which can be seen as free radiation (zero chemical potential) at the hot carrier temperature.

Würfel also points out that, provided we can find a material in which a weak phonon coupling is produced in order to manufacture a solar cell, we still should be careful with the contacts because they do not allow for the maintenance of hot carriers inside the absorbing material. These special contacts must be able to cool the electrons from the hot temperature T_{hc} to the contact temperature T_a reversibly by changing their electrochemical potential from ε_{F0} to the electron electrochemical potential at the contacts (Fermi level at the metals) ε_{F+} and ε_{F-}. In Wurfel's Reference [47], these special contacts are devised as selective membranes (Figure 4.12) that only allow electrons with energy centred around ε_e (left contact) and ε_h (right contact) to pass through. The reversible change in temperature and electrochemical potential of the electrons at the membranes is obtained by setting

$$\frac{\hat{\varepsilon}_e - \mu_{hc}}{kT_{hc}} = \frac{\hat{\varepsilon}_e - \varepsilon_{F-}}{kT_a} \Leftrightarrow \varepsilon_{F-} = \hat{\varepsilon}_e\left(1 - \frac{T_a}{T_{hc}}\right) + \mu_{hc}\frac{T_a}{T_{hc}}$$
$$\frac{\hat{\varepsilon}_h - \mu_{hc}}{kT_{hc}} = \frac{\hat{\varepsilon}_h - \varepsilon_{F+}}{kT_a} \Leftrightarrow \varepsilon_{F+} = \hat{\varepsilon}_h\left(1 - \frac{T_a}{T_{hc}}\right) + \mu_{hc}\frac{T_a}{T_{hc}} \tag{4.76}$$

where $T_{hc} = T_a/(1 - \beta)$. The cell voltage will therefore be given by

$$qV = \varepsilon_{F-} - \varepsilon_{F+} = (\hat{\varepsilon}_e - \hat{\varepsilon}_h)\left(1 - \frac{T_a}{T_{hc}}\right) \tag{4.77}$$

The current extracted from the cell is determined by the rate at which electron–hole pairs of energy $\hat{\varepsilon}_e - \hat{\varepsilon}_h$ can be withdrawn from the cell. Since no energy is lost as heat, the energy balance equation (first principle) leads to

$$I(\hat{\varepsilon}_e - \hat{\varepsilon}_h)/q = \dot{E}(T_s, 0, \varepsilon_g, \infty, H_s) - \dot{E}(T_{hc}, 0, \varepsilon_g, \infty, H_r) \tag{4.78}$$

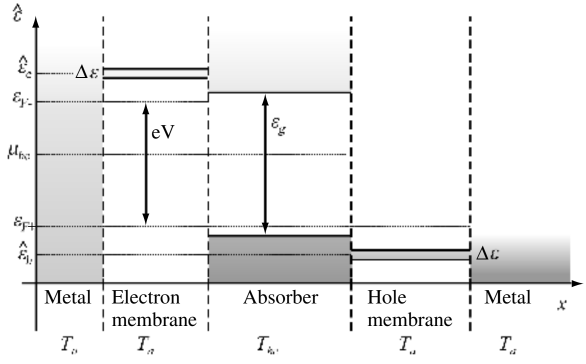

Figure 4.12 Band structure of a hot electron solar cell showing contacting scheme by means of selective membranes. (Reprinted from Solar Energy Materials and Solar Cells V. 46, N. 1, Würfel P., *Solar Energy Conversion with Hot Electrons from Impact Ionisation*, 43–52, © 1997 with permission from Elsevier Science)