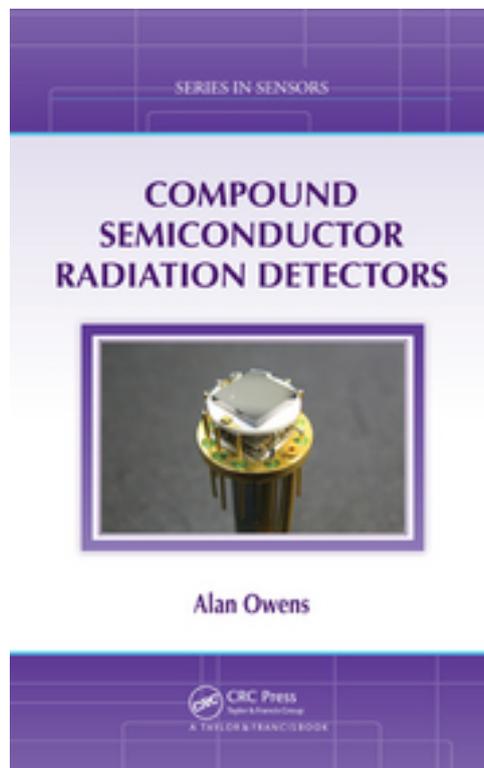


Colour Images from
Compound Semiconductor Radiation Detectors
Chapter 1

Alan Owens



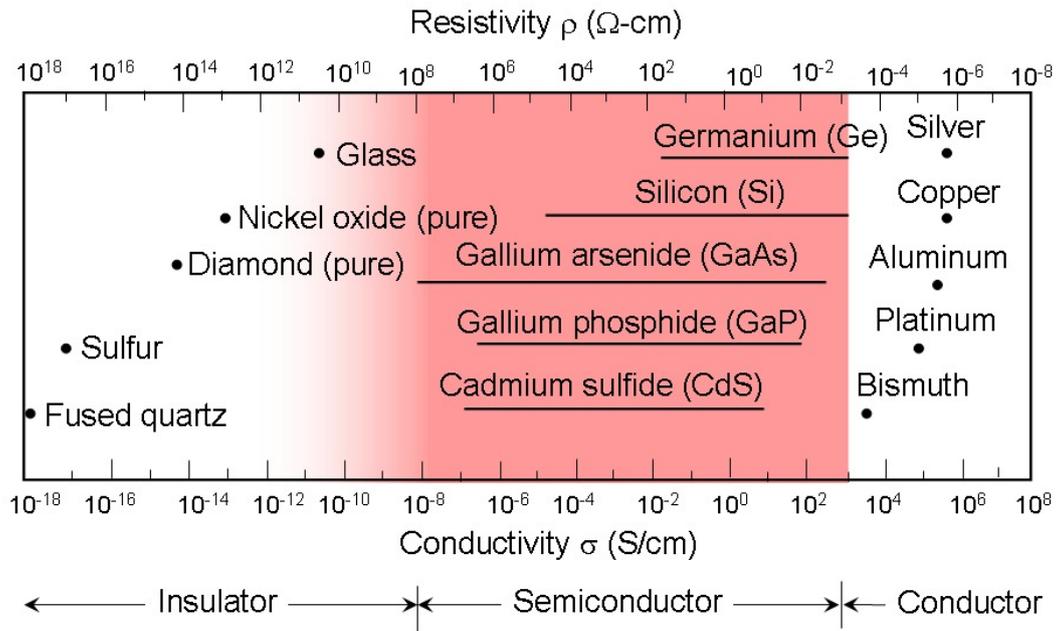


Figure 1.1: Typical range of resistivities/conductivities for insulators, semiconductors, and conductors (adapted from [1]). Semiconductors exist in the shaded region. At resistivities above $10^8\Omega\text{-cm}$, the distinction between insulators and semiconductors is blurred and ultimately depends on temperature, since an insulating material can only become semiconducting (in the sense it can pass a current) if a sufficient number of electrons can be excited into the conduction band.

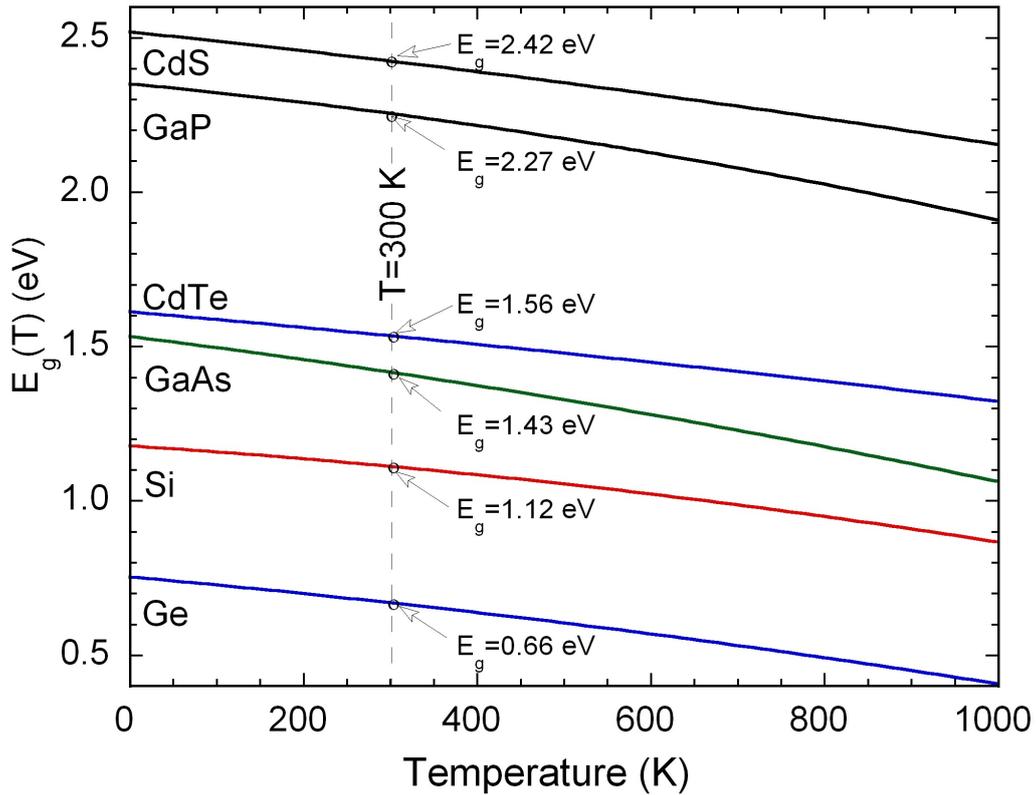


Figure 1.5: Temperature dependence of the bandgap energy for common semiconductors from groups IV, III-V and II-VI compounds. Bandgap energies decrease by ~ 0.4 meV per degree K for most semiconductors.

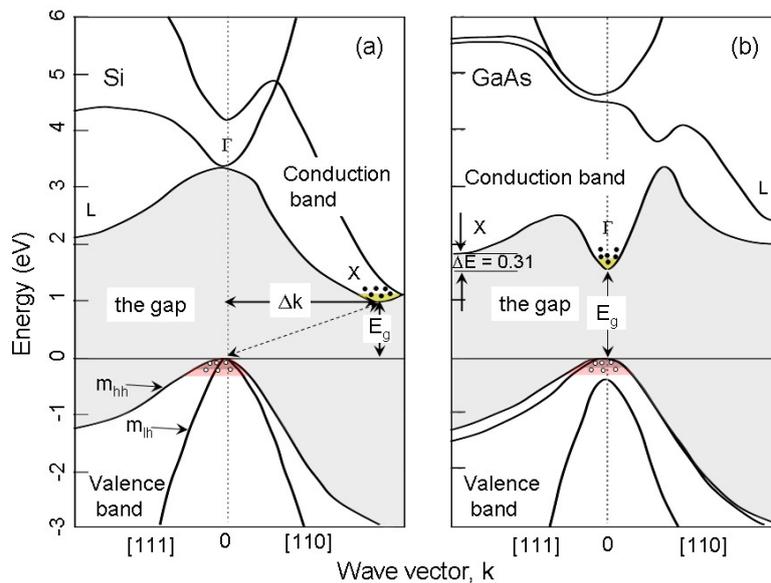


Figure 1.6: Energy band structures of (a) Si and (b) GaAs. Circles (\circ) indicate free holes in the valence bands and filled circles (\bullet) indicate free electrons in the conduction bands. Γ , X and L refer to different conduction band minima along the main crystallographic directions in the crystal. Si is an indirect bandgap material while GaAs is a direct bandgap material (adapted from [16]). The important difference is that for the direct band gap material, an electron can transit between the lowest potential in the conduction band to the highest potential in the valence band without a change in momentum, Δk , whereas for an indirect band gap material it cannot do so without the mediation of a third body (e.g., phonon) to conserve momentum. Here m_{hh} and m_{lh} show the valence band maxima that contain heavy and light holes (see section 1.5).

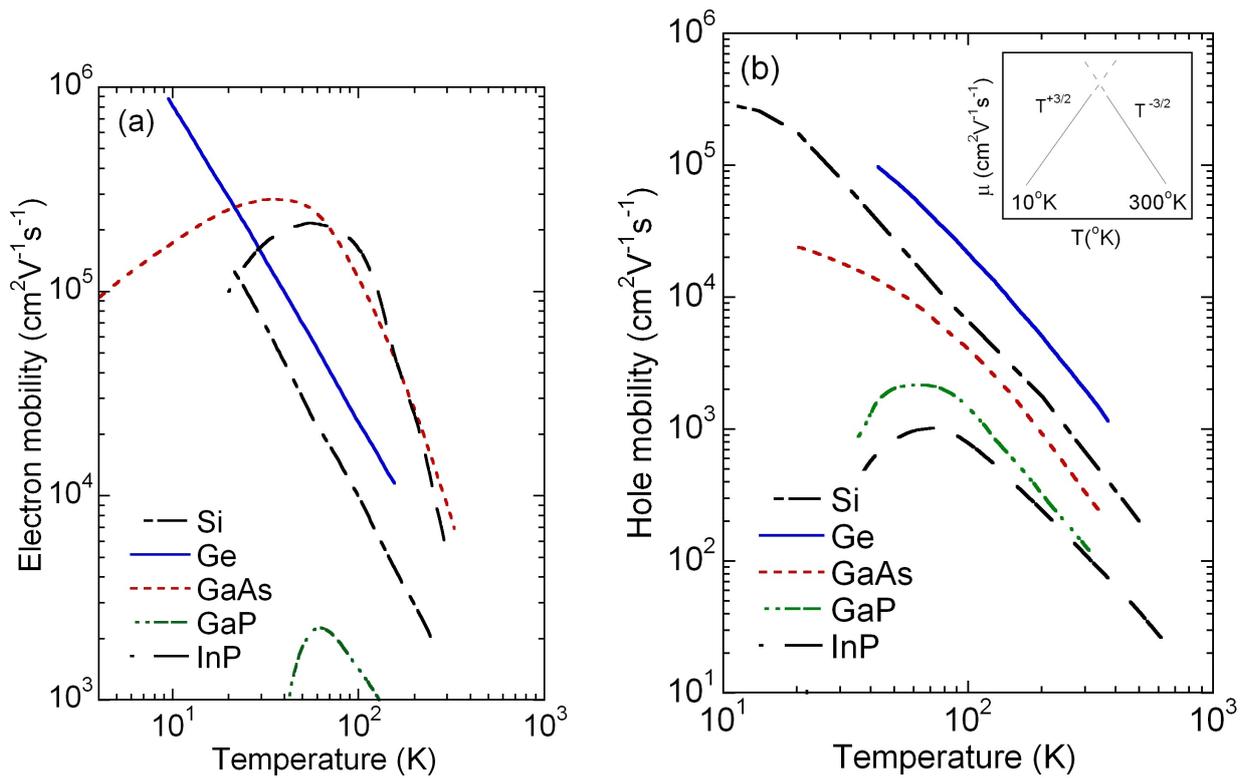


Figure 1.8: Temperature dependence of (a) electron mobilities and (b) hole mobilities for a number of group IV and III-V semiconductors [17–23]. The roll over in mobilities for some group III-V materials below $\sim 100\text{K}$ is due to impurity scattering. For comparison, the inset in fig. (b) illustrates the mobility temperature dependence on the two main scattering processes.

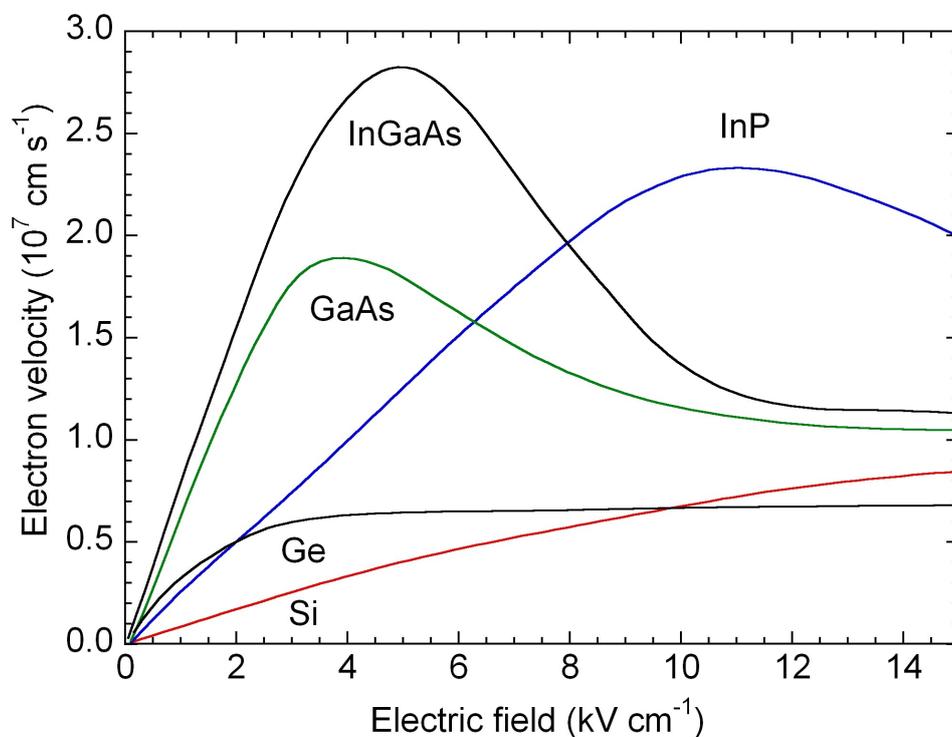


Figure 1.9: The electron velocity as a function of electric field for a number of semiconducting materials at 300K [18,31,32]. At high fields the drift velocity saturates for the elemental semiconductors. However for compound semiconductors the velocity reaches a maximum at fields around 4 kV cm^{-1} and then begins to decrease due to the increasing influence of additional minima in the conduction bands.

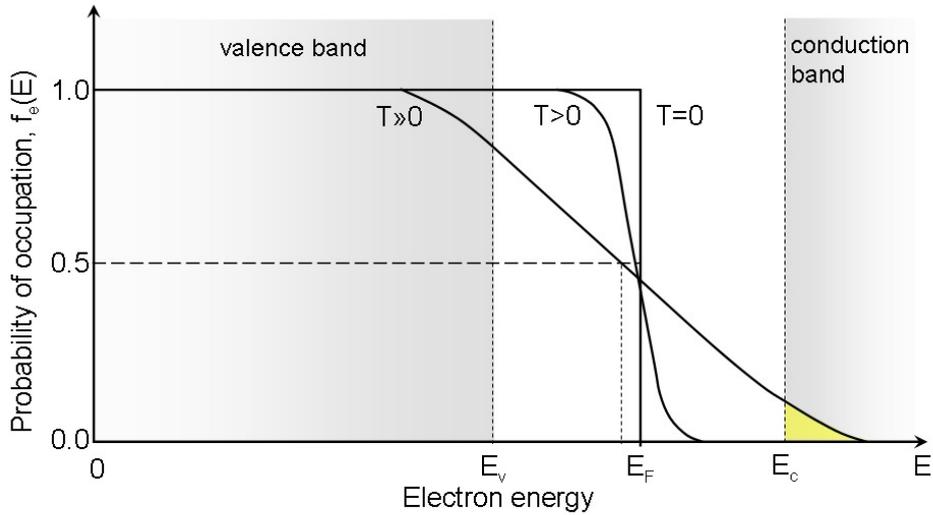


Figure 1.10: The Fermi energy distribution function $f(E)$ as a function of electron energy, E . Here, E_v and E_c are the energy levels of the valence and conduction bands, respectively. The defining parameter of this distribution is the Fermi energy E_F , which is the energy at which the probability of occupation by an electron is exactly one-half at T_i0K . Note the reduction of E_F with increasing temperature. However, at room temperature it is still very close to mid-band gap.

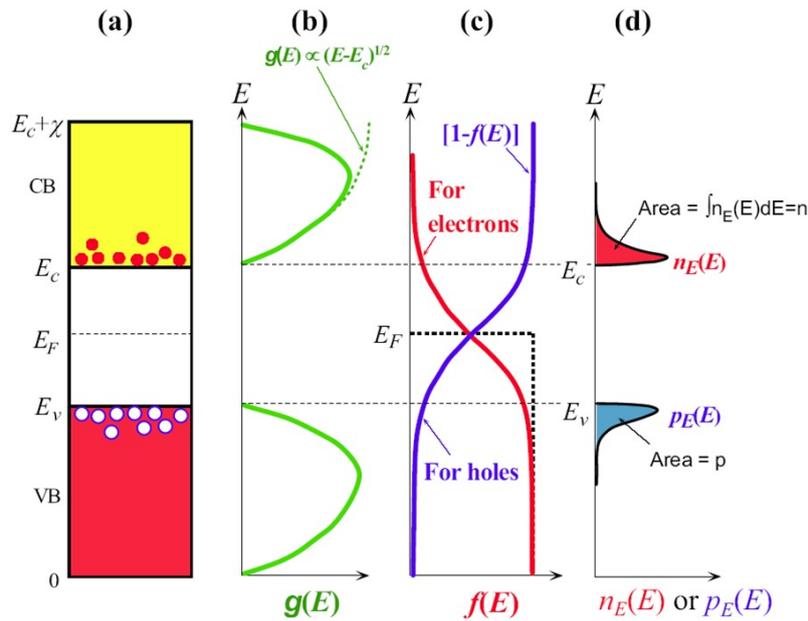


Figure 1.11: Schematic of the various distributions discussed in the text leading up to the energy density of electrons and holes in the conduction and valence bands, respectively (from reference [36]). The example given is for an intrinsic semiconductor. (a) The energy band diagram. (b) The density of states (number of states per unit energy per unit volume). The total number of states in the valence band and conduction bands is equal to the number of valence electrons. However in metals the total number of states in the valence band is much larger, which is the reason why electrons in metals need no activation to become mobile. (c) The Fermi-Dirac probability function (probability of occupancy of a state) and (d) The product of $g(E)$ and $f(E)$ which gives the energy density of electrons in the conduction band. The area under $n_E(E)$ versus E is the electron concentration in the conduction band.

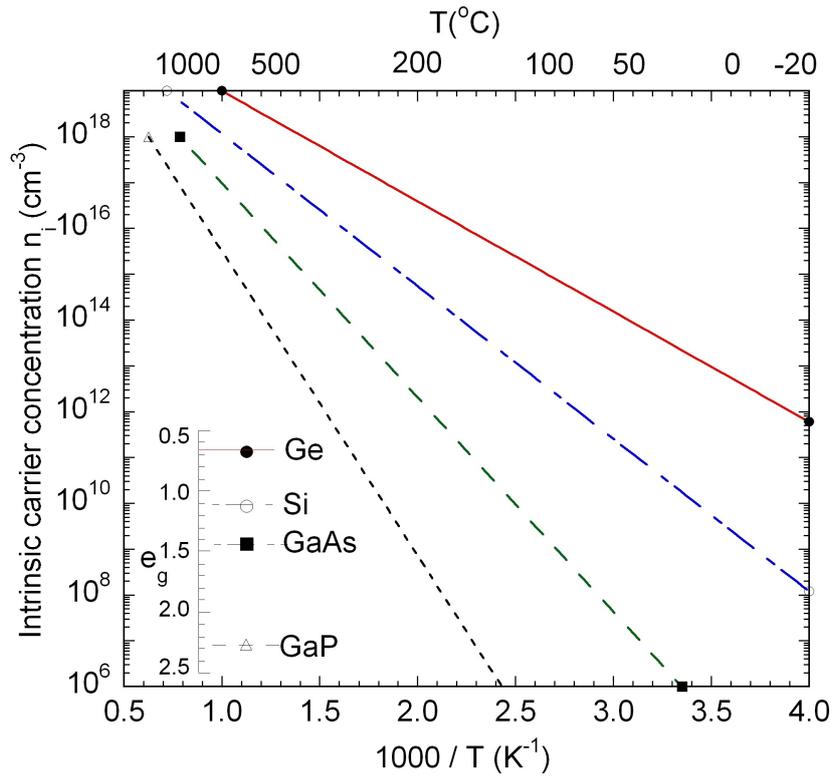


Figure 1.12: Intrinsic carrier concentrations in Ge, Si, GaAs, eV) and GaP as a function of reciprocal temperature. The effect of increasing band-gap on the intrinsic carrier density is apparent.

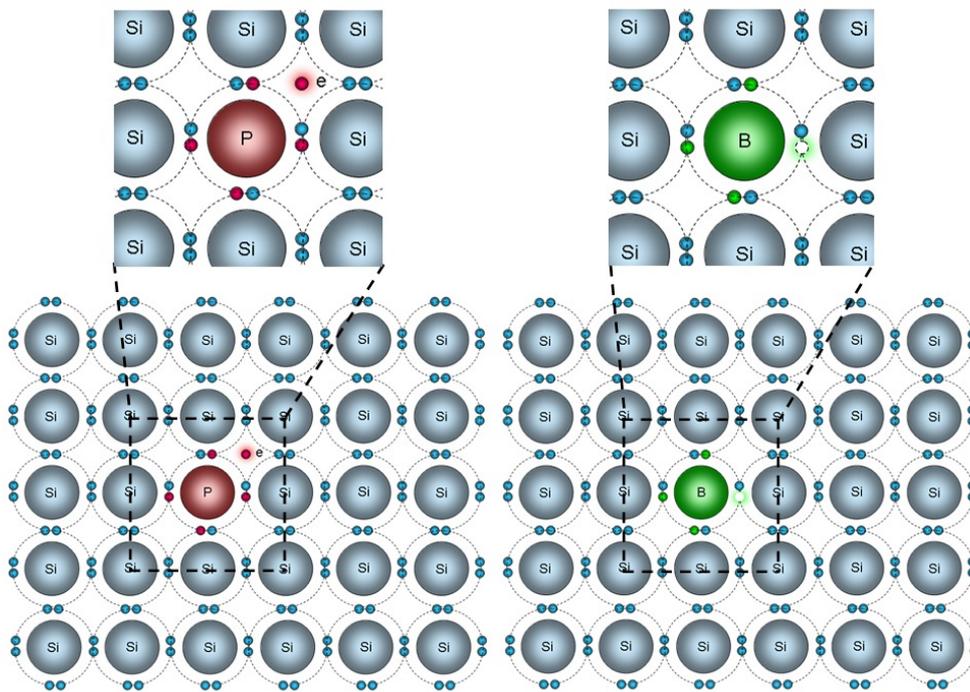


Figure 1.13: Schematic illustrating the physical implementation of doping in silicon. Left: n-type silicon doped with phosphorus. The effect of the phosphorus atom is to introduce an extra electron into the lattice and thus the phosphorus now acts as a donor for electrons. Right: p-type silicon doped with boron. In this case, the boron atom is missing one electron to fill its outer shell and thus the boron behaves as an electron acceptor.