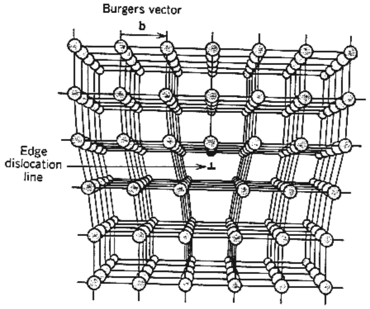
Line Defects: Dislocations

- What are dislocations ? They are line defects which arise during crystal growth or as a result of mechanical deformation of a crystal. (10^6 to 10^7 in best crystals (Si, Ge) and upto 10^{16} per cm^2)
- Why dislocations are important :
  - Explain why the strength of “real” crystalline materials is much less (10^2 to 10^3 times) than the theoretical value.
  - Motion of dislocations is the mechanism at the origin of plastic deformation of crystals (ductile vs. brittle behavior).
  - Allows some “cohesion“ between crystals of different orientations (low angle grain boundaries are arrays of dislocations).
  - Explains a number of crystal-crystal transitions.

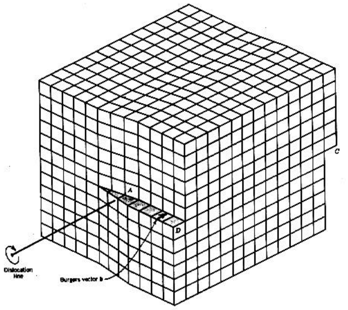
Example of an Edge Dislocation



The dislocation line runs parallel to the end of the extra plane of atoms

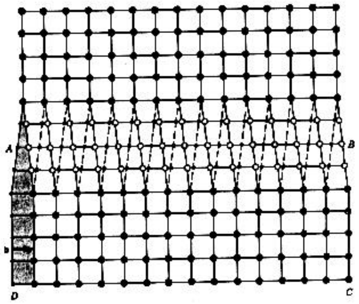
An edge dislocation can be viewed as created when an extra portion of a plane of atoms is introduced in a crystal, the edge of the plane being in the crystal interior.

Screw Dislocation (side view)



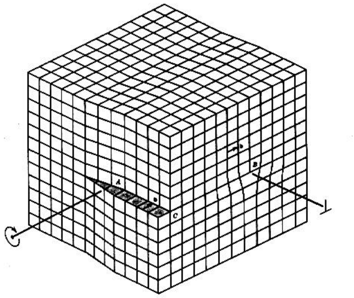
Can be viewed as formed by shearing the top part of the crystal with respect to the bottom part.

Screw Dislocation (top view)



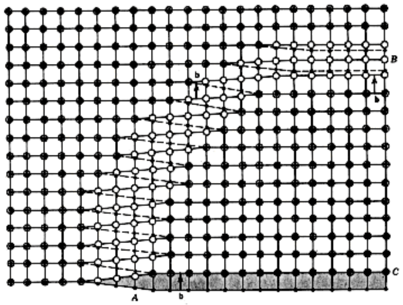
The dislocation line extends from A to B. Atom positions above the slip plane are designated by open circles, below the slip plane with small filled circles. Name is derived from spiral path along the dislocation line (AB).

Mixed Dislocation



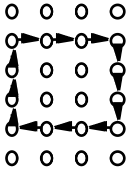
Most dislocations are neither pure edge nor pure screw, but are mixed

Mixed Dislocation

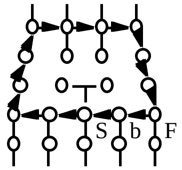


Note that in A the dislocation is pure screw and in in B is pure edge

Determination of the Burgers Vector



Perfect Crystal



Crystal with Distortion

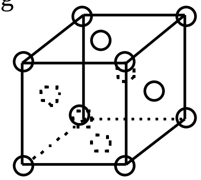
Choose a line direction (positive direction into the page) for the dislocation direction. Perform a circuit in the perfect reference lattice in a right handed fashion. Repeat the circuit in the real lattice so as to enclose the dislocation. The Burgers vector is the vector from the finishing point F to the starting point S using the FS/RH convention.

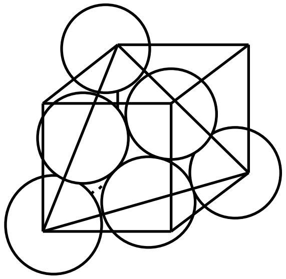
Further Information...

- For an edge dislocation the Burgers vector is orthogonal to the dislocation line. For a screw dislocation, the Burgers vector is parallel to the dislocation line.
- The elastic strain energy associated with the dislocation is proportional to the square of the Burgers vector.
- For metallic materials, the Burgers vector for a dislocation will point in a closed-packed crystallographic direction and will be of magnitude equal to the interatomic spacing.

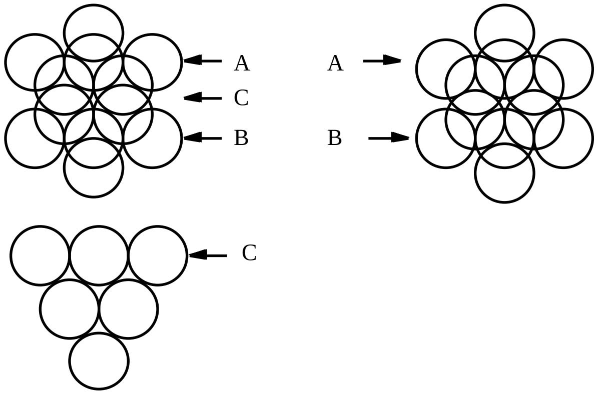
Stacking and Packing

- In FCC structures the nearest neighbors are along the <110> . To visualize this, consider the atoms as hard spheres, which touch only in the face diagonal directions. There are 12 closest neighbors for each atom.
- Consider now the (111) plane in the FCC structure. This plane has the highest atomic density (it is called a close-packed plane. There are four such planes in the FCC structure.



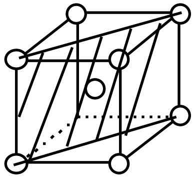


Stacking of (111) planes of FCC and (0001) planes (HCP)



ABC Stacking for FCC and ABA Stacking for HCP

- For BCC, the most densely packed planes are the {110} planes. Note that these planes are not closed-packed (lower density than that of (111) in FCC).



BCC

Coordination Number
8 instead of 12

Plastic deformation of metals occurs by sliding of adjacent closed-packed or densely-packed planes (slip planes). In FCC, the slip planes are (111) and the slip directions are <110>. In HCP, the slip planes are (0001) and the slip direction is <11$\underline{2}$0>. In BCC the slip planes are (110), (112) and (123), the slip direction is only the body diagonal <111>. (Slip plane = glide plane = plane containing **b** and dislocation line). Deformation of a crystal occurs through motion of dislocations