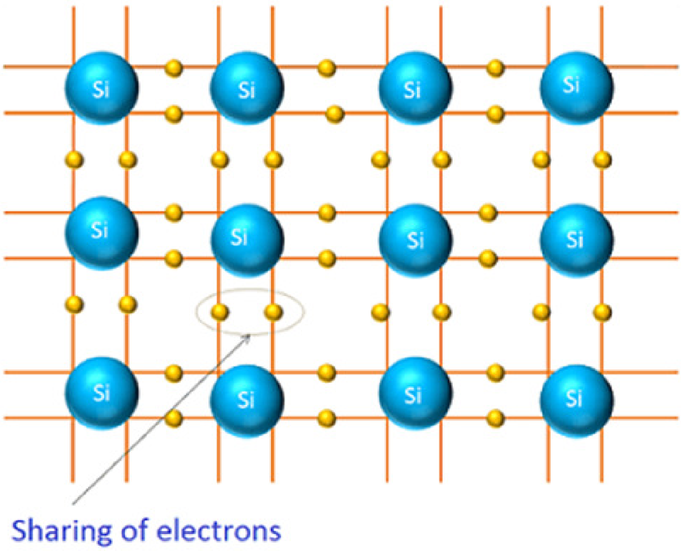
Intrinsic semiconductor

Covalent bonding in silicon

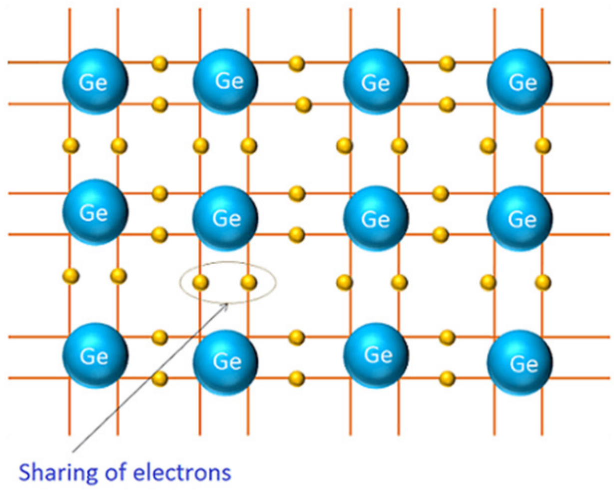
The atomic number of Silicon is 14. Its electronic configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$.The outermost shell of atom is capable to hold up to eight electrons. The atom which has eight electrons in the outermost orbit is said to be completely filled and most stable. But the outermost orbit of silicon has only four electrons. Silicon atom needs four more electrons to become most stable. Silicon atom forms four covalent bonds with the four neighboring atoms. In covalent bonding each valence electron is shared by two atoms.



When silicon atoms comes close to each other, each valence electron of atom is shared with the neighboring atom and each valence electron of neighboring atom is shared with this atom. Likewise each atom will share four valence electrons with the four neighboring atoms and four neighboring atoms will share each valence electron with this atom. Therefore, total eight electrons are shared.

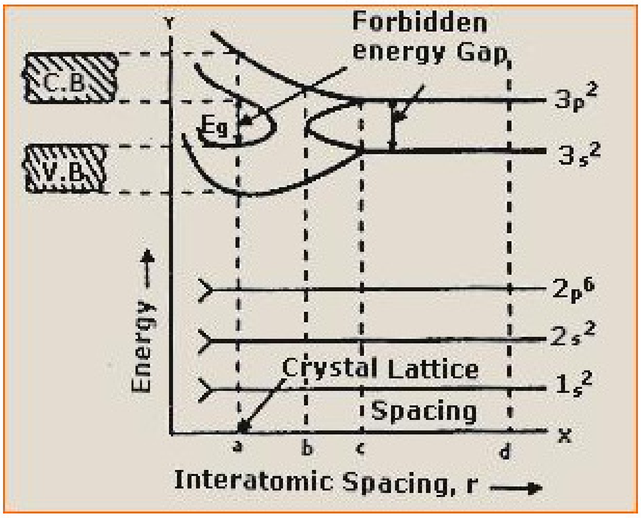
Covalent bonding in germanium

The atomic number of Silicon is 32. Its electronic configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 4s^2 3d^{10} 4p^2$. The outermost orbit of germanium has only four electrons. Germanium atom needs four more electrons to become most stable. Germanium atom forms four covalent bonds with the four neighboring atoms. In covalent bonding each valence electron is shared by two atoms. When germanium atoms comes close to each other each valence electron of atom is shared with the neighboring atom and each valence electron of neighboring atom is shared with this atom. Likewise each atom will share four valence electrons with the four neighboring atoms and four neighboring atoms will share each valence electron with this atom. Therefore, total eight electrons are shared.



The outermost shell of silicon and germanium is completely filled and valence electrons are tightly bound to the nucleus of atom because of sharing electrons with neighboring atoms. In intrinsic semiconductors free electrons are not present at absolute zero temperature. Therefore intrinsic semiconductor behaves as perfect insulator.

Energy band formation in Silicon



- We consider a case in which N silicon atoms approach each other to form a silicon crystal. When the atoms are very far apart, as at position'd' in the above figure, the electronic energy levels of the crystal will be the same as those of isolated atoms.
- At position 'c' the energy levels 3s and 3p start splitting and little below the position 'c' two bands are formed. The band corresponding to 3s level has N energy levels. It accommodates 2N electrons. The band corresponding to 3p level has 3N energy levels. It also accommodates 2N electrons.
- There is an energy gap between these two bands. When the interatomic spacing decreases, the energy gap decreases.
- At position 'b', the two bands merge and form a composite band. The 3N upper energy levels merge with the lower N energy levels, giving rise to a total of 4N levels. Of these 4N levels, the lowest 2N energy levels are occupied by 4N electrons.

- Little below the position ‘b’, the composite band branches out into two bands separated by an energy gap. The 4N energy levels are equally divided between the two bands.
- At position ‘a’, the bond is relatively more stable. Therefore, we have to consider the energy gap at ‘a’. The 4N electrons available in total at 3s and 3p levels occupy now the lower energy band. The upper band is left vacant. The lower completely filled band is called valence band and upper unfilled band is called conduction band. The value of energy gap at 0K is 1.12eV.
- At normal temperature, a significant number of electrons are excited thermally from valence band to conduction band.