Lecture 30

Defects in solids

Why things are weak?

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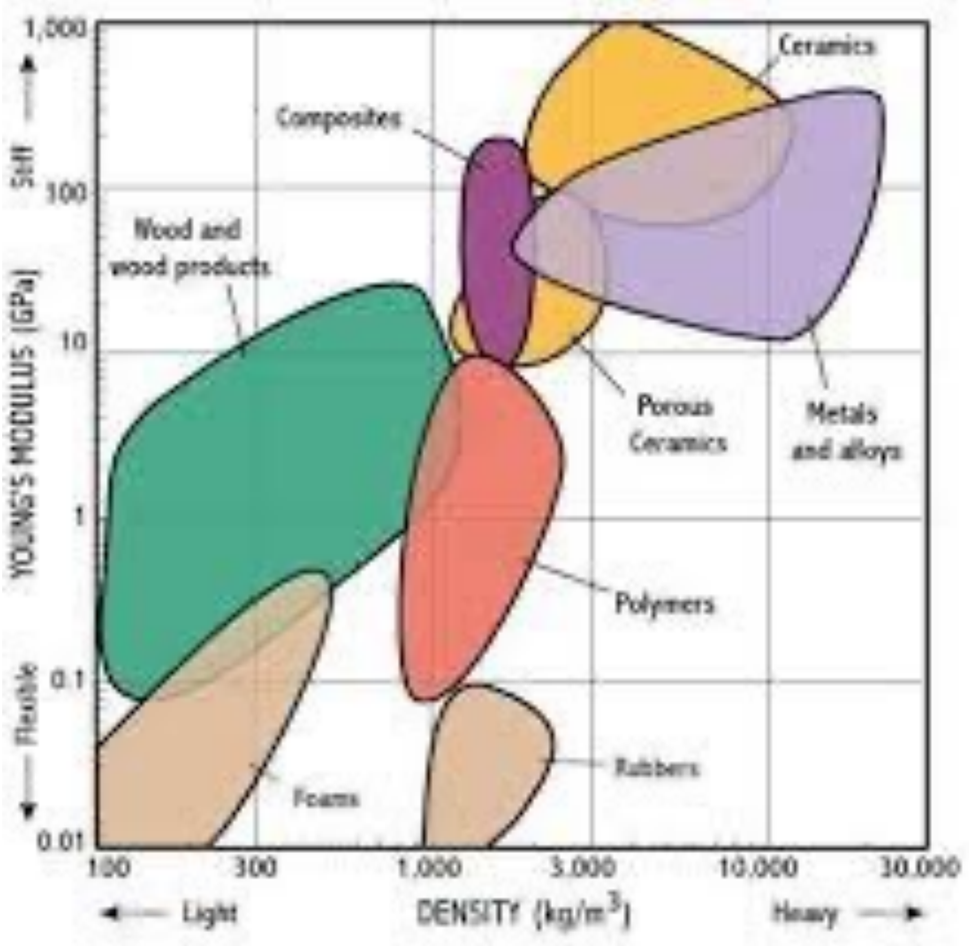
Previous lectures..

- *Why don’t all solids have same strength?*
- *Why do they have any strength at all?*
- *When do we call them strong?*

In the coming two lectures:

- *Why aren’t they much stronger?*
- *Why materials are weak?*
- *Why and how do materials fail?*



An important engineering problem

Blades of wind turbine

Light, strong, sustain wind speed: balance of elastic-plastic deformation!!

Ice forming on wind blades

Blowing at the blades at 100 mph!

Bugs infesting the blades

Defects in solids

Based on dimensionality

- Point defects (0-D): vacancies (interstitial)
- Line defects (1-D): Dislocations
- Surface defects (2-D): free surface, grain boundaries, twin boundaries, stacking fault
- Volume (or bulk) defects (3-D): pores, cracks, foreign inclusions.

Dislocations

A *dislocation* is a linear or one-dimensional defect around which some of the atoms are misaligned

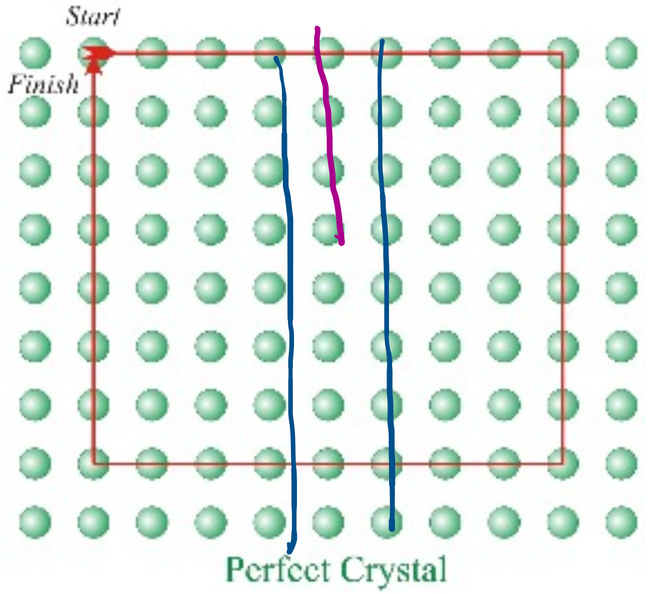
Three types of dislocations:

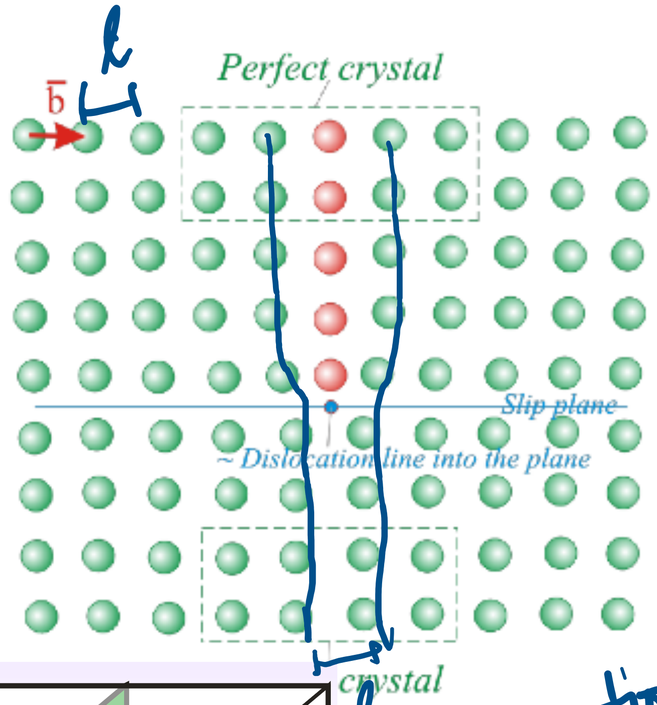
1. **Edge dislocation:** This imperfection is associated with the insertion of an extra half-plane of atoms or removal of half-plane of atoms
2. **Screw dislocation:** associated with a shearing deformational shift along a regular plane.
3. **Mixed dislocation:** combination of both edge and screw dislocation.

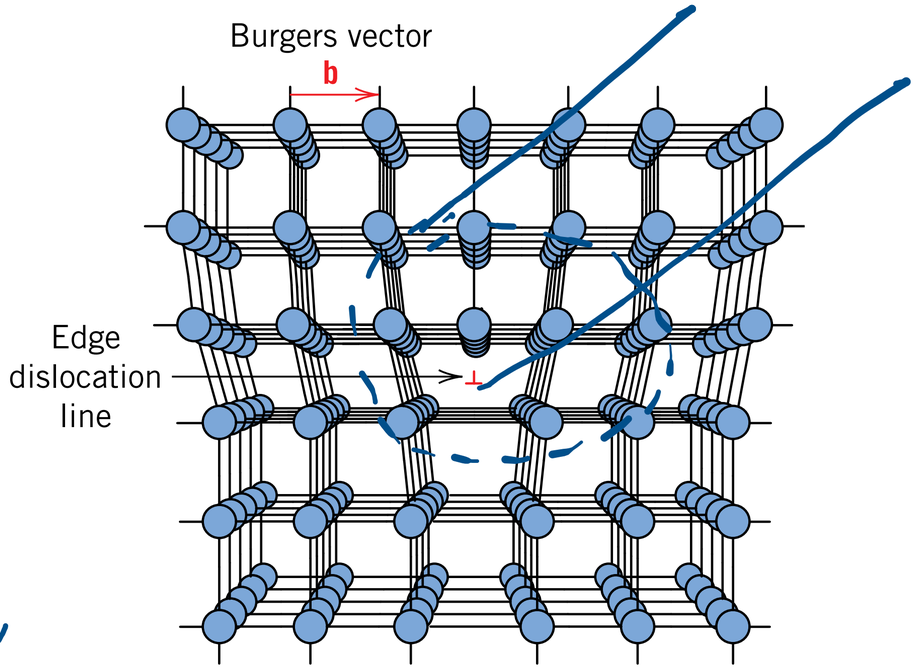
- **Plastic deformation corresponds to the motion of large numbers of dislocations.**
- **They prevent the synchronized breakage of bonds between atoms in materials and cause gradual deformation by making the one-by-one breakage of single bonds possible**.

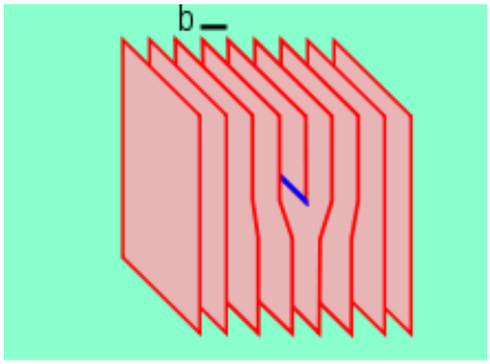
Edge dislocation

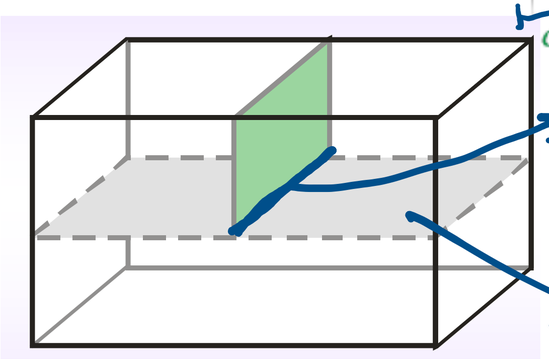
- **Edge dislocation:** it is a linear defect that centers around the line that is defined along the end of the extra half-plane of atoms.
- **Dislocation line**: For an edge dislocation, the intersection of the extra half-plane of atoms with the slip plane defines the dislocation line











Dislocation line

Slip plane

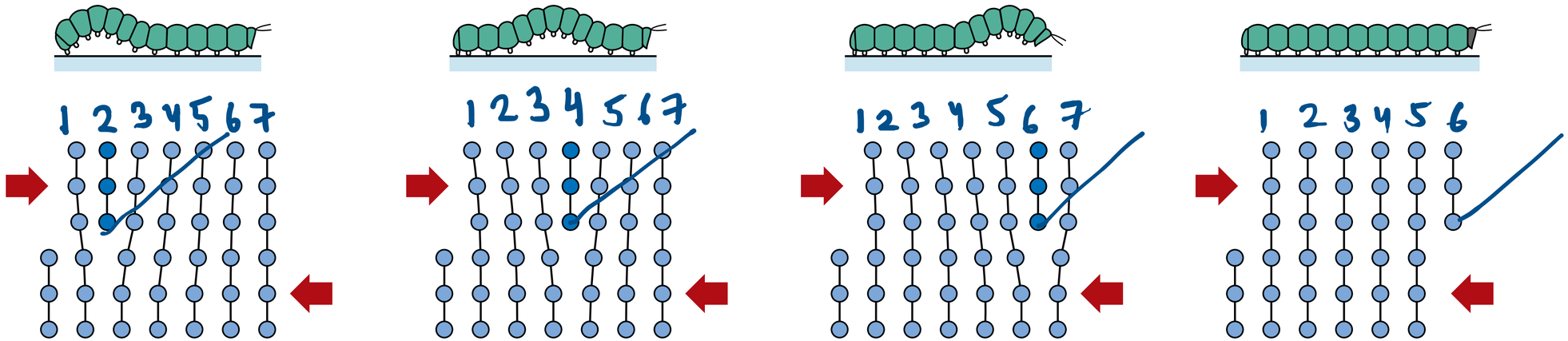
⊥ : if half plane is missing from bottom

T : if half plane is missing from top

Edge dislocation: slip

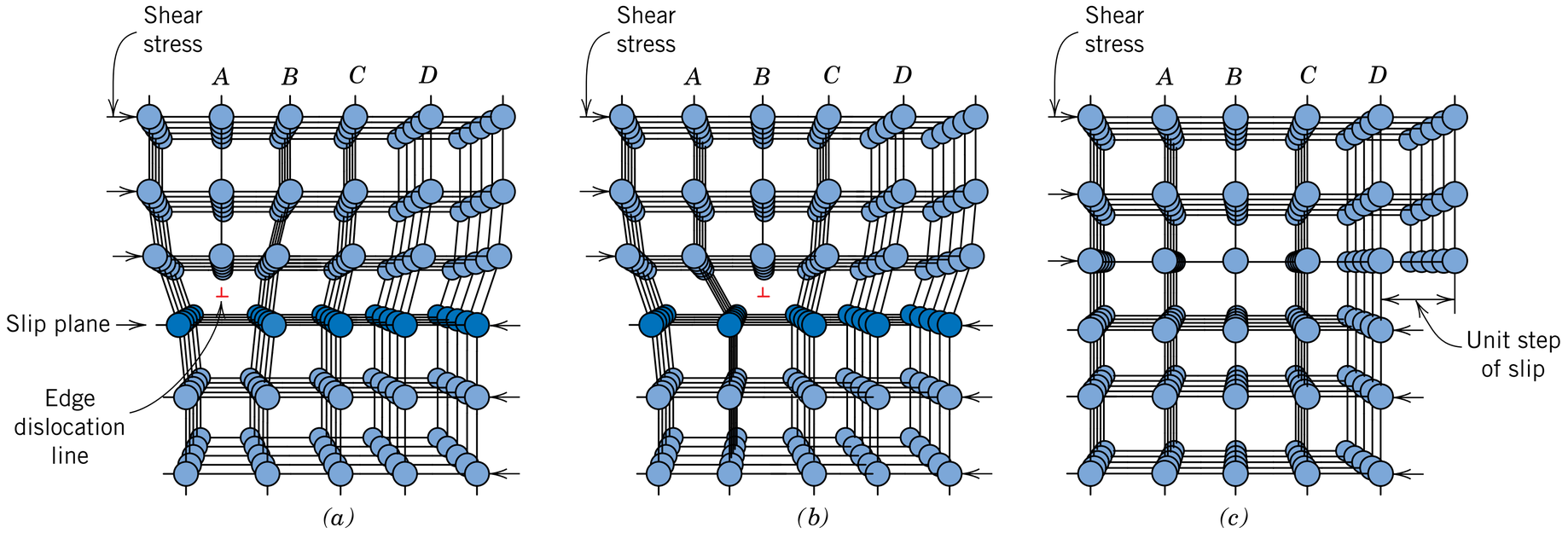
The process by which plastic deformation is produced by dislocation motion is termed *slip*

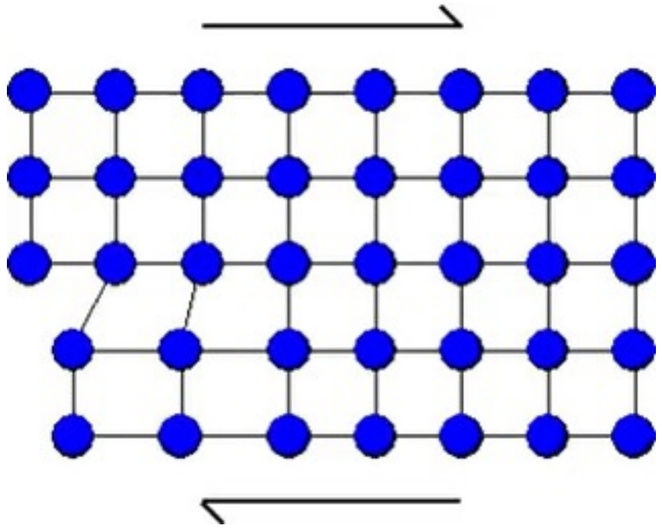
- An edge dislocation moves in response to a shear stress applied in a direction perpendicular to its line.
- This process is subsequently repeated for the other planes, such that the extra half-plane, by discrete steps, moves from left to right by successive and repeated breaking of bonds and shifting by interatomic distances of upper half-planes.
- Only during the passage of the extra half- plane that the lattice structure is disrupted.
- Ultimately this extra half-plane may emerge from the right surface of the crystal, forming an edge that is one atomic distance wide.
- The crystallographic plane along which the dislocation line traverses is the ***slip plane.***
- **Dislocation line** can be considered as the boundary between the slipped and the unslipped parts of the crystal lying over a slip plane.

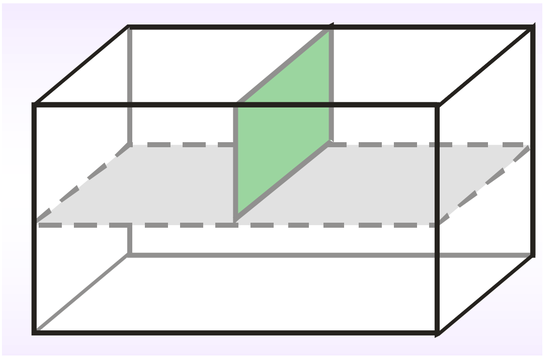


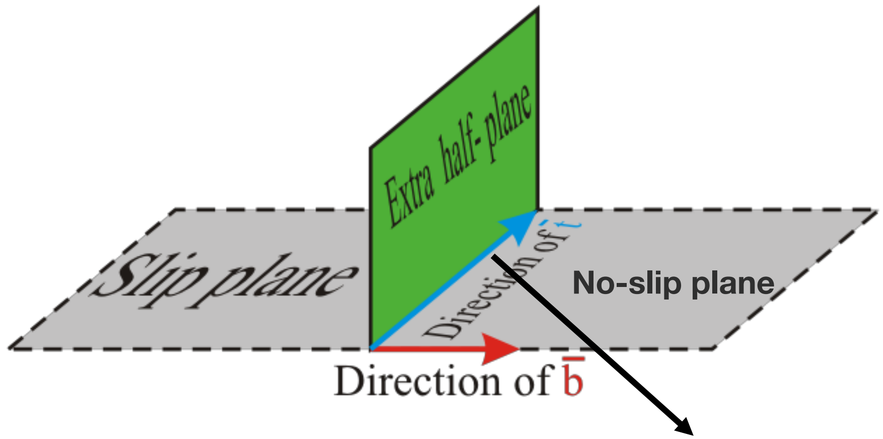
Dislocations prevent the synchronized breakage of bonds between atoms in materials and cause gradual deformation by making the one-by-one breakage of single bonds possible

Edge dislocation: Slip



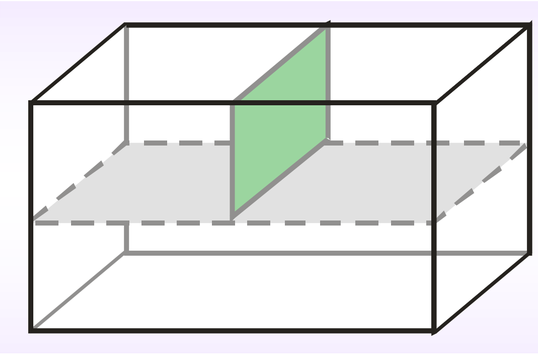


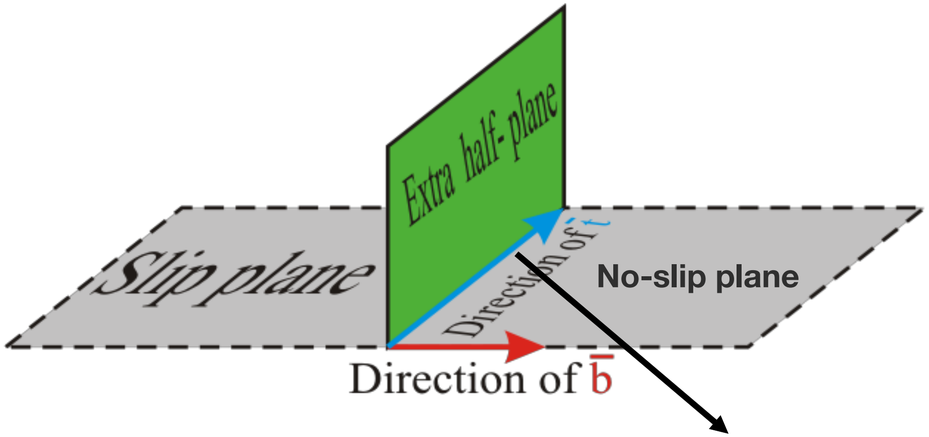




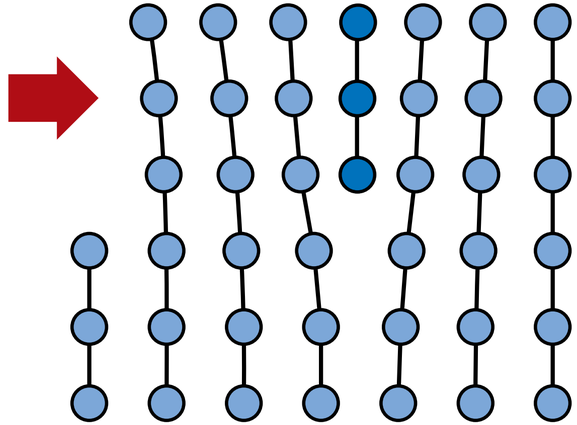
Dislocation line

Vectors characterizing dislocation





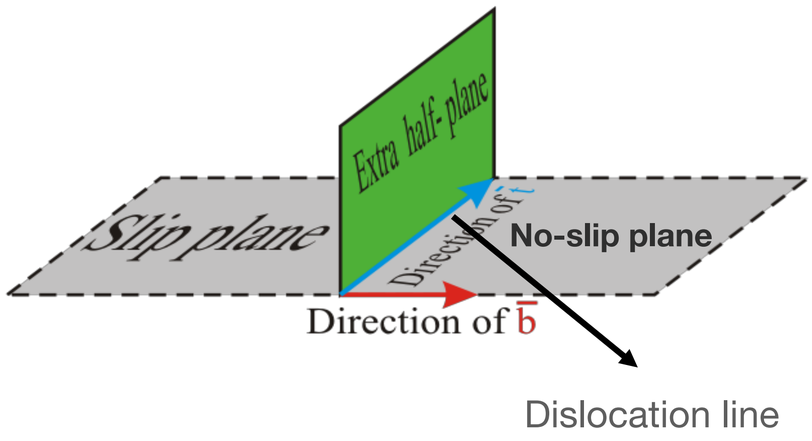
Dislocation line

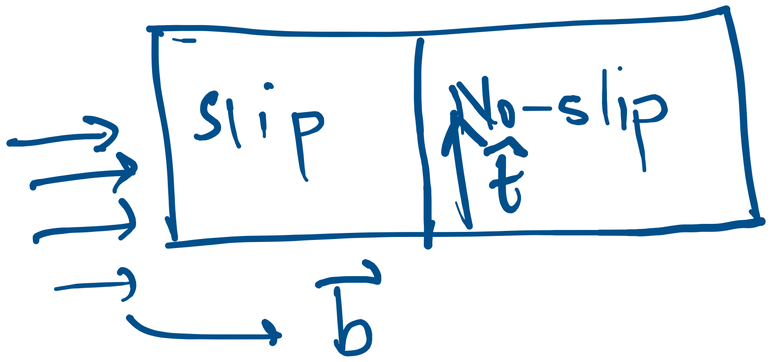


Tangent vector $\hat{t}$: unit vector parallel or tangent to the dislocation line

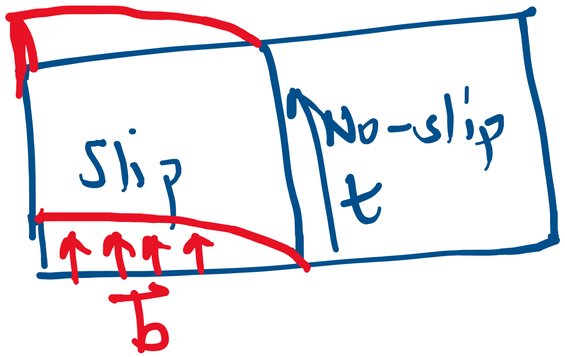
Burgers vector $\vec{b}$: magnitude & direction of slip

Edge, screw and mixed dislocation

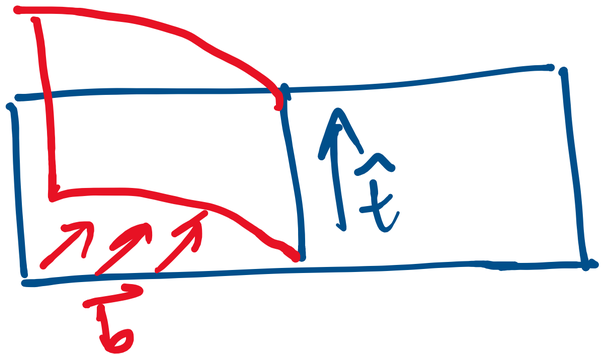




$\vec{b} \perp \hat{t}$: Edge dislocation



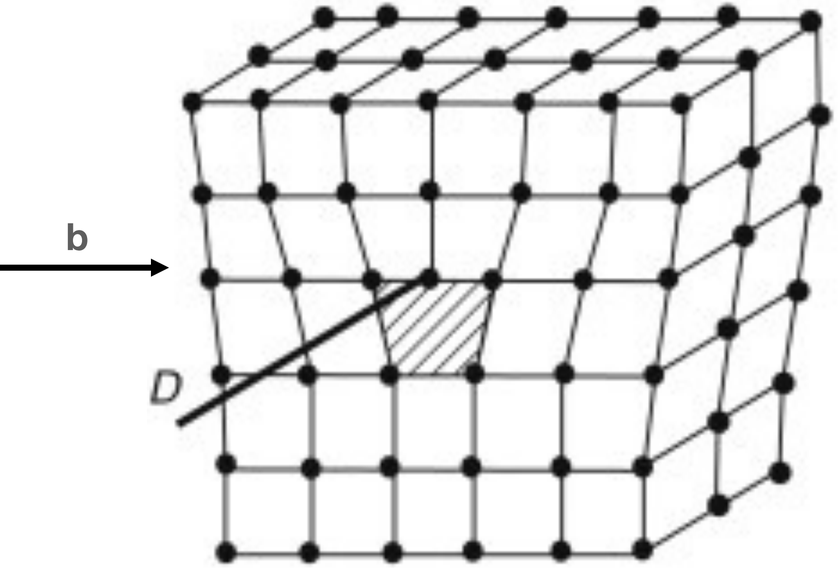
$\vec{b} \parallel \hat{t}$: Screw dislocation



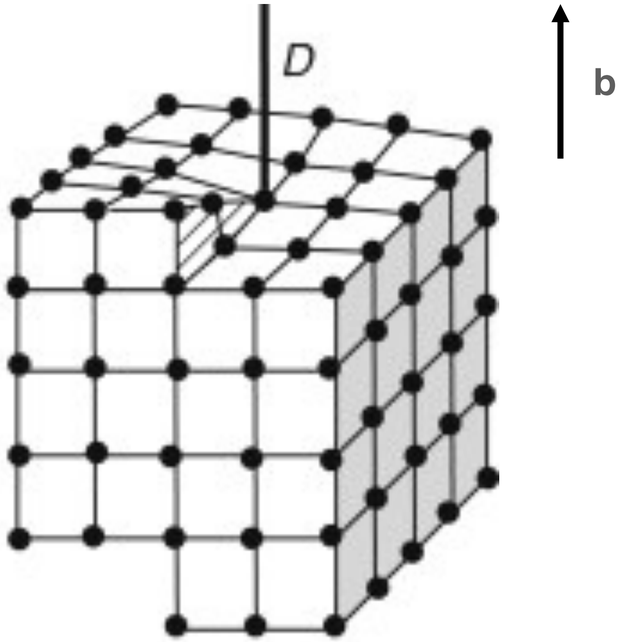
$\vec{b} \not\perp \hat{t}$, $\vec{b} \not\parallel t$:

Mixed dislocation

Edge and screw dislocation



(Edge Dislocation)



(Screw Dislocation)

A transmission electron micrograph of a titanium alloy in which the dark lines are dislocations. 51,450X