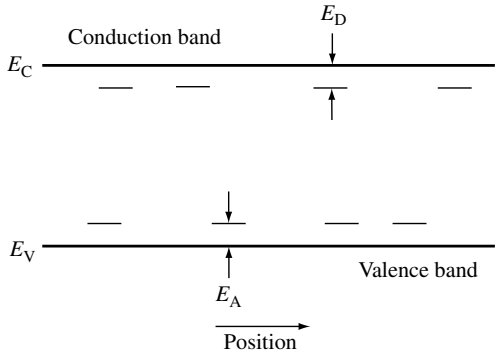

Figure 3.5 Donor and acceptor levels in a semiconductor. The nonuniform spatial distribution of these states reinforces the concept that these are localized states

in n-type material and as

$$E_F = E_i - kT \ln \frac{N_A}{n_i} \tag{3.23}$$

in p-type material.

When a very large concentration of dopants is introduced into the semiconductor, the dopants can no longer be thought of as a minor perturbation to the system. Their effect on the band structure must be considered. Typically, this so-called heavy doping effect manifests itself as a reduction in the band gap, E_G, and thus an increase in the intrinsic carrier concentration, as can be seen from equation (3.18). This band gap narrowing (BGN) [8] is detrimental to solar cell performance and solar cells are typically designed to avoid this effect, though it may be a factor in the heavily doped regions near the solar cell contacts.

3.2.5 Light Absorption

The creation of electron–hole pairs via the absorption of sunlight is fundamental to the operation of solar cells. The excitation of an electron directly from the valence band (which leaves a hole behind) to the conduction band is called *fundamental absorption*. Both the total energy and momentum of all particles involved in the absorption process must be conserved. Since the photon momentum, $p_\lambda = h/\lambda$, is very small compared to the range of the crystal momentum, $p = h/\ell$, the photon absorption process must, for practical purposes, conserve the momentum of the electron.[1] The absorption coefficient for a given photon energy, $h\nu$, is proportional to the probability, P_{12}, of the transition of an electron from the initial state E_1 to the final state E_2, the density of electrons in the initial state, $g_V(E_1)$, and the density of available final states, and is then summed over

[1] The wavelength of sunlight, λ, is on the order of a micron (10^{-4} cm), while the lattice constant is a few angstroms (10^{-8} cm). Thus, the crystal momentum is several orders of magnitude larger than the photon momentum.