Si Conduction

The conduction of electricity in Si is quite different from the conduction in metals. Metals have an ionic structure with a vast number of conduction electrons available - one per metal atom, typically. Since there are ~ 10^{22} atoms cm^{-3} in a metal, the density of conduction electrons is very high. When a potential is placed across a metal the electrons move due to the force of the electric field and the conductivity σ is proportional to the electron density. The resistivity $\rho = \frac{1}{\sigma}$ is low (ρ ~ 10^{-6} ohm-cm for a good conductor such as Cu or Al at room temperature). Si has a diamond like structure due to the fact that Si has four valence electrons and each atom bonds to four nearest neighbors by this strong, two-electron valence bond (each atom in a Si - Si bond contributes one electron to the bond).

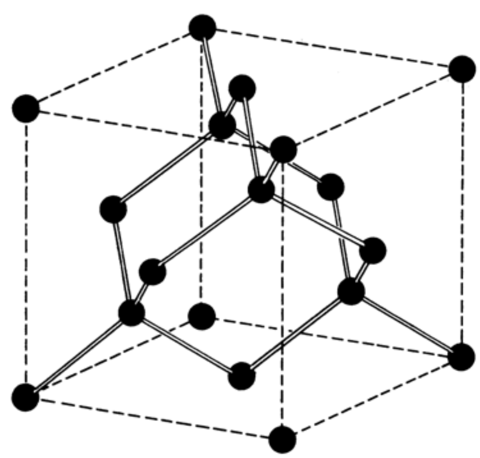

Fig. 1. The three-dimensional representation of the Si lattice (diamond-like). Each Si atom bonds covalently to the four nearest neighbors.

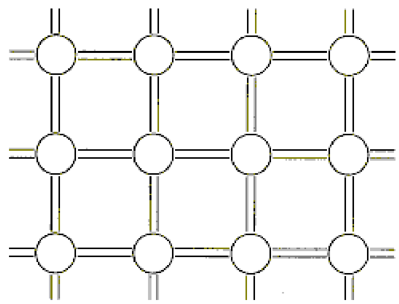

Figure 2. A two-dimensional representation of the Si lattice explicitly showing the two-electron covalent bonds.

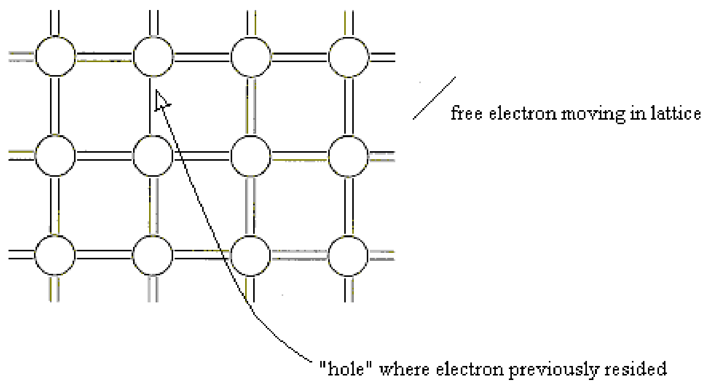

Figure 3. Two-dimensional representation of the Si lattice showing formation of an electron-hole pair.

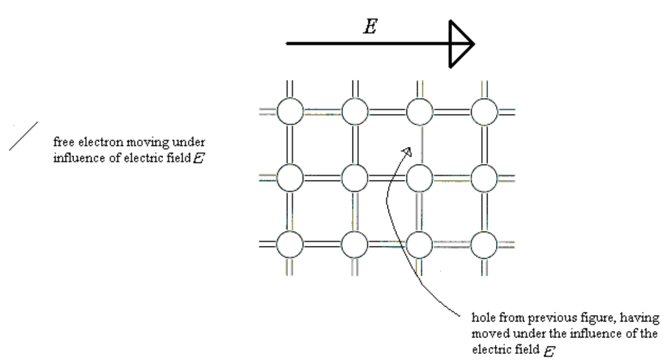

Figure 4. Schematic representation of the motion of the electron and the hole from Figure 3 moving in an applied electric field *E*.

At 0K essentially every valence electron is bound to two Si atoms and the resistivity of the Si is extremely high. At higher temperatures thermal jostling of the atoms occasionally will allow an electron to free itself from a bond and to wander through the crystal lattice. The vacancy left behind by the electron is called a hole, and it too can move from atom to atom. At room temperature ($\approx$ 293 K) there are about 10^{10} electrons and holes cm^{-3} in pure Si and the resistivity is correspondingly high - hundreds of thousands of ohm-cm.

The motion of holes and electrons is random unless an electric field is applied to the Si. In this case a general drift is imposed on the random motion of the electrons and holes: the electrons move in the direction opposite to the electric field vector while the holes move in the same direction as the electric field. Because the density of holes and electrons in Si is vastly less than the density of electrons in a metal, the conductivity is much less than a metal and so Si is called a semiconductor. The resistivity of pure Si at room temperature is about 3×10^5 ohm-cm, some ten orders of magnitude greater than copper and about ten orders of magnitude less than that of an excellent insulator such as SiO_2 (quartz).