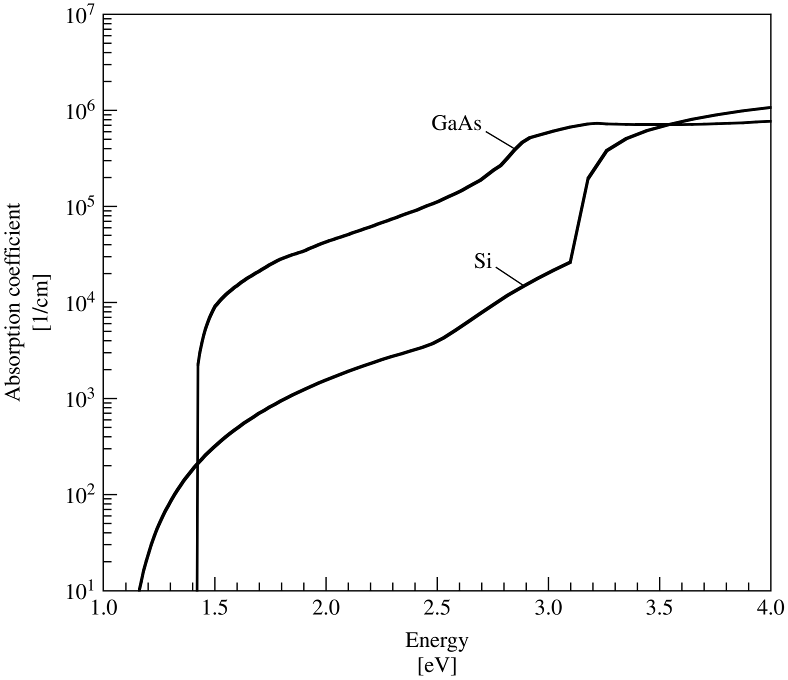

Figure 3.8 Absorption coefficient as a function of photon energy for Si (indirect band gap) and GaAs (direct band gap) at 300 K. Their band gaps are 1.12 and 1.4 eV, respectively

Since both a phonon and an electron are needed to make the indirect gap absorption process possible, the absorption coefficient depends not only on the density of full initial electron states and empty final electron states but also on the availability of phonons (both emitted and absorbed) with the required momentum. Thus, compared to direct transitions, the absorption coefficient for indirect transitions is relatively small. As a result, light penetrates more deeply into indirect band gap semiconductors than direct band gap semiconductors. This is illustrated in Figure 3.8 for Si, an indirect band gap semiconductor, and GaAs, a direct band gap semiconductor. Similar spectra are shown for other semiconductors elsewhere in this handbook.

In both direct band gap and indirect band gap materials, a number of photon absorption processes are involved, though the mechanisms described above are the dominant ones. A direct transition, without phonon assistance, is possible in indirect band gap materials if the photon energy is high enough (as seen in Figure 3.8 for Si at about 3.3 eV). Conversely, in direct band gap materials, phonon-assisted absorption is also a possibility. Other mechanisms may also play a role in defining the absorption process in semiconductors. These include absorption in the presence of an electric field (the Franz–Keldysh effect), absorption aided by localized states in the forbidden gap, and degeneracy effects when a significant number of states in the conduction band are not empty and/or when a significant number of state in the valence band are not full, as can happen in heavily doped materials (BGN) and under high-level injection (the Burstein–Moss shift). The net absorption coefficient is then the sum of the absorption coefficients due to all absorption