Fundamentals of Electronics Devices

Unit-2

Lecture-6

Diffusion and Recombination

- In the discussion of diffusion of excess carriers, we have thus far neglected the important effects of recombination.
- These effects must be included in a description of conduction processes, however, since recombination can cause a variation in the carrier distribution.

Introduction

- For example, consider a differential length Δx of a semiconductor sample with area A in the yz-plane.
- The hole current density leaving the volume, $J_p(x + \Delta x)$, can be larger or smaller than the current density entering, $J_p(x)$, depending on the generation and recombination of carriers taking place within the volume.

- The net increase in hole concentration per unit time is the difference between the hole flux per unit volume entering and leaving, minus the recombination rate .
- We can convert hole current density to hole particle flux density by dividing J_p by q. the current densities are already expressed per unit area; thus dividing $J_p(x)/q$ by Δx gives the number of carriers per unit volume entering .

Continuity Equation

- When the current is carried strictly by diffusion (negligible drift), we can replace the currents in equations by the expressions for diffusion current; for example, for electron diffusion we have

$$J_e(\text{diff.}) = qD_e \Delta\delta n/\Delta x$$

- Substituting this into continuity equation we obtain the *diffusion equation* for electrons and similarly for holes.

Steady State Carrier Injection

- In many problems a steady state distribution of excess carriers is maintained, such that the time derivatives in diffusion equations are zero.
- The physical significance of the diffusion length can be understood best by an example.
- Let us assume that excess holes are somehow injected into a semi-infinite semiconductor bar at $x = 0$.

- The injected holes diffuse along the bar, recombining with a characteristic lifetime τ_p.
- In steady state we expect the distribution of excess holes to decay to zero for large values of x, because of the recombination.
- For this problem we use the steady state diffusion equation for holes.

- The injected excess hole concentration dies out exponentially in x due to recombination, and the diffusion length L_p *is the average distance a hole diffuses before recombining.*
- To calculate an average diffusion length, we must obtain an expression for the probability that an injected hole recombines in a particular interval *dx.*