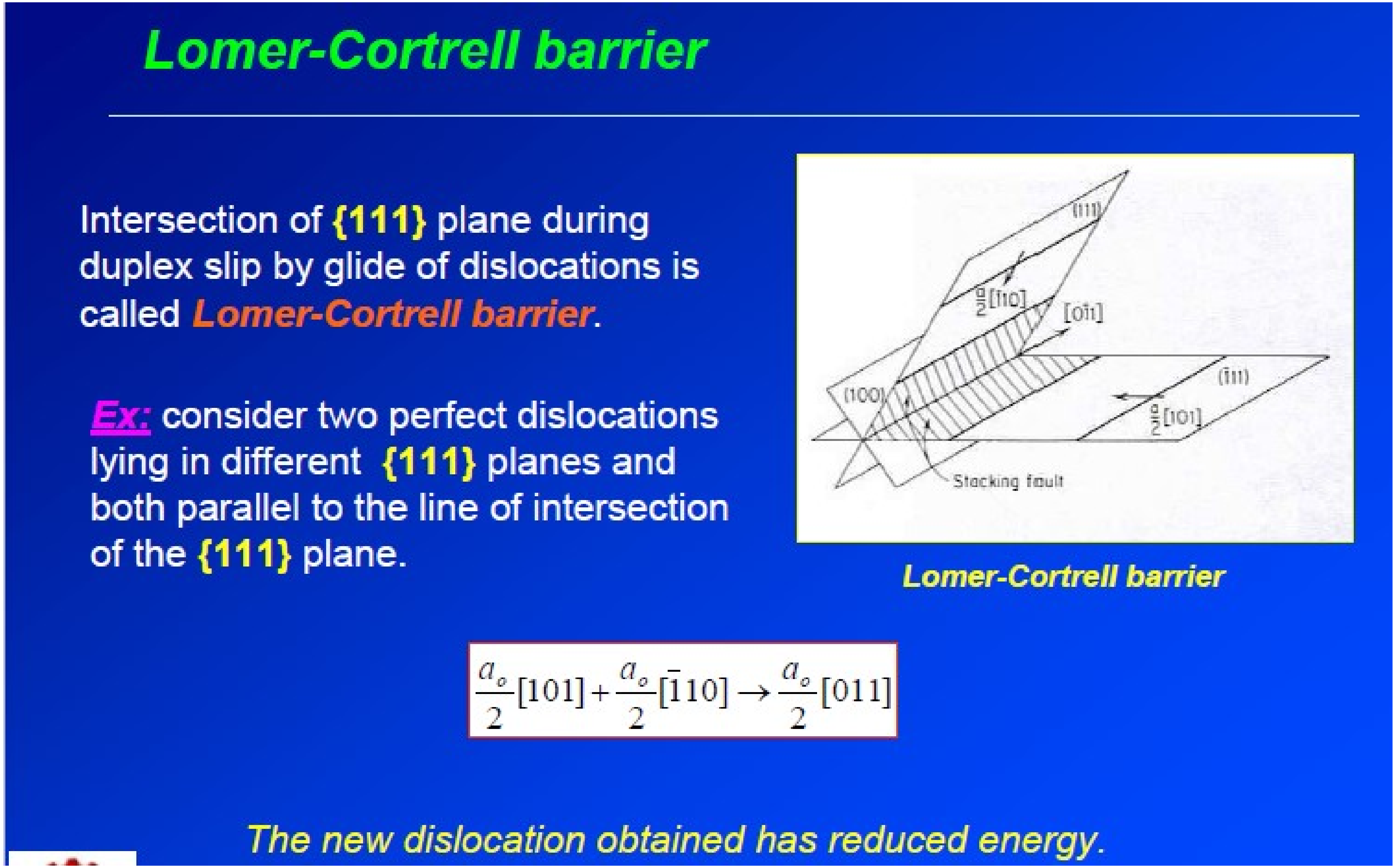
Frank partial dislocations

Frank partial dislocations are another type of partial dislocation in ***FCC*** lattice, which provide ***obstacles*** to the movement of other dislocations.



Frank partial dislocation or sessile dislocation.

- A set of **(111)** plane (viewed from the edge) has a missing middle ***A*** plane with a **Burgers vector (a_o/3) [111]** perpendicular to the central stacking fault.
- Unlike perfect dislocation, ***Frank partial dislocation*** cannot move by glide ***(sessile dislocation)*** but by diffusion of atom.



Lomer-Cortrell barrier

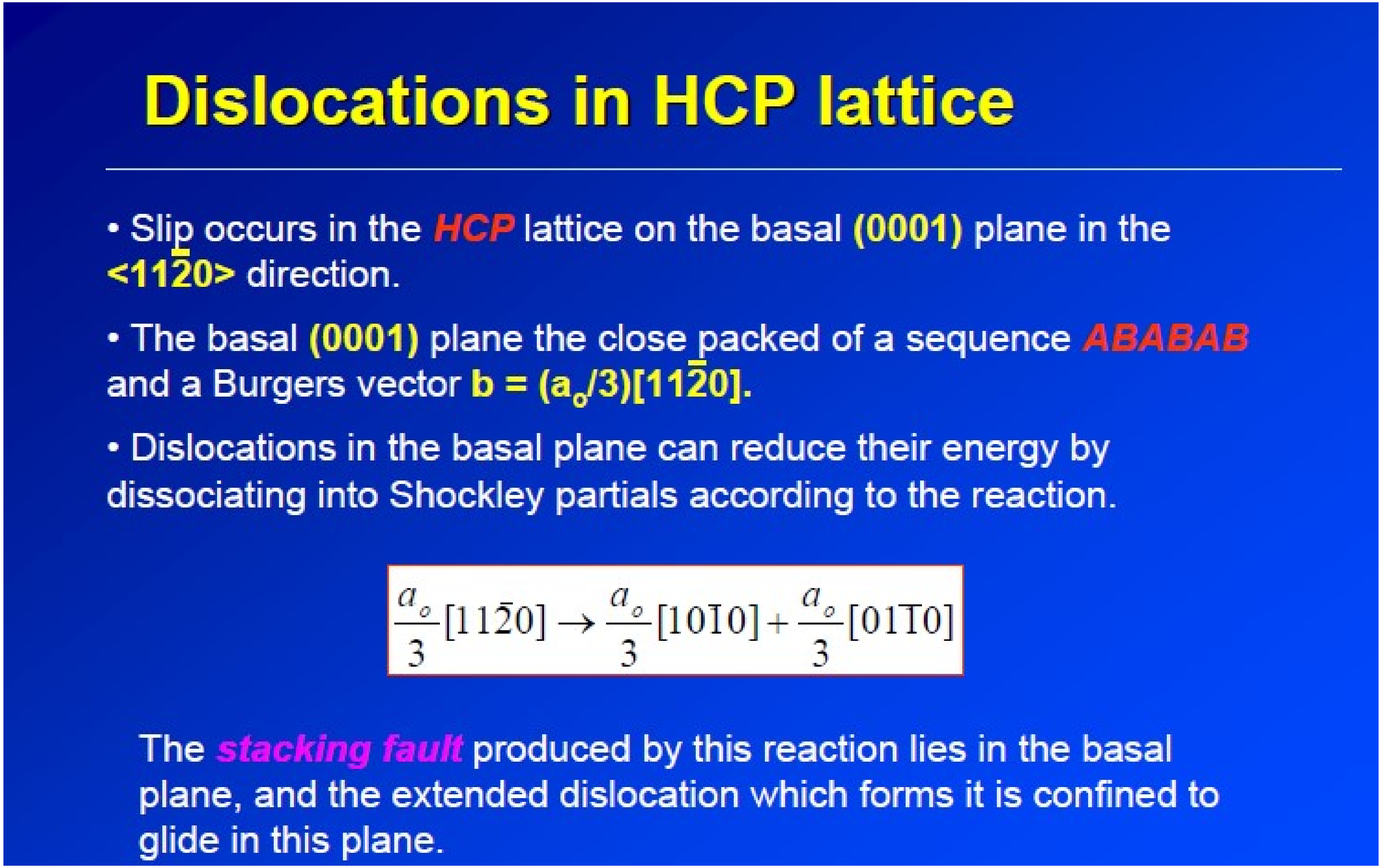
Intersection of **{111}** plane during duplex slip by glide of dislocations is called ***Lomer-Cortrell barrier***.

Ex: consider two perfect dislocations lying in different **{111}** planes and both parallel to the line of intersection of the **{111}** plane.

Lomer-Cortrell barrier

$$\frac{a_o}{2}[101]+\frac{a_o}{2}[\bar{1}10]\rightarrow\frac{a_o}{2}[011]$$

The new dislocation obtained has reduced energy.



Dislocations in HCP lattice

- Slip occurs in the ***HCP*** lattice on the basal **(0001)** plane in the **<11$\bar{2}$0>** direction.
- The basal **(0001)** plane the close packed of a sequence ***ABABAB*** and a Burgers vector **b = (a_o/3)[11$\bar{2}$0].**
- Dislocations in the basal plane can reduce their energy by dissociating into Shockley partials according to the reaction.

$$\frac{a_o}{3}[11\bar{2}0] \rightarrow \frac{a_o}{3}[10\bar{1}0] + \frac{a_o}{3}[01\bar{1}0]$$

The ***stacking fault*** produced by this reaction lies in the basal plane, and the extended dislocation which forms it is confined to glide in this plane.

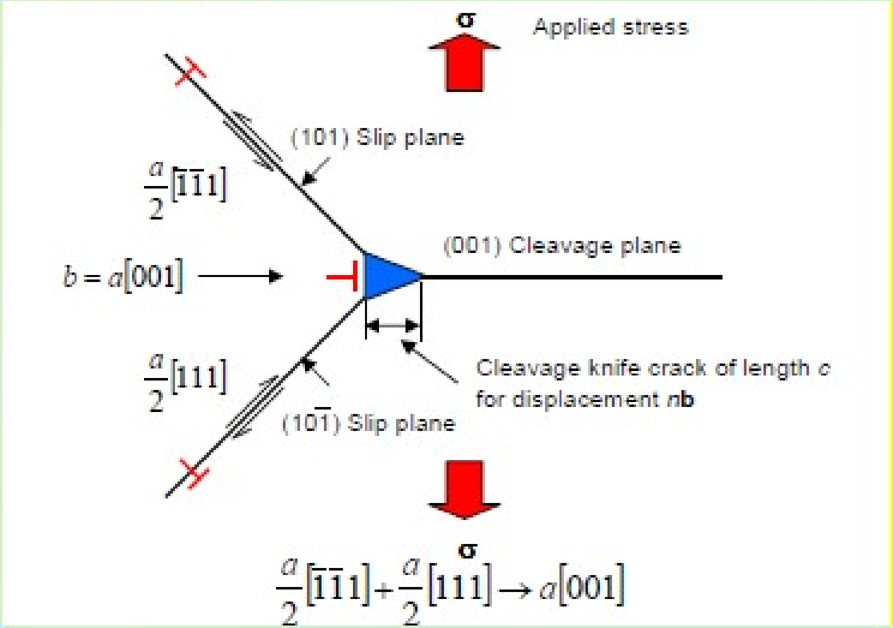
Dislocations in BCC cubic lattice

- Slip occurs in the ***BCC*** lattice on **{110}, {112}, {123}** planes in the **<111>** direction and a ***Burgers vector*** **b = (a_o/2)[111].**

Cottrell has suggested a dislocation reaction which appears to cause ***immobile dislocations***. (**a_o/2[001]** in iron) → leading to a crack nucleus formation mechanism for brittle fracture.

$$\boxed{\frac{a_o}{2}[\bar{1}\bar{1}1] + \frac{a_o}{2}[111] \rightarrow a_o[001]}$$

the dislocation is ***immobile*** since the **(001)** is not a close-packed slip plane, the **(001)** plane is therefore the ***cleavage plane*** when brittle fracture occurs.



Sources of Dislocation

- Except single crystal like whiskers, all other crystals have dislocations.
- The dislocations are produced during the growth of the crystal from the melt or vapour phase. Temperature and composition gradients may produce misalignments and produce dislocation in grain boundaries.
- Dislocations can be generated by thermal and mechanical stress near the particles, twins, cracks or surface flaws.
- Annihilation of vacancies produces dislocation like Frank partial dislocations in FCC metals.
- Plastic deformation produces or multiplying the dislocations. Cold worked metals have many dislocations.

Dislocation Multiplication

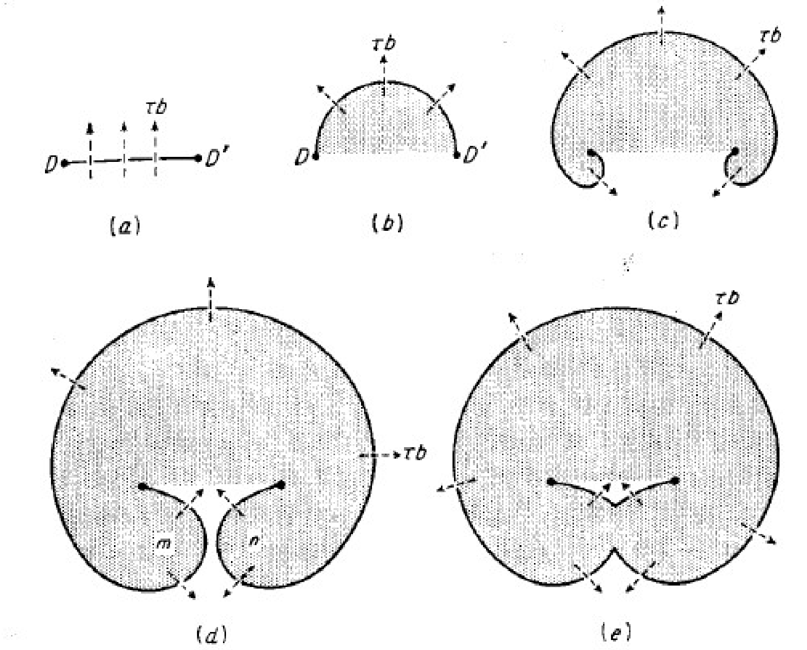
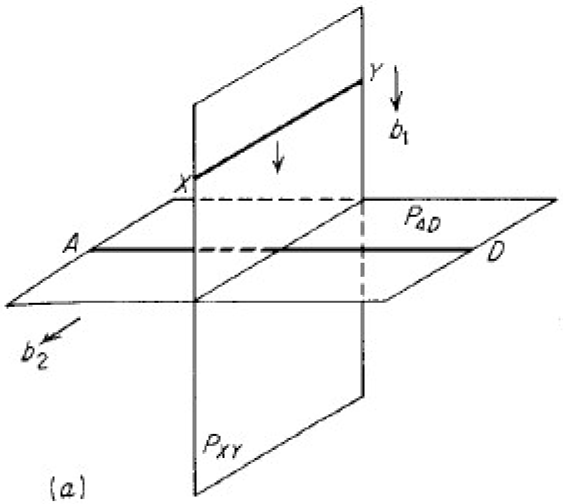


Figure : Frank-Read source for dislocation multiplication.

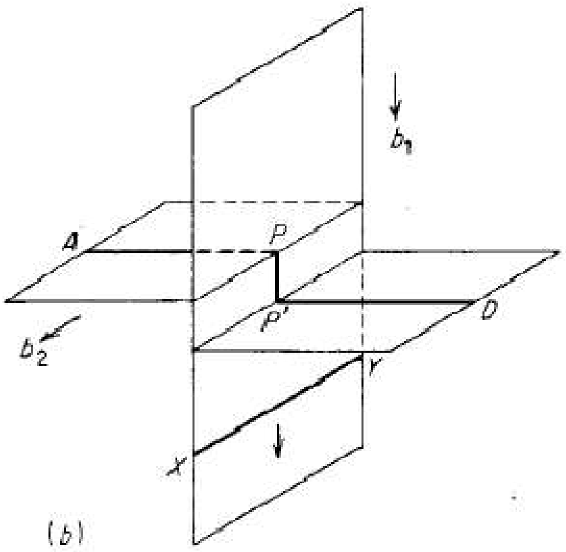
Intersection of Dislocation

- The intersection of two dislocations produces a sharp break, a few atom spacing in length, in the dislocation line. These breaks are two types.
  - Jog : A sharp break in the dislocation moving it out of the slip plane.
  - Kink: A sharp break in the dislocation line which remains in the slip plane.
- Possibilities
  - Intersection of two edge dislocations with perpendicular Burgers vectors
  - Intersection of two edge dislocations with parallel Burgers vectors
  - Intersection of an edge dislocation and screw dislocation
  - Intersection of two screw dislocation

Intersection of two edge dislocations with perpendicular Burgers vectors



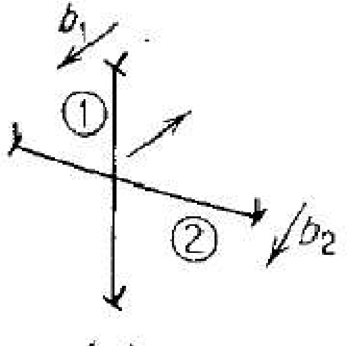
Before intersection



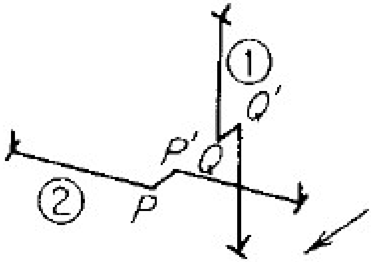
After intersection

Produce jog PP’ has edge nature

Intersection of two edge dislocations with parallel Burgers vectors



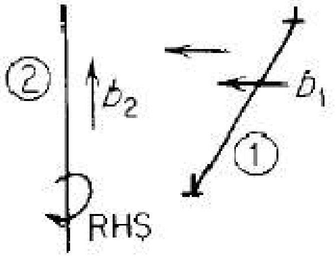
(a)



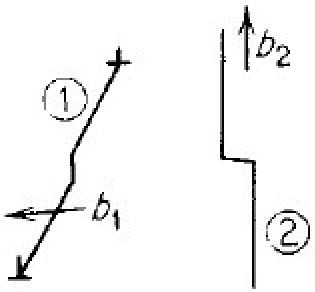
(b)

Both kinks are in screw nature.

Intersection of an edge dislocation and screw dislocation



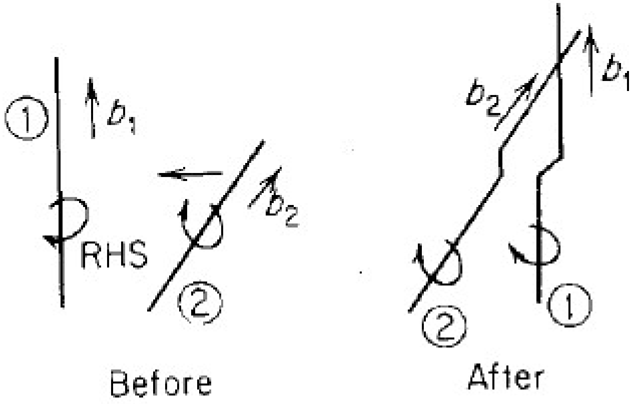
Before



After

Produce jog in edge dislocation with edge nature and a kink in screw dislocation with edge nature.

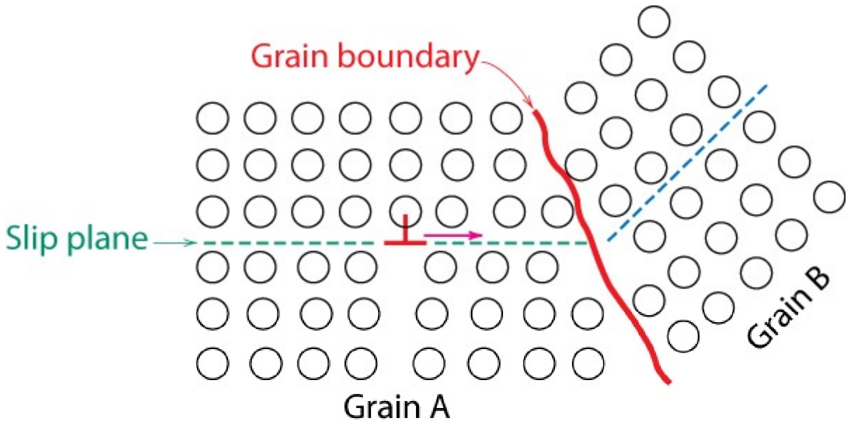
Intersection of two screw dislocation



Intersection of two screw dislocations develops a jog in edge nature.

Grain size Strengthenging

- Grain boundary act as barrier for dislocation motion: slip plane discontinues or change orientation.
- Dislocations gliding on a slip plane are unable to cross the boundary but get piled up against it. This happens more often in a fine grained material.
- Small angle grain boundaries are not very effective in blocking dislocations.



- High-angle grain boundaries block slip and increase strength of the material.

The yield strength of a poly crystalline material is a function of its grain size as given by the Hall petch equation

$$\sigma_y = \sigma_i + kd^{-1/2}$$

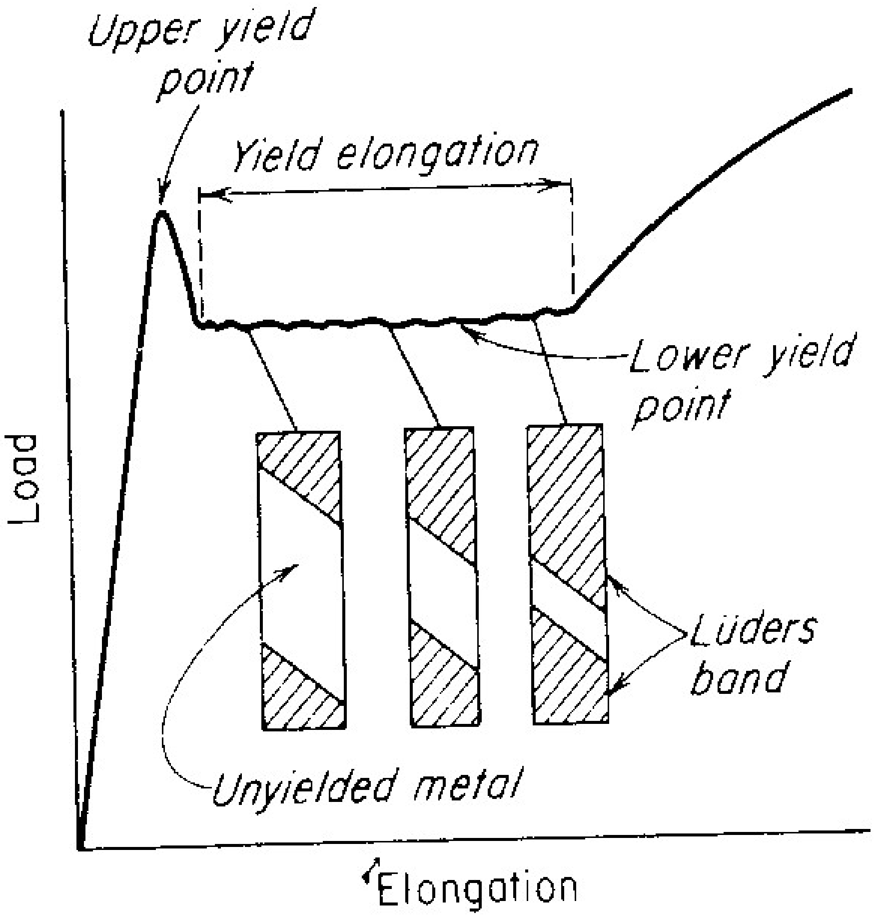
σ_i the yield strength of the material where there are no grain boundaries (single crystal),

k is the relative hardening contribution of the grain boundaries or the Hall Petch constant

d is the grain diameter, which can be derived from the ASTM grain size number.

Yield Point Phenomenon

- The load at which sudden drop occurs – Upper Yield Point
- The average constant load – Lower yield point
- The elongation which occurs at constant load – yield point elongation
- Discrete band formation in the material during yield – Luders band



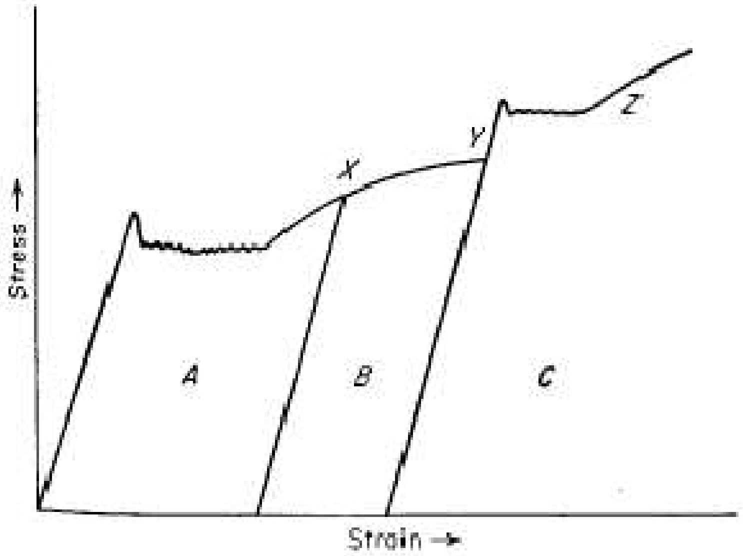
Due to interstitial or substitutional impurities

Yield point phenomena observed in

- Steel
- Mo, Ti and Al alloys
- Single crystals of Fe, Cd, Zn, brass, Al

Strain Ageing

- A metal hardens as a result of ageing after plastic deformation is called strain ageing.

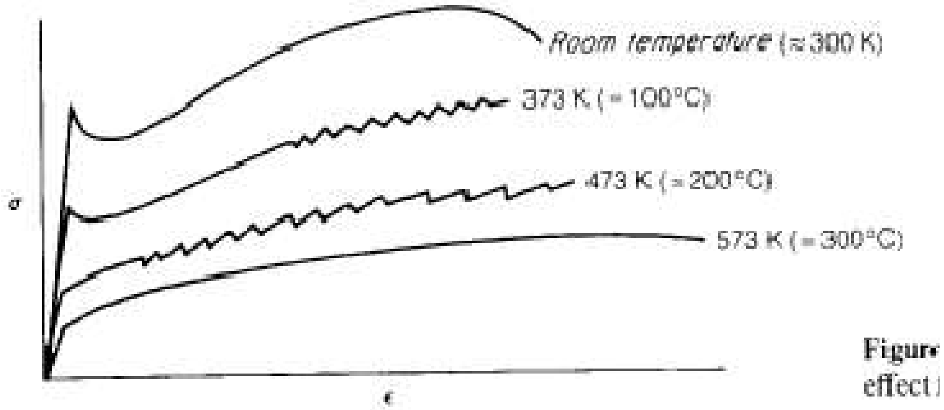


To control the strain ageing,

- Lower the amount of carbon and nitrogen.
- Alloying element Al, V, Ti, and boron are added to convert carbon and nitrogen as stable carbides or nitrides.
- Deform the metals immediately before it can age.

Dynamic strain-ageing

- Strain ageing is associated with the occurrence of serrations in the stress-strain curve
- Dynamic strain-ageing behaviour or Portevin-LeChatelier effect



For plain C steel

- The solute atoms are diffuse in the specimen at a rate faster than the speed of the dislocations and arrest the dislocations
- Due to mechanical twinning during deformation or stress assisted martensitic transformations

- PCS discontinuous yielding / dynamic strain-ageing occurs in the temperature region of 500 to 650 K. This temperature region is known as ***blue brittle region***