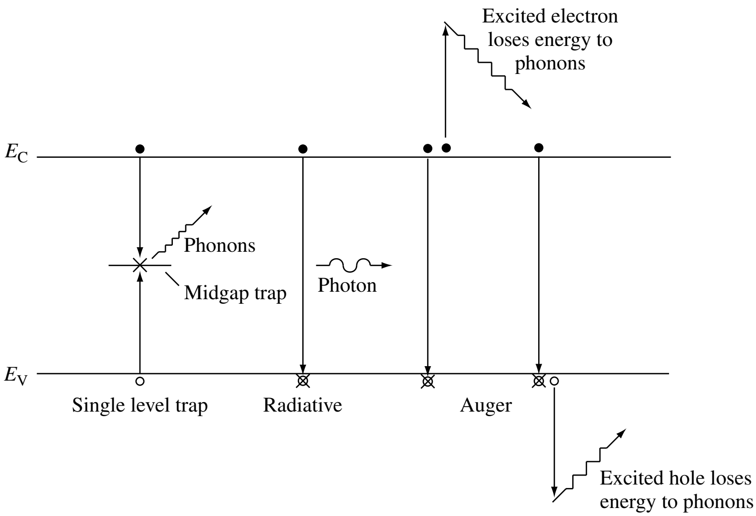

Figure 3.9 Recombination processes in semiconductors

The net recombination rate per unit volume per second through a single level trap (SLT) located at energy $E = E_T$ within the forbidden gap, also commonly referred to as *Shockley–Read–Hall recombination*, is given by [11]

$$R_{SLT} = \frac{pn - n_i^2}{\tau_{SLT,n}(p + n_i e^{(E_i - E_T)/kT}) + \tau_{SLT,p}(n + n_i e^{(E_T - E_i)/kT})} \tag{3.37}$$

where the carrier lifetimes are given by

$$\tau_{SLT} = \frac{1}{\sigma v_{th} N_T} \tag{3.38}$$

where σ is the capture cross section, v_{th} is the thermal velocity of the carriers, and N_T is the concentration of traps. The capture cross section can be thought of as the size of the target present to a carrier traveling through the semiconductor at velocity v_{th}. Small lifetimes correspond to high rates of recombination. If a trap presents a large target to the carrier, the recombination rate will be high (low carrier lifetime). When the velocity of the carrier is high, it has more opportunity within a given time period to encounter a trap and the carrier lifetime is low. Finally, the probability of interaction with a trap increases as the concentration of traps increases and the carrier lifetime is therefore inversely proportional to the trap concentration.

Some reasonable assumptions allow equation (3.37) to be simplified. If the material is p-type ($p \approx p_o \gg n_o$), in low injection ($n_o \leq n \ll p_o$), and the trap energy is near the middle of the forbidden gap ($E_T \approx E_i$), the recombination rate can be written as

$$R_{SLT} \approx \frac{n - n_o}{\tau_{SLT,n}}. \tag{3.39}$$