3. Auger Recombination

There is a physical process known as the **impact ionization effect** by which a high-energy electron collides with an atom, giving enough energy to one of the atom’s electrons to break its bond and create an electron-hole pair. The **Auger effect** is just the reverse process of this\(^1\); in this type of recombination, the excess energy given off by an electron recombining with a hole is given to a second electron (in either band) instead of just emitting the energy as a photon. The newly excited electron then gives up its additional energy in a series of collisions with the lattice\(^2\), relaxing back to the edge of the band. Thus, this effect is a result of interactions between multiple particles, including multiple electrons and a hole. Note: this process can also occur with multiple holes and one electron, depending on whether charge carriers in the valence or conduction band are involved.

Because this process is based on the ability of the charge carriers to exchange energy, the probability of Auger recombination increases with a higher concentration of charge carriers. For an electron-hole-hole process we expect then that the reaction mechanism will be proportional to \(p^2n\) and for an electron-electron-hole process that it will be proportional to \(n^2p\) (where \(n\) and \(p\) are the electron and hole concentrations respectively)\(^2\). The recombination rates, \(R_E\) for electrons and \(R_H\) for holes, are given by

\[
R_E = Bn^2p \\
R_H = Bp^2n
\]

where \(B\) is the **Auger coefficient** based on the material. Furthermore, we can use the recombination rates to obtain an **Auger lifetime** \(\tau_{\text{Aug}}\) for both electrons and holes:

https://eng.libretexts.org/Bookshelves/Materials_Science/Supplemental_Modules_(Materials_Science)/The_Science_of_Solar…

Updated: Mon, 07 Oct 2019 07:54:32 GMT
Powered by
There is a form for the lifetimes that include the minority carrier contribution as well, however it is this previous form for the majority carrier of the material that is most prominent. Including the term for the contribution from the minority carrier band, we have

\[
\tau_{E,Aug} = \frac{p}{R_E} = \frac{1}{Bn^2}
\]

\[
\tau_{H,Aug} = \frac{n}{R_H} = \frac{1}{Bp^2}
\]

where \( C \) is a constant also depending on the material. The term describing majority carrier behavior has a squared term that indicates effectiveness at very high doping levels. So, only in relatively highly doped semiconductors does Auger recombination become a dominant process, because the lifetime of the carrier becomes much shorter. In many semiconductor devices, the dopant concentrations are less than \( 10^{18} \text{ cm}^{-3} \), so it is of lesser significance in most semiconductor devices; however, under certain conditions, such as highly concentrated sunlight, Auger recombination does significantly limit solar efficiency because of shorter carrier lifetimes.

References
