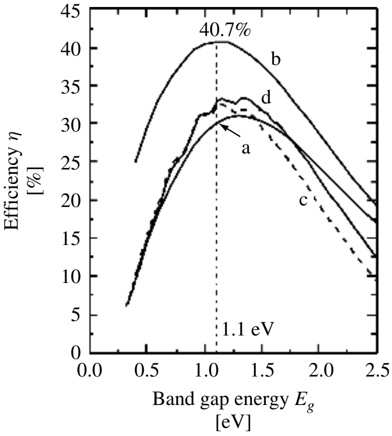

Figure 4.3 SQ efficiency limit for an ideal solar cell versus band gap energy for unconcentrated black body illumination, for full concentrated illumination and for illumination under the terrestrial sun spectrum: (a) unconcentrated 6000 K black body radiation (1595.9 $\mathrm{Wm^{-2}}$); (b) full concentrated 6000 K black body radiation (7349.0×10^4 $\mathrm{Wm^{-2}}$); (c) unconcentrated AM1.5-Direct [18] (767.2 $\mathrm{Wm^{-2}}$) and (d) AM1.5 Global [18] (962.5 $\mathrm{Wm^{-2}}$)

It is interesting to note that the SQ analysis limit does not make any reference to semiconductor *pn* junctions. William Shockley, who first devised the *pn*-junction operation [21], was also the first in implicitly recognising [2] its secondary role in solar cells. In fact, a *pn* junction is not a fundamental constituent of a solar cell. What seems to be fundamental in a solar cell is the existence of two gases of electrons with different quasi-Fermi levels (electrochemical potentials) and the existence of selective contacts [22] that are traversed by each one of these two gases. The importance of the role of the existence of these selective contacts has not been sufficiently recognised. This is achieved today with *n*- and *p*-doped semiconductor regions, not necessarily forming layers, as in the point contact solar cell [23], but in the future it might be achieved otherwise, maybe leading to substantial advancements in PV technology. The role of the semiconductor, of which the cell is made, is to provide the two gases of electrons that may have different quasi-Fermi levels owing to the gap energy separation that makes the recombination difficult.

So far, for non-concentrated light, the most efficient single-junction solar cell, made of GaAs, has achieved an efficiency of 25.1% [24] of AM1.5G spectrum. This is only 23% below the highest theoretical efficiency of 32.8% for the GaAs band gap, of 1.42 eV, for this spectrum [25]. The theoretical maximum almost corresponds to the GaAs band gap. However, most cells are manufactured so that the radiation is also emitted towards the cell substrate located in the rear face of the cell, and little radiation, if any, turns back to the active cell. The consequence of this is that the étendue of the emitted radiation, which is π for a single face radiating to the air, is enlarged. The étendue is then $\pi + \pi n_r^2$. The term πn_r^2 proceeds from the emission of photons towards the substrate of the cell, which has a refraction index n_r. This reduces the limiting efficiency of the GaAs solar cell from 32.8 to 30.7%. Taking this into account, the efficiency of this best experimental cell is only 18.2% below the achievable efficiency of this cell, only on the basis of radiative recombination. Some substantial increase in efficiency might then be achieved by putting a reflector at the rear side of the active layers