



ENGINEERING MATERIALS

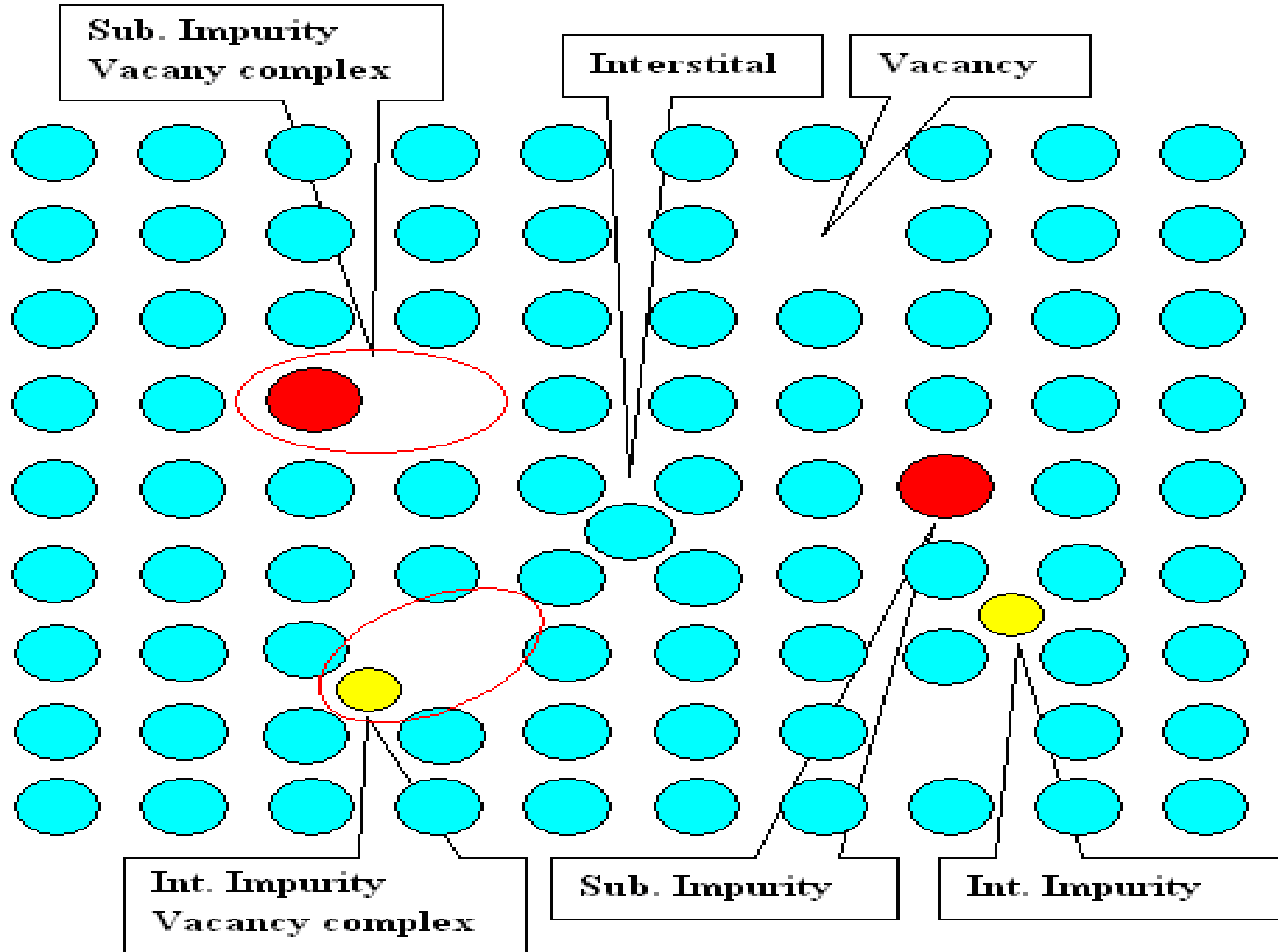
Lecture No. 4

Defects

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CRYSTAL DEFECTS

The arrangement of the atoms or ions in engineered materials contains imperfections or defects عيوب . These defects often have a profound effect on the properties of materials. Classification of crystalline imperfections is frequently made according to **geometry or dimensionality of the defect**



POINT DEFECTS

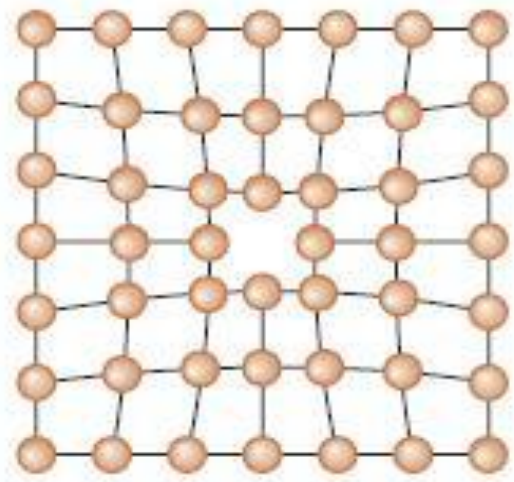
Point defects: are localized disruptions in an otherwise perfect atomic or ionic arrangements in a crystal structure. Even though we call them point defects, the disruption affects a region involving several of the surrounding atoms or ions. These imperfections, shown in Figure1, may be introduced by movement of the atoms or ions when **they gain energy by heating, during processing of the material** or by **introduction of other atoms**. A point defect typically involves one atom or ion, or a pair of atoms or ions.

VACANCIES الفراغات

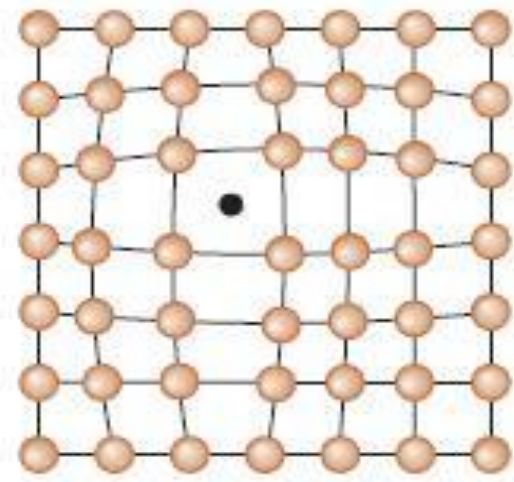
A vacancy is produced when an atom or an ion is missing from its normal site in the crystal structure, as in Figure1. When atoms or ions are missing (i.e., when vacancies are present), the overall randomness or entropy of the material increases, which increases the thermodynamic stability of a crystalline material. All crystalline materials have vacancy defects. Vacancies are introduced into metals and alloys **during solidification, at high temperatures.** At room temperature, the concentration of vacancies is *small*, but the concentration of vacancies increases with increase the temperature

INTERSTITIAL DEFECTS عيوب الخلالية

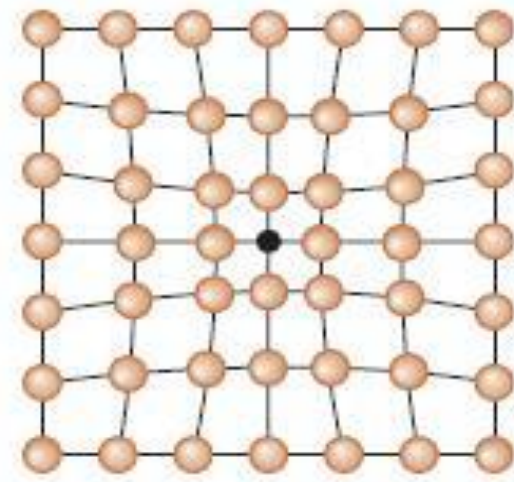
An interstitial defect is formed when an extra atom or ion is inserted into the crystal structure at a normally unoccupied position, as in Figure1 (b). Interstitial atoms or ions, although much smaller than the atoms or ions located at the lattice points, are still larger than the interstitial sites that they occupy. Consequently, the surrounding crystal region is compressed and distorted. Interstitial atoms such as hydrogen are often present as impurities; whereas carbon atoms are intentionally added to iron to produce steel



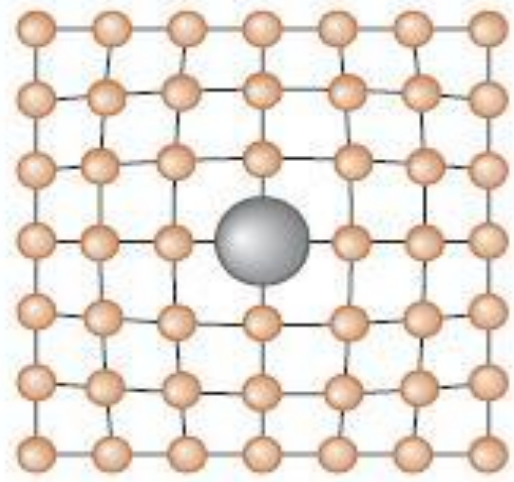
(a)



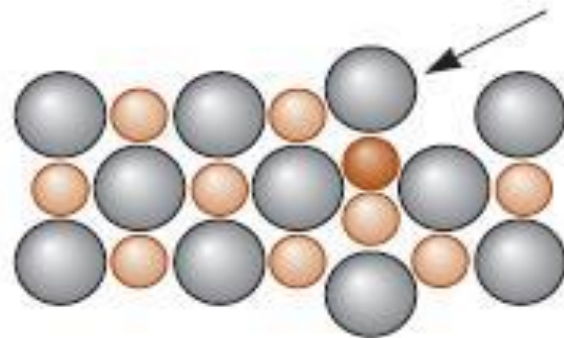
(b)



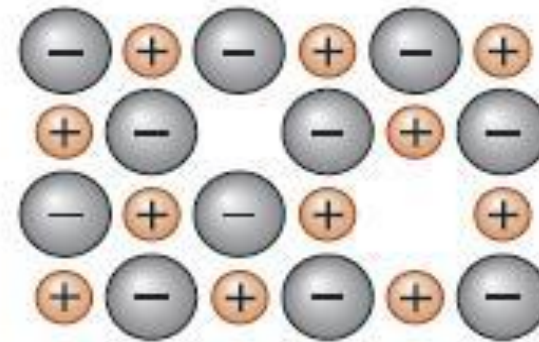
(c)



(d)



(e)



(f)

Figure 1: Point defects: (a) vacancy, (b) interstitial atom, (c) small substitutional atom, (d) large substitutional atom, (e) Frenkel defect, and (f) Schottky defect.

SUBSTITUTIONAL DEFECTS عيوب الاستبدال

A substitutional defect is introduced when one atom or ion is replaced by a different type of atom or ion as in Figure1 (c) and (d). The substitutional atoms or ions occupy the normal lattice sites. Substitutional atoms or ions may either be larger than the normal atoms or ions in the crystal structure, in which case the surrounding interatomic spacings are reduced, or smaller causing the surrounding atoms to have larger interatomic spacings. In either case, the substitutional defects alter the interatomic distances in the surrounding crystal. Again, the substitutional defect can be introduced either as an impurity or as a deliberate alloying addition. The substitutional atoms will often increase the strength of the metallic material. Substitutional defects also appear in ceramic materials.

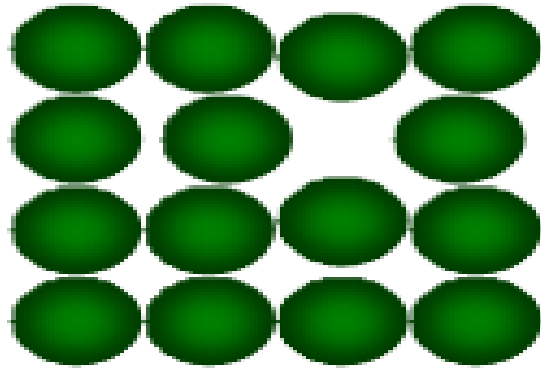
FRENKEL DEFECT

Frenkel defect is a **vacancy-interstitial pair** formed when an ion jumps from a normal lattice point to an interstitial site, as in Figure 1 (e), leaving behind a vacancy. Although this is described for an ionic material, a Frenkel defect can occur in metals and covalently bonded materials

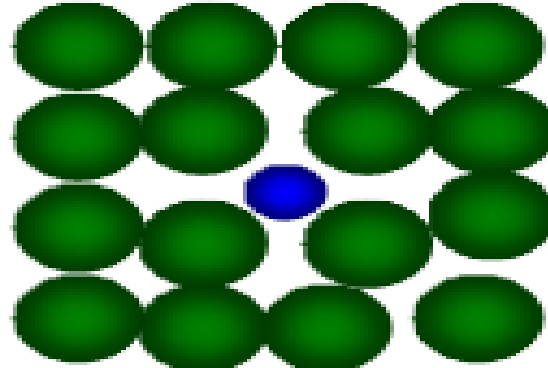
SCHOTTKY DEFECT

Figure 1 (f), is unique to ionic materials and is commonly found in many ceramic materials. In this defect vacancies occur in an ionically bonded material; a number of anions and cations must be missing from the crystal if electrical neutrality is to be preserved in the crystal. For example, one Mg^{+2} and one O^{-2} missing in MgO constitute a Schottky pair. In ZrO_2 , for one missing zirconium ion there will be two oxygen ions missing.

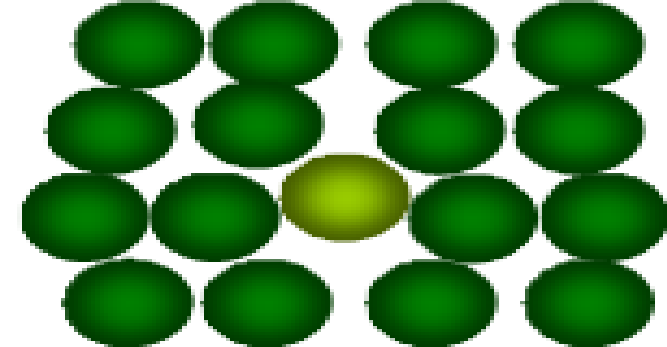
Point defects of crystals



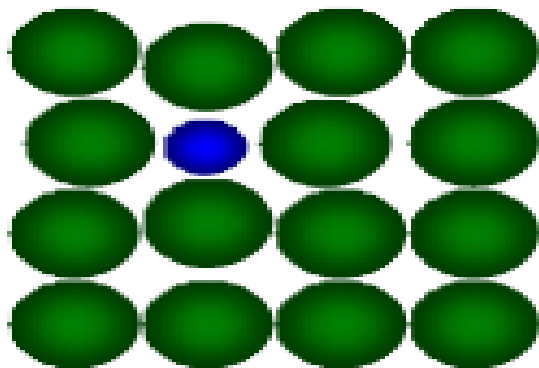
Vacancy



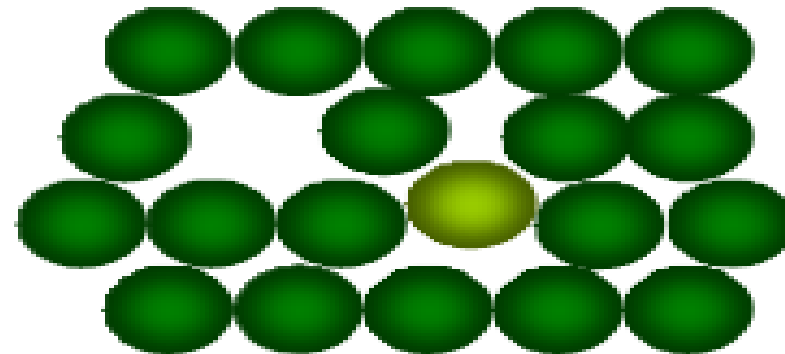
Interstitial impurity



Self-interstitial



Substitution impurity



Frenkel defect

DISLOCATIONS – LINEAR DEFECTS

Dislocations – Linear Defects are line imperfections in an otherwise perfect crystal. They are introduced typically into the crystal during solidification of the material or when the material is deformed permanently. Although dislocations are present in all materials, including ceramics and polymers, they are particularly useful in explaining deformation and strengthening in metallic materials. We can identify three types of dislocations: the edge dislocation, the screw dislocation, and the mixed dislocation

EDGE DISLOCATION

One type of dislocation is represented in Figure 2: an extra portion of a plane of atoms, or half-plane, the edge of which terminates within the crystal. This is termed an edge dislocation. Within the region around the dislocation line there is some localized lattice distortion. The atoms above the dislocation line are squeezed together, and those below are pulled apart.

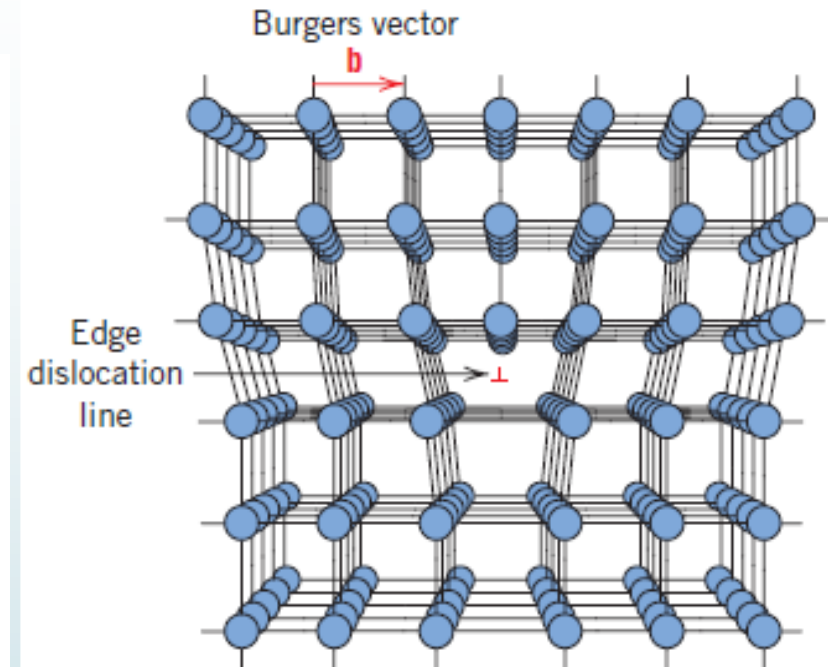
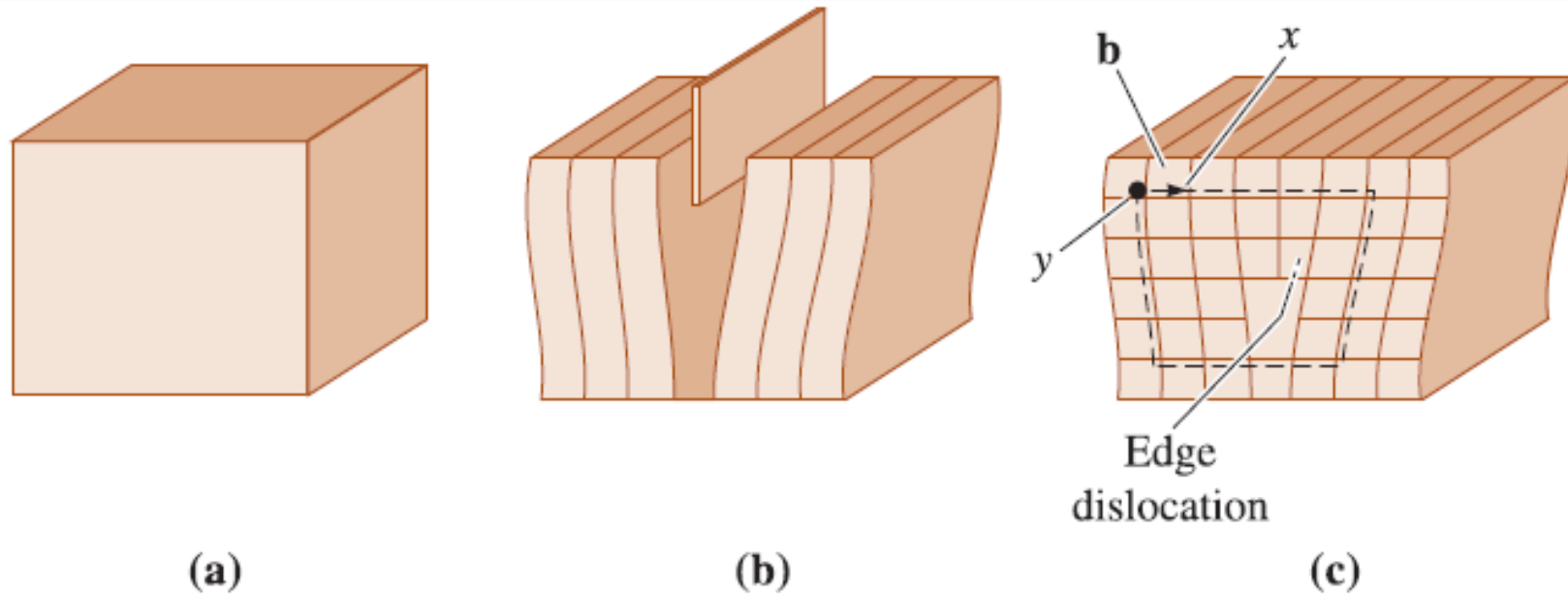


Figure 2: The perfect crystal in (a) is cut and an extra plane of atoms is inserted (b). The bottom edge of the extra plane is an edge dislocation (c). (d) The atom positions around an edge dislocation; extra half-plane of atoms shown in perspective.

SCREW DISLOCATION

Another type of dislocation, called a screw dislocation, may be thought of as being formed by a shear stress that is applied to produce the distortion shown in Figure 3: the upper front region of the crystal is shifted one atomic distance to the right relative to the bottom portion.

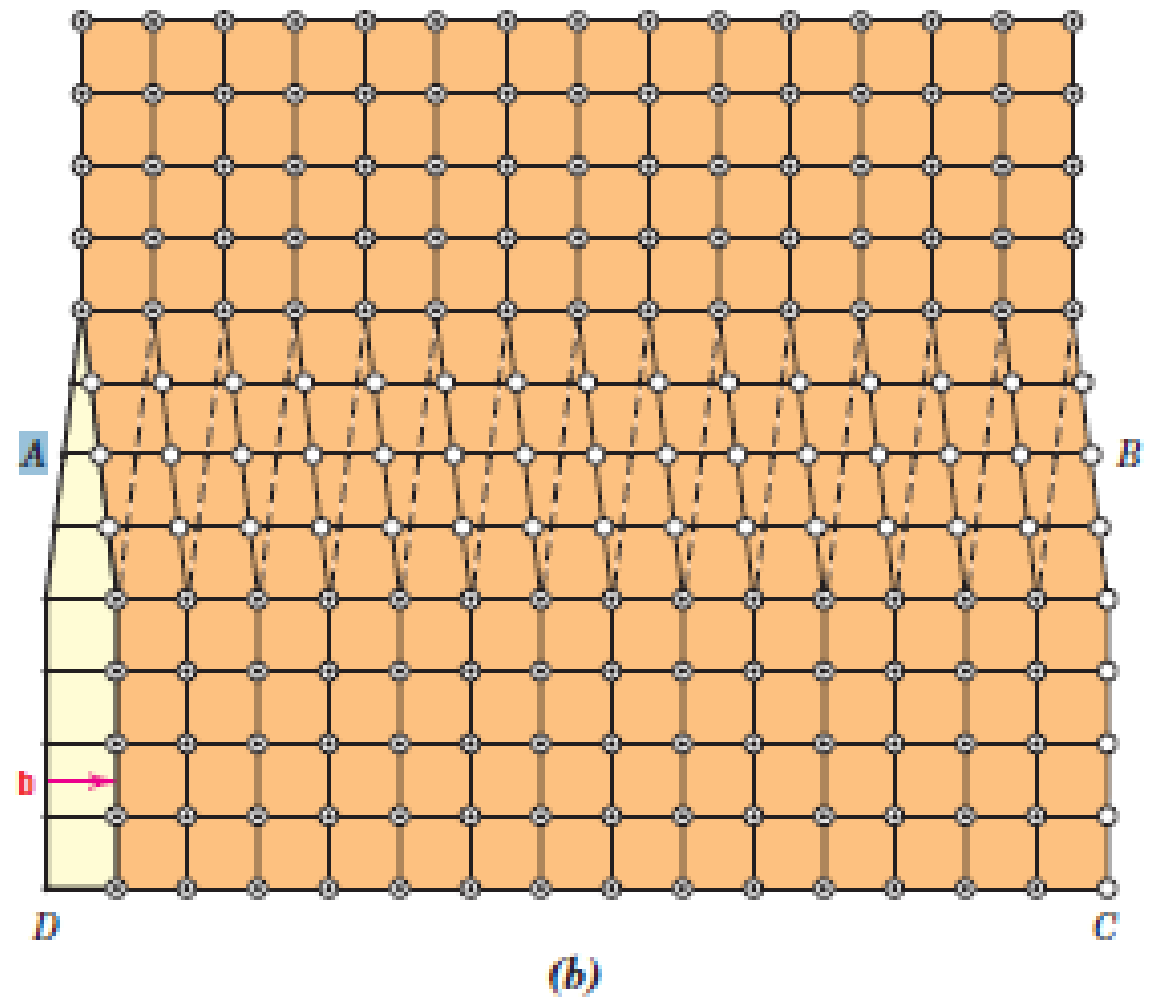
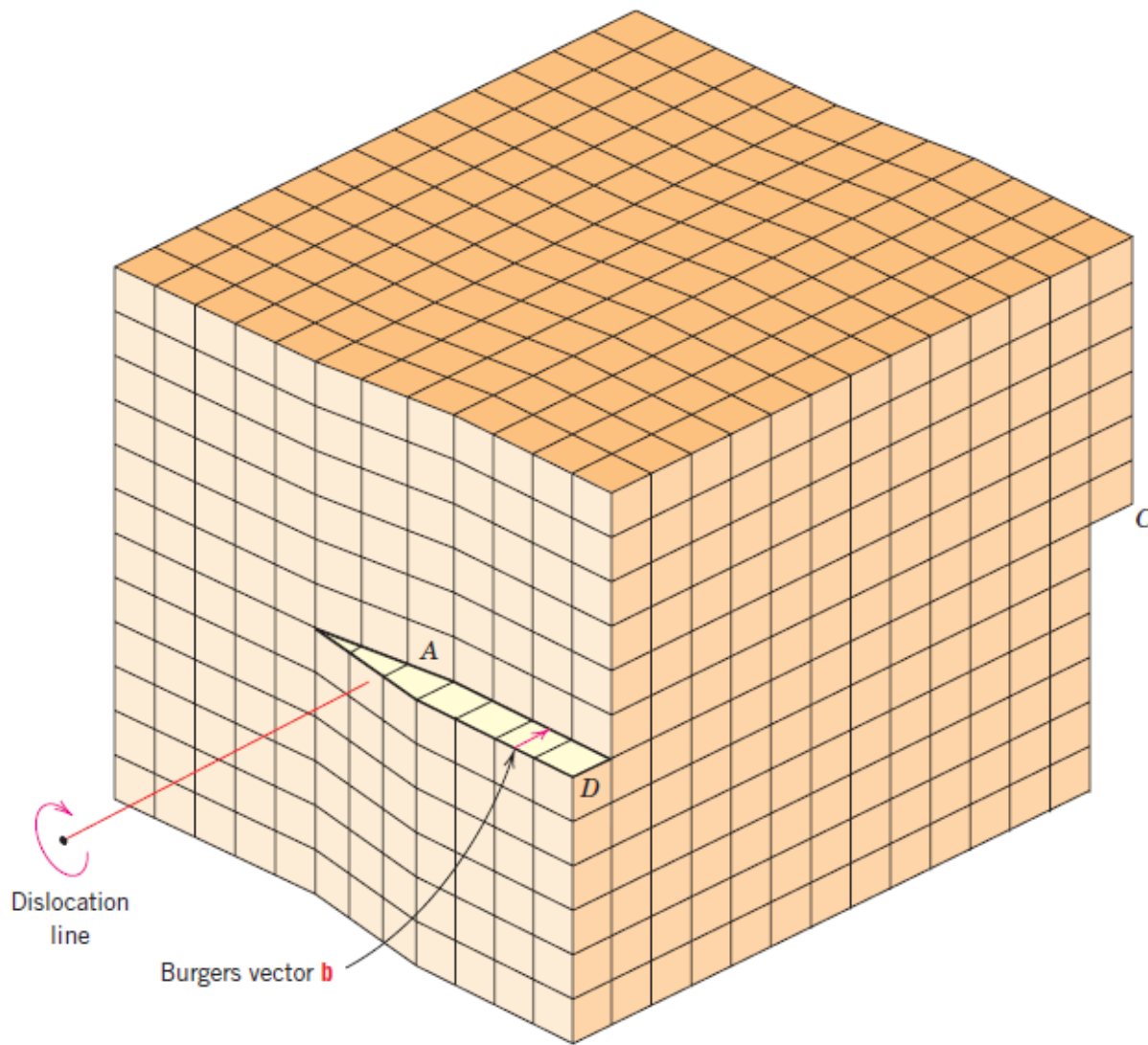


Figure 3: A screw dislocation within a crystal

MIXED DISLOCATIONS

Most dislocations found in crystalline materials are probably neither pure edge nor pure screw, but exhibit components of both types; these are termed mixed dislocations as shown in Figure 4.

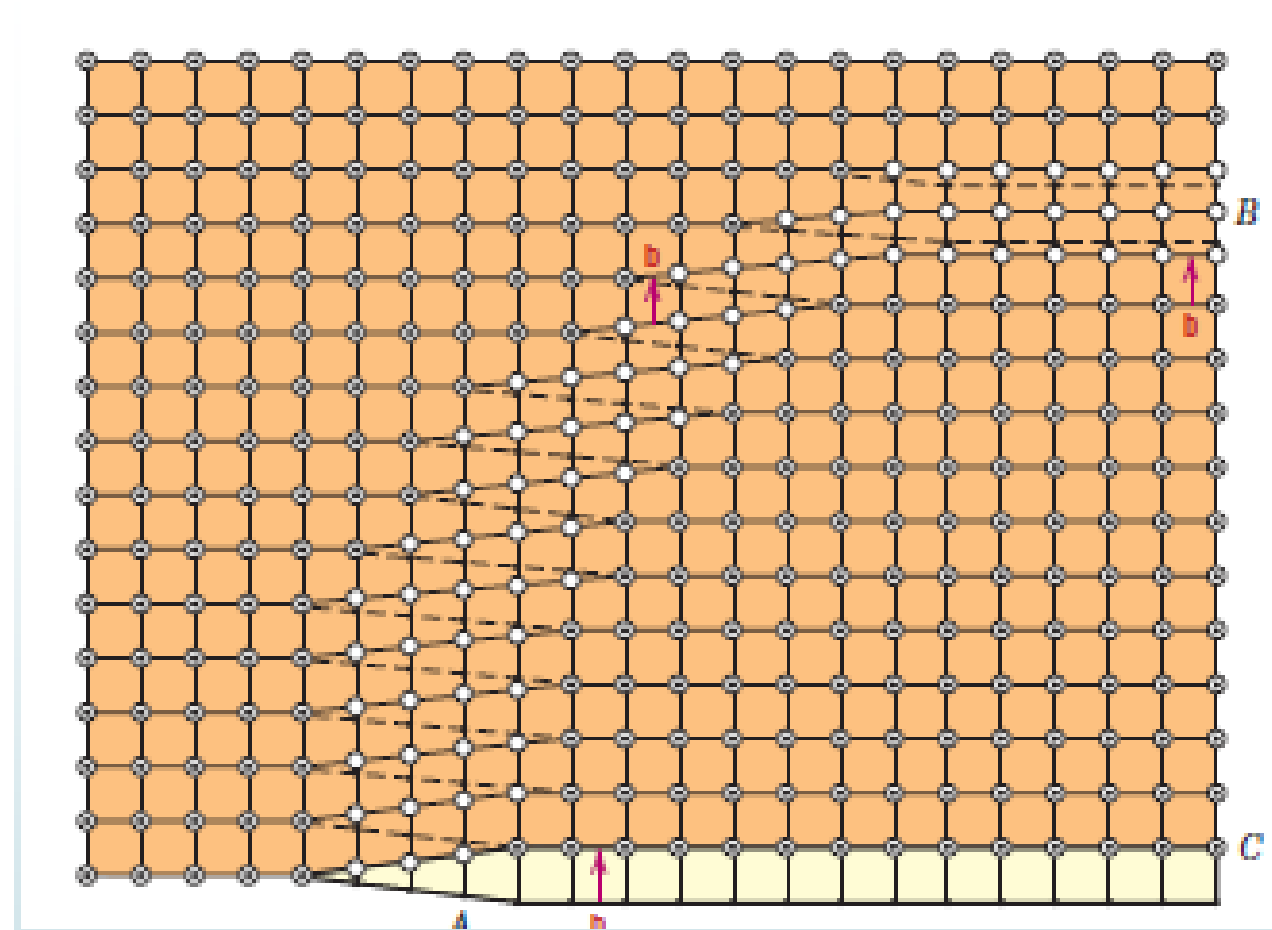
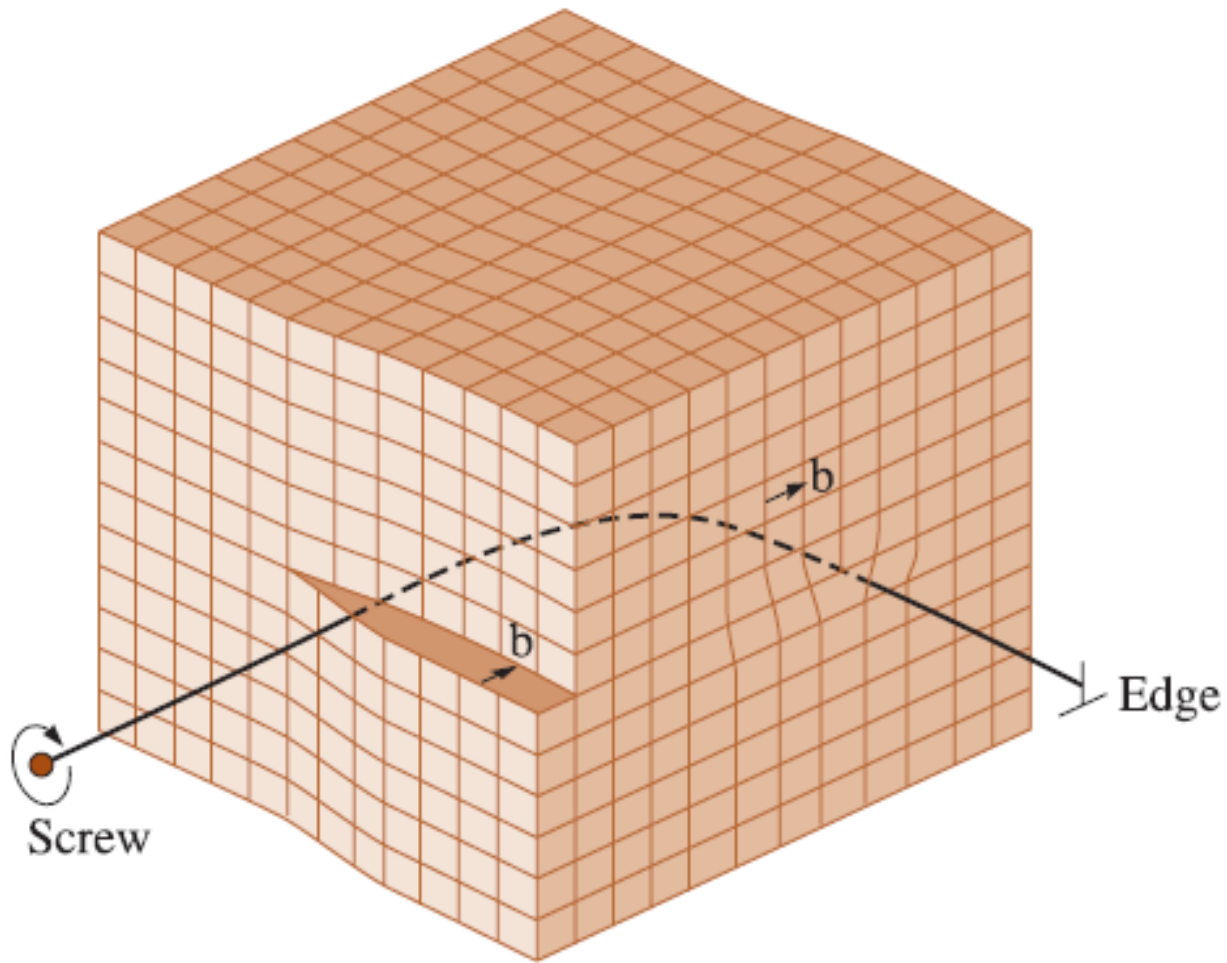


Figure 4: A mixed dislocation. The screw dislocation at the front face of the crystal gradually changes to an edge dislocation at the side of the crystal.

Transmission electron micrograph of a titanium alloy in which the dark lines are dislocations, 50,000 \times .



BURGERS VECTOR

The magnitude and direction of the lattice distortion associated with a dislocation is expressed in terms of a Burgers vector, denoted by \mathbf{b} . Burgers vectors are indicated in Figures 2 and 3 for edge and screw dislocations, respectively. Furthermore, the nature of a dislocation (i.e. edge, screw, or mixed) is defined by the relative orientations of dislocation line and Burgers vector. For an edge, they are perpendicular (Figure:2), whereas for a screw, they are parallel (Figure:3); they remain the same for all portions of the mixed dislocation.

Thank you for listening