(c) Electrons and Holes

As the temperature of a semiconductor is raised from $0\,K$, some electrons in the valence band receive enough thermal energy to be excited across the band gap to the conduction band. The result is a material with some electrons in an otherwise empty conduction band and some unoccupied states in an otherwise filled valence band (Figure). For convenience, an empty state in the valence band is referred to as a *hole*. If the conduction band electron and the hole are created by the excitation of a valence band electron to the conduction band, they are called an ***electron-hole pair*** (abbreviated EHP).

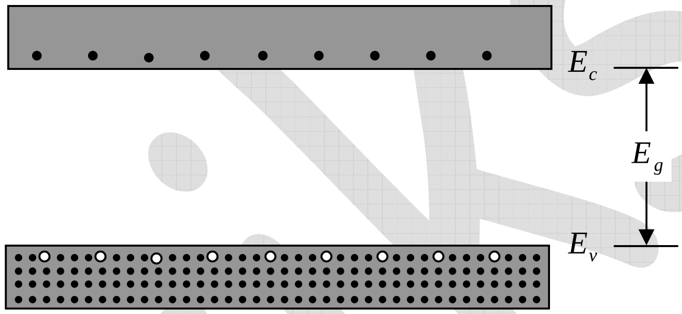

Figure: Electron-hole pairs in a semiconductor.

After excitation to the conduction band, an electron is surrounded by a large number of unoccupied energy states. For example, the equilibrium number of electron-hole pairs in pure Si at room temperature is only about $10^{10}\,EHP/cm^3$, compared to the Si atom density of more than $10^{22}\,atoms/cm^3$. Thus the few electrons in the conduction band are free to move about via the many available empty states.

Effective Mass

The electrons in a crystal are not completely free, but instead interact with the periodic potential of the lattice. As a result, their "wave-particle" motion can-not be expected to be the same as for electrons in free space. Thus, in applying the usual equations of electrodynamics to charge carriers in a solid, we must use altered values of particle mass. In doing so, we account for most of the influences of the lattice, so that the electrons and holes can be treated as "almost free" carriers in most computations. The calculation of effective mass must take into account the shape of the energy bands in three-dimensional k-space, taking appropriate averages over the various energy bands.