1–2 Materials used in Electronics

In terms of their electrical properties, materials can be classified into three groups: **conductors**, **semiconductors**, and **insulators**. When atoms combine to form a solid, crystalline material, they arrange themselves in a symmetrical pattern. The atoms within the crystal structure are held together by covalent bonds, which are created by the interaction of the valence electrons of the atoms. Silicon is a crystalline material.

- **Insulator**: material that doesn't conduct current (very high resistivity, very few free e). Valence electrons are tightly bound to the atom. Examples: rubber, plastic, glass,...
- **Conductor**: material that easily conducts current. Most metals are good conductors: Cu, Ag, Au, Al. These are characterized by atom with one valance, loosely bound electron.
- **Semiconductors**: between conductor and insulator in its conductivity.
  - **Single-element semiconductors (4-valence electrons):** Silicon(Si), Germanium(Ge), Antimony(Sb), Arsenic(As), Astatine(At), Boron(B), Polonium(Po), Tellurium(Te).
  - **Compound semiconductors:** Gallium Arsenide(GaAs), Indium Phosphide (InP), Gallium Nitride (GaN), Silicon Carbide (SiC).

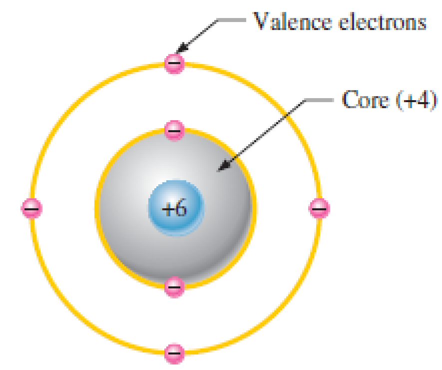


FIGURE 1–6
Diagram of a carbon atom.

Bandgap

- The difference in energy between the valence band and the conduction band.
- It is the energy that the valence electron must have to jump from the valence band to conduction band.
- In conduction band, the electrons become free to move through the material.

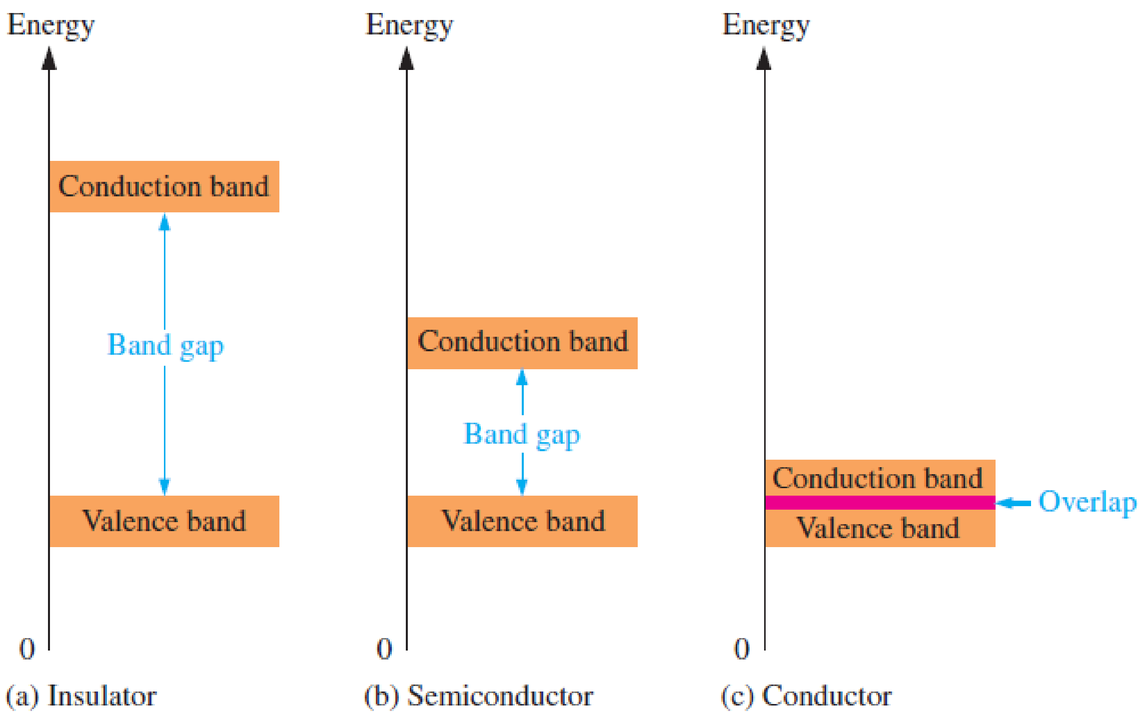


FIGURE 1–7

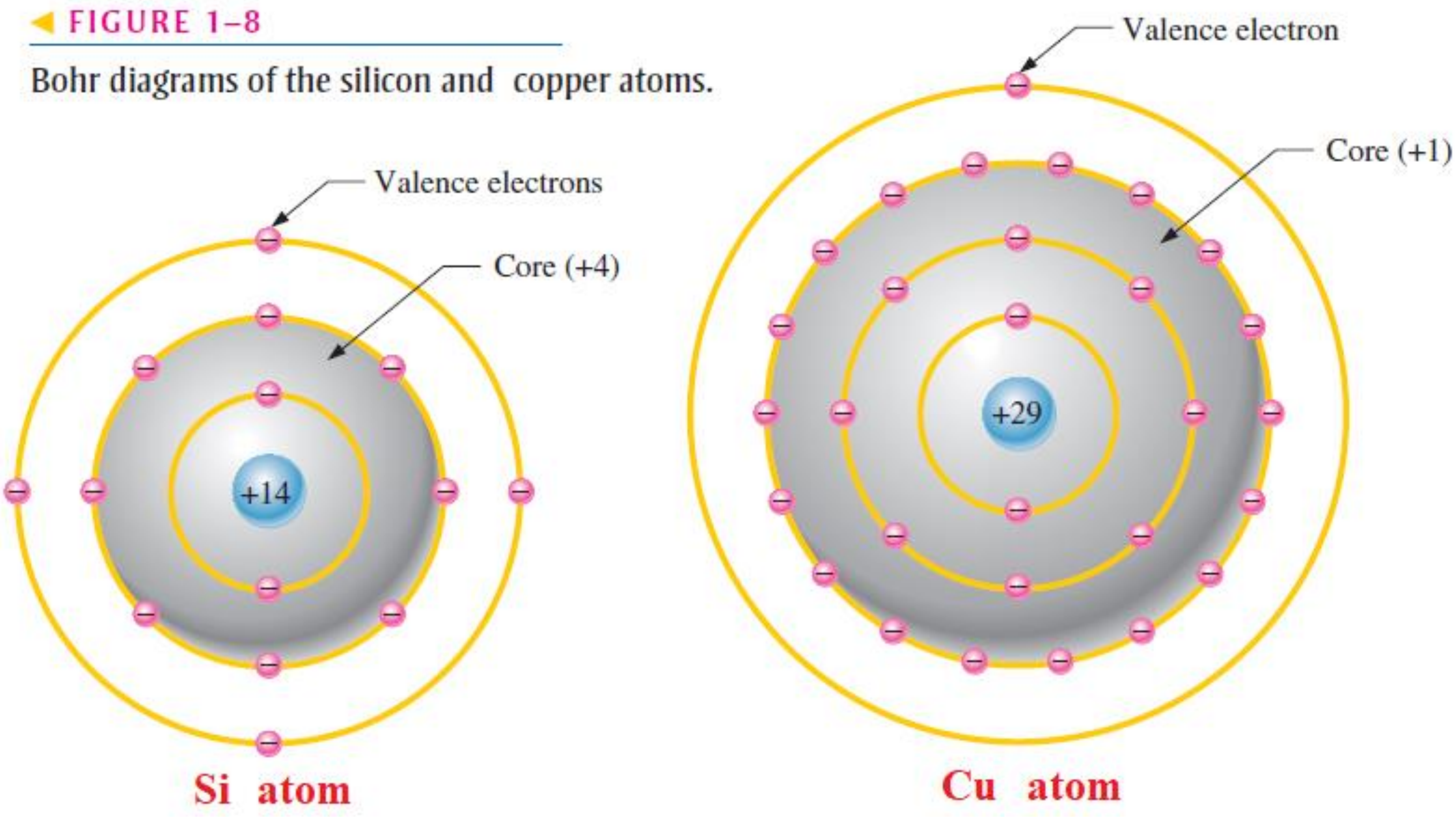
Energy diagrams for the three types of materials.

Comparison of a Semiconductor Atom to a Conductor Atom

- valence electron in Cu feels attractive force (+1) compared to (+4) in Si.
- also, Cu valence electron in 4th shell, Si valence electron in 3ed shell.
- valence electron in Cu has more energy
- so, it is easier in Cu to acquire energy and let valence electron escape to become free.

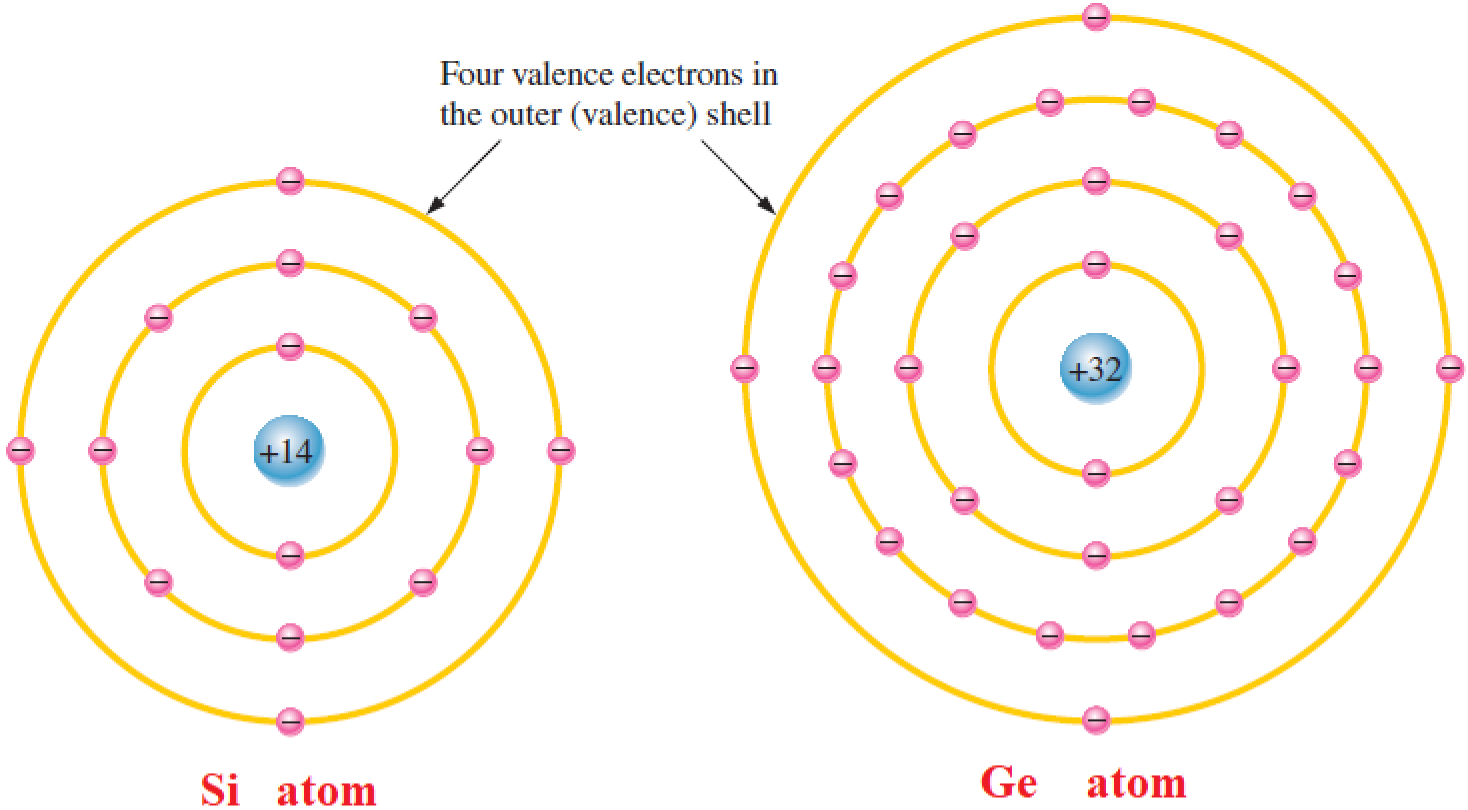
FIGURE 1–8

Bohr diagrams of the silicon and copper atoms.



Silicon and Germanium:

- Silicon is used in diodes, transistors, integrated circuits, and other semiconductor devices.
- Silicon and germanium have 4 valence electrons.
- Ge valence electrons are at higher energy levels (4th shell) than those in Si (shell 3)
- **Si is more stable at High T and thus, widely used**.



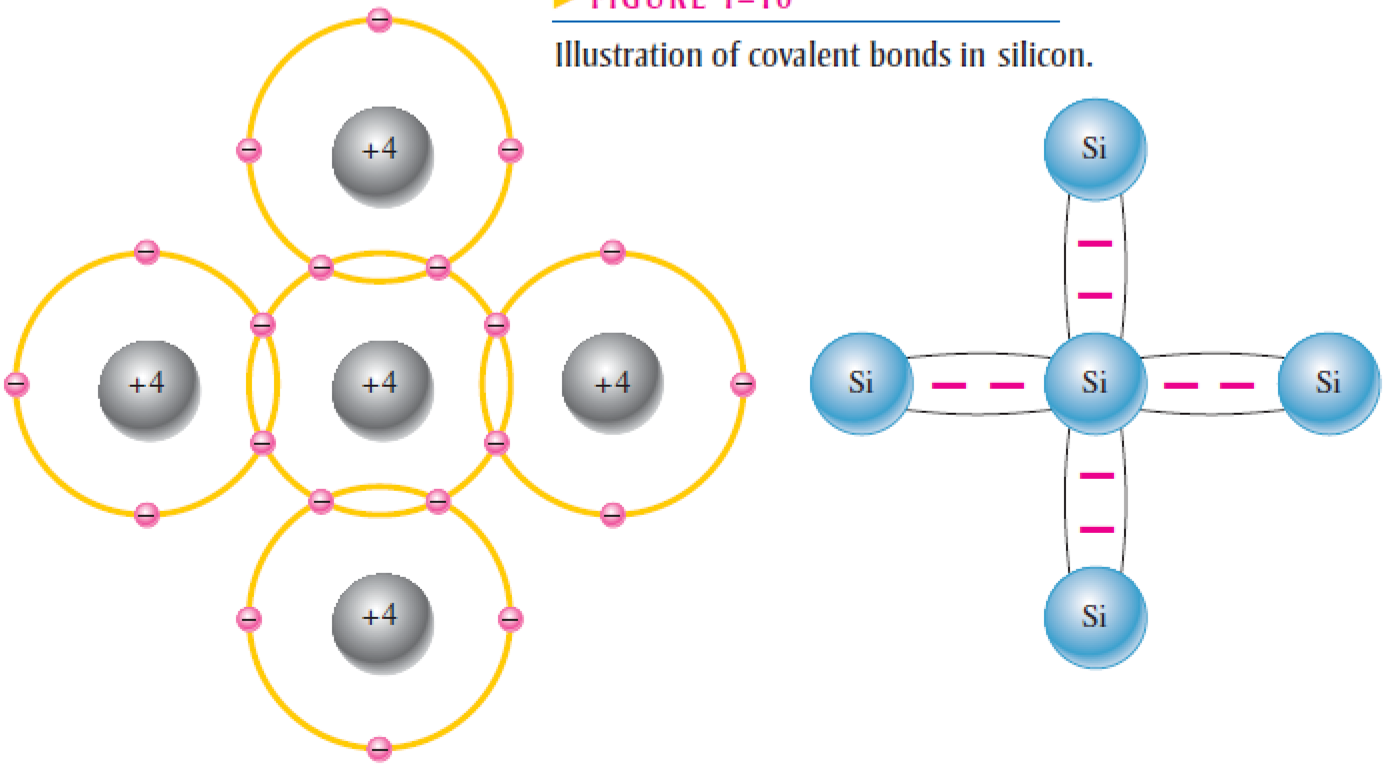
Covalent Bonds to form a Crystal

- The center silicon atom shares an electron with each of the four surrounding silicon atoms, creating a **covalent bond** with each. The surrounding atoms are in turn bonded to other atoms, and so on.

- Creates 8 shared valence electrons for each atom produce **chemical stability**.

FIGURE 1–10

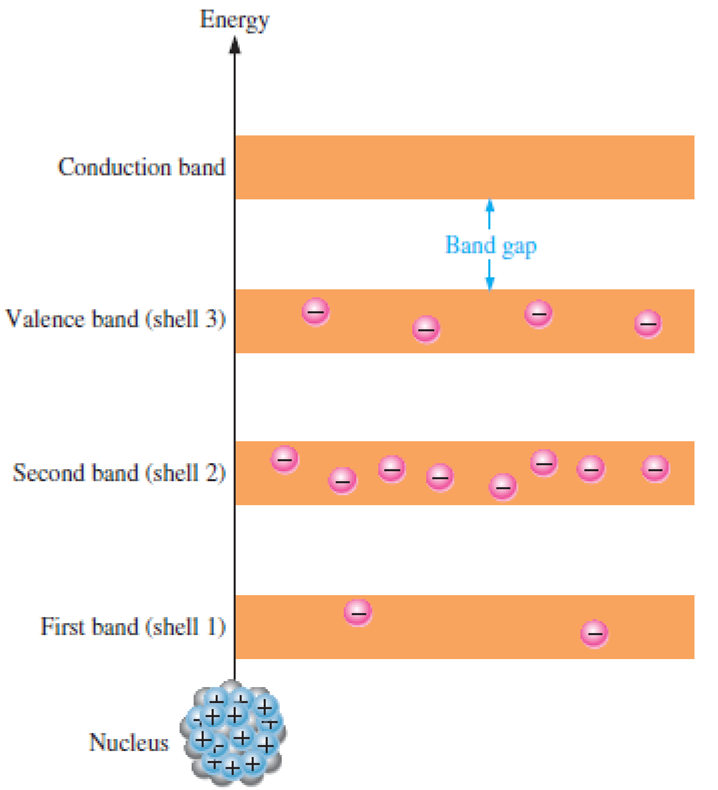
Illustration of covalent bonds in silicon.

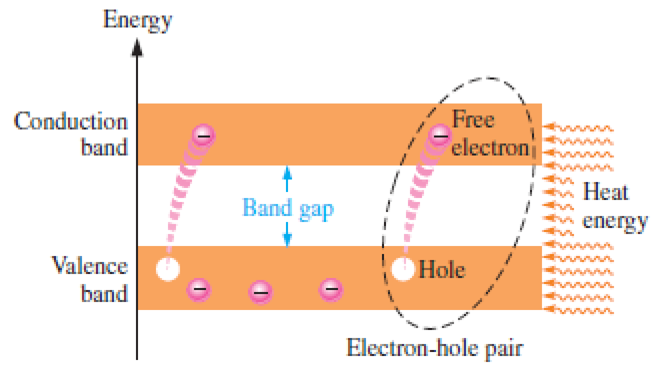


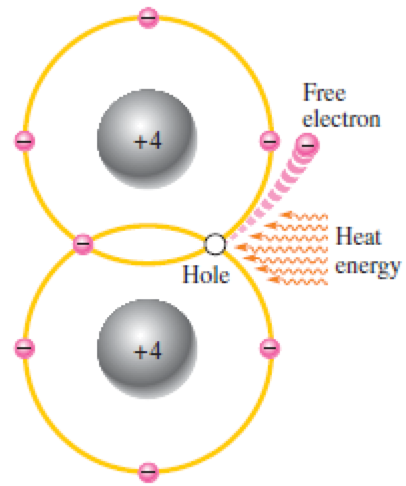
(a) The center silicon atom shares an electron with each of the four surrounding silicon atoms, creating a covalent bond with each. The surrounding atoms are in turn bonded to other atoms, and so on.

(b) Bonding diagram. The red negative signs represent the shared valence electrons.

Current in Semiconductors







- The energy band diagram for an **unexcited atom** (no external energy such as heat) in a pure silicon crystal. This condition occurs *only* at a temperature of absolute **0 Kelvin**.

- **At room temperature**: an intrinsic (pure) silicon crystal has sufficient heat (thermal) energy for some valence electrons to jump the gap from the valence band into the conduction band, becoming free electrons.

- When an electron jumps to the conduction band, a **vacancy** is left in the valence band (**Hole**). This is called an **electron-hole pair.**
- **Recombination** occurs when a conduction-band electron loses energy and falls back into a hole in the valence band.