

## 3.2 FUNDAMENTAL PROPERTIES OF SEMICONDUCTORS

An understanding of the operation of semiconductor solar cells requires familiarity with some basic concepts of solid-state physics. Here, an introduction is provided to the essential concepts needed to examine the physics of solar cells. More complete and rigorous treatments are available from a number of sources [2–6].

Solar cells can be fabricated from a number of semiconductor materials, most commonly silicon (Si) – crystalline, polycrystalline, and amorphous. Solar cells are also fabricated from GaAs, GaInP, Cu(InGa)Se<sub>2</sub>, and CdTe, to name but a few. Solar cell materials are chosen largely on the basis of how well their absorption characteristics match the solar spectrum and their cost of fabrication. Silicon has been a common choice due to the fact that its absorption characteristics are a fairly good match to the solar spectrum, and silicon fabrication technology is well developed as a result of its pervasiveness in the semiconductor electronics industry.

### 3.2.1 Crystal Structure

Electronic grade semiconductors are very pure crystalline materials. Their crystalline nature means that their atoms are aligned in a regular periodic array. This periodicity, coupled with the atomic properties of the component elements, is what gives semiconductors their very useful electronic properties. An abbreviated periodic table of the elements is given in Table 3.1.

Note that silicon is in column IV, meaning that it has four valence electrons, that is, four electrons that can be shared with neighboring atoms to form covalent bonds with those neighbors. In crystalline silicon, the atoms are arranged in a *diamond lattice* (carbon is also a column IV element) with tetrahedral bonding – four bonds from each atom where the angle between any two bonds is 109.5°. Perhaps surprisingly, this arrangement can be represented by two interpenetrating face-centered cubic (*fcc*) unit cells where the second *fcc* unit cell is shifted one-fourth of the distance along the body diagonal of the first *fcc* unit cell. The lattice constant,  $\ell$ , is the length of the edges of the cubic unit cell. The entire lattice can be constructed by stacking these unit cells. A similar arrangement, the *zincblende* lattice, occurs in many binary III–V and II–VI semiconductors such as GaAs (a III–V compound) and CdTe (a II–VI compound). For example, in GaAs, one interpenetrating *fcc* unit cell is composed entirely of Ga atoms and the other entirely of As atoms. Note that the average valency is four for each compound, so that there are four bonds to and from each atom with each covalent bond involving two valence electrons. Some properties of semiconductors are dependent on the orientation of the crystal

**Table 3.1** Abbreviated periodic table of the elements

I	II	III	IV	V	VI
		B	C	N	O
		Al	Si	P	S
Cu	Zn	Ga	Ge	As	Se
Ag	Cd	In	Sn	Sb	Te