Crystal Defects and Imperfections

-impurities and disruptions in the pattern of atoms
-affect many physical properties

3 Main Types of Defects

Ask the students what comes to mind when you hear the word "defect". They usually say something "bad" or "unwanted" or "negative". When discussing that point defects can be used to make alloys point out that we create "defects" on purpose because they result in useful changes in properties. Reinforce the idea that defects can lead to positive changes when discussing that line defects can increase the hardness or strength of metals.

1. **Point Defects** – single atom defects
   Use overhead to illustrate the types of point defects – have students draw them in their journal.

   a. **Vacancy** – atom is missing (void)
      -move around in crystal by diffusion
      -*use BB board to illustrate*

   b. **Interstitial** – extra atoms inserted in the gaps between the regular atoms
      -used in making alloys – ex. steel

   c. **Substitutional** – replace some of the original atoms with different atoms
      -used in making alloys

2. **Line Defects – dislocations**
   -regions in crystals where atoms are not perfectly aligned – *use overheads to illustrate*
   -can move
   -a small number make a metal more workable – a large number make a metal harder to work
   -when working a metal, dislocations can get "jammed" or "pinned". This can make the metal harder = work-hardening

3. **Interfacial Defects**
   -grain boundaries
   -3-D
   -*affected by size of grains*

"Working a metal"

-changing its shape while a solid

Ex. – pounding
bending
stretching
rolling

Copper Wire Activity

Work-hardening and Heat-treating

Students bend ~ 6" – 8" piece of copper wire in the middle feeling the strength it takes to bend it. The wire needs to be fairly thick-gauged. Then they try to bend it back exactly the way it was – straight. Once again noticing the strength it takes. They do this several times. Students should notice that it is practically impossible to bend the wire back to its original shape – perfectly straight. It will appear to have small "kinks" or "bumps" in it. The wire will want to bend in a location to the side of the original bend. The students should also notice that it takes an increasing amount of strength to bend the wire. This is called "work-hardening".

Have the students hammer one end of the wire. Then compare the strength it takes to bend the hammered end versus the unhammered end.

Ask the students if they can hypothesize why the wire changes – what is going on inside.

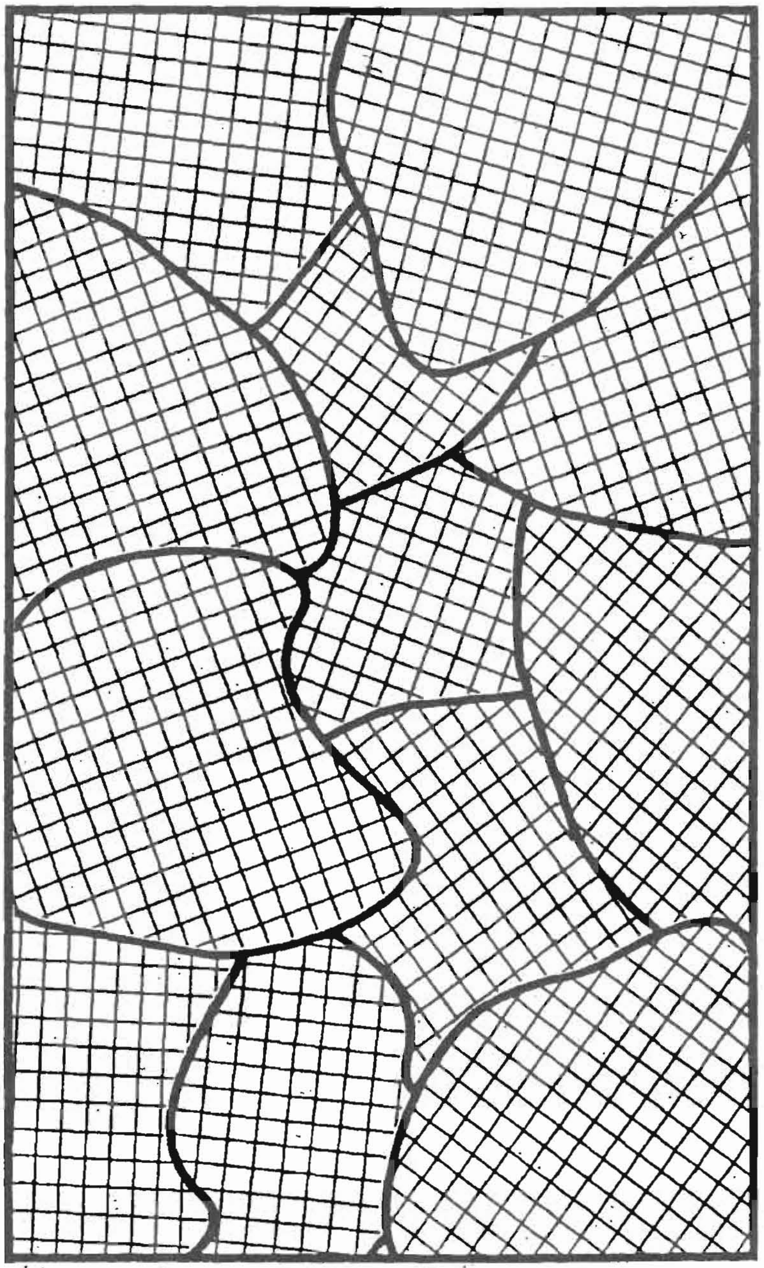
They are increasing the number of dislocations when they "work" the metal – bending or hammering. The dislocations are also attempting to move through the metal. The dislocations get "pinned" or "jammed" when they meet up coming from different directions. This causes an increase in the strength or hardness of the metal. It decreases the workability and can make it more brittle.

Now have the students heat-treat the copper by holding it in the flame of a propane torch or Bunsen burner (using pliers to hold the metal). Have them heat the hammered end holding the metal vertically in the flame so that part of the middle where it was bent will also be heat-treated. The wire should be heated until it is red hot. The wire can then be cooled – either slowly in air or by quenching it in a can of water.

Have students bend the heat-treated end of the wire and compare it to the feel of the work-hardened wire. It should be noticeably softer and more workable. If they continue to bend it, it will once again work-harden and they will feel the difference in stiffness.

Ask the students to explain how or why the heat changed the metal.

The heat gave the atoms enough mobility to re-grow the crystals in the metal. Dislocations were eliminated (decreased) and bigger crystals with fewer grain boundaries may form. This results in a softer, more workable metal.



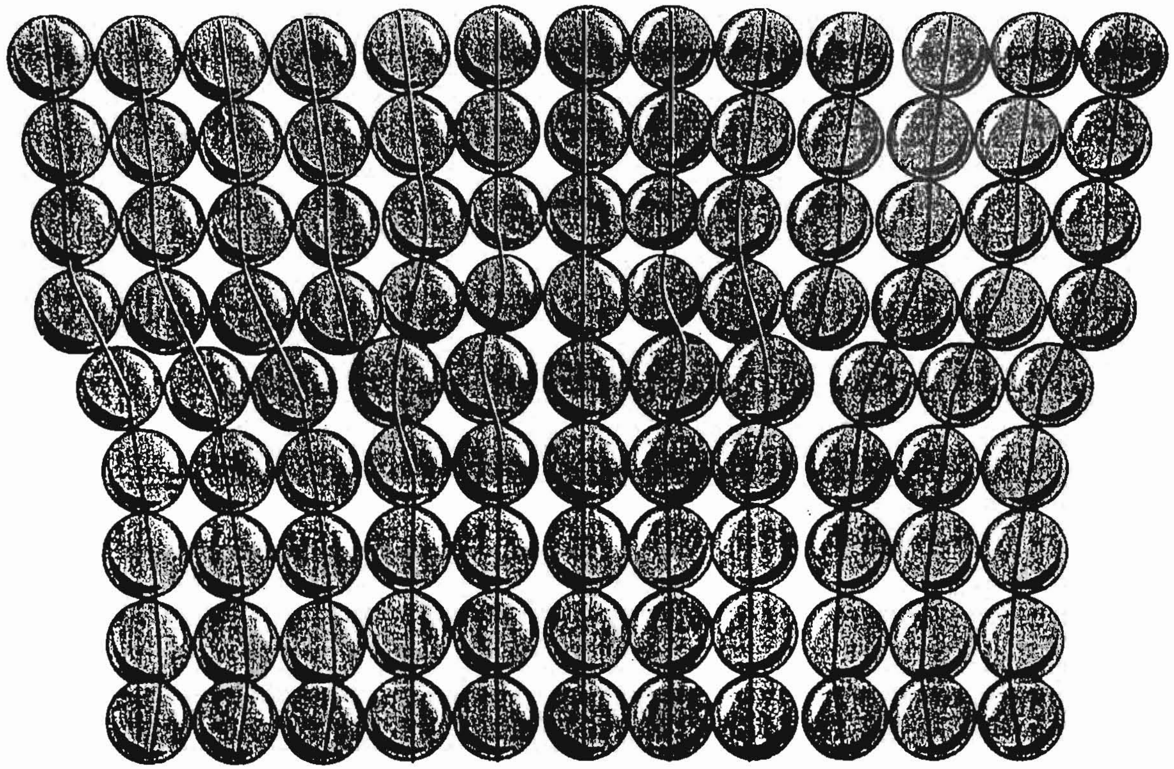
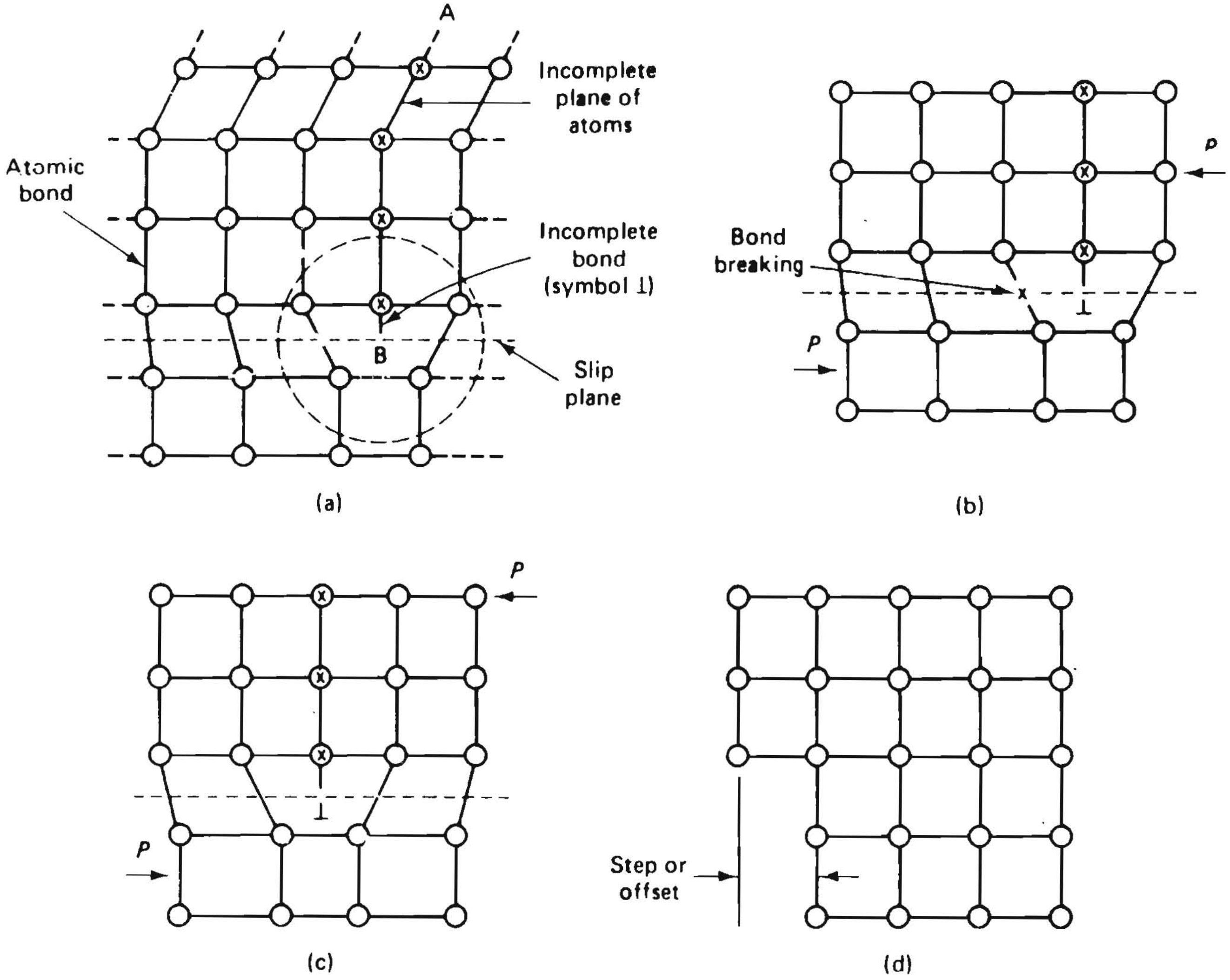


Figure 3
Examples of line defects in a crystal



Edge dislocation movement (slip).

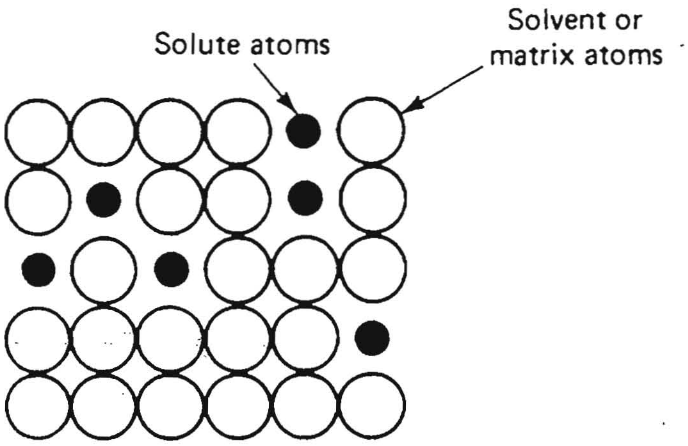


Figure 3-44 Substitutional solid solution.

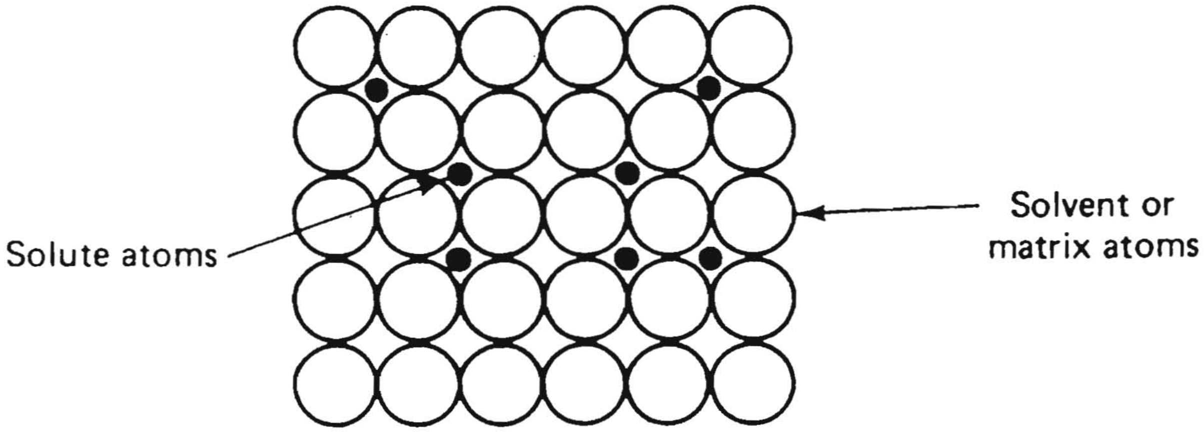


Figure 3-45 Interstitial solid solution.

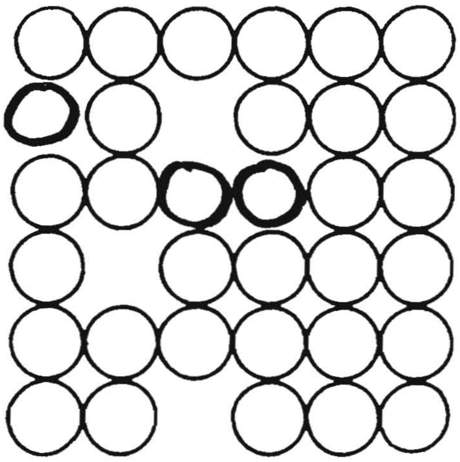


Figure 3-46 Point defects (vacancies).