Solid State Devices I - Purdue ECE-606

Homework No. 5

Student name: _____

Student ID: _____

I solved the homework assignment myself without copying a solution from someone else or from the web. Student Initials here: _____

Problem 1. (12 Points total)

The energy band diagram for a reverse-biased Si pn-junction diode under steady-state conditions is pictured in Fig. below

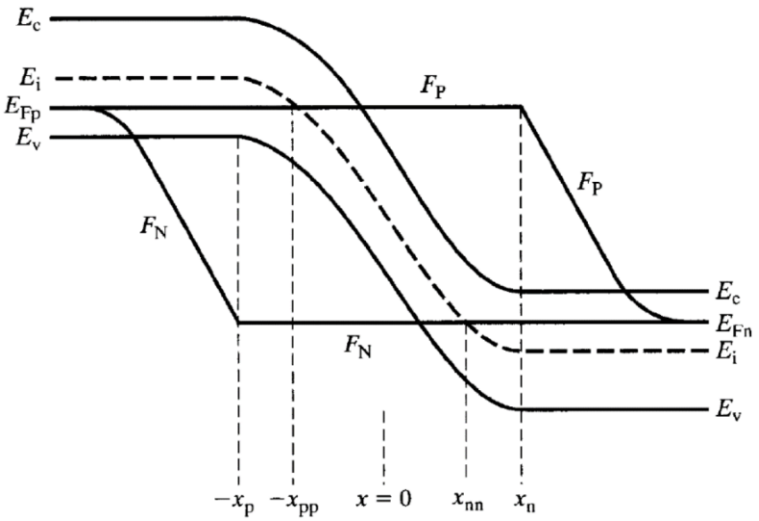
a) With the aid of the diagram and assuming single-level R-G center statistics, $\tau_n=\tau_p=\tau$, and $E_T'=E_i$, simplify the general steady-state net recombination rate expression to obtain the simplest possible relationship for R at (i) x=0, (ii) $x=-x_{pp}$, (iii) $x=x_{nn}$, (iv) $x=-x_p$, and (v) $x=x_n$.

b) Sketch R versus x for x-values lying within the electrostatic depletion region ($-x_p \le x \le x_n$).

c) Compare the reverse saturation current discussed in this problem to the diffusion-only model presented in undergraduate semiconductor textbooks.

$$I_0 = qA\left(\frac{D_p}{L_p}n_{p0} + \frac{D_n}{L_n}p_{n0}\right)$$

What new information or phenomenon does this problem introduce to update that equation?



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Problem 2. (18 points total)

In this problem, we examine the statistics of thermal band-to-band recombination-generation.

a) Using the energy band diagram, indicate the possible electronic transitions giving rise to (i) band-to-band recombination and (ii) band-to-band generation.

b) Taking the semiconductor to be nondegenerate and paralleling the text derivation of Eqs. (5.14), establish the general relationship

$$r_b = c_b(n_p - n_i^2)$$

Where r_b is the net band-to-band recombination rate and c_b is the band-to-band recombination coefficient (units of cm^3/sec). (Note from the nature of the band-to-band processes that the net electron and hole recombination rates are always equal; $r_{electron}=r_{hole}=r_b$. It also follows, of course, that there is no special relationship for steady-state conditions.)

c) Show that the general rb relationship reduces to

$$r_b = \frac{\Delta n}{\tau_b}$$

$$\tau b \equiv \frac{1}{c_b(n_0 + p_0)}$$

Under low level injection conditions where $\Delta n=\Delta p$

d) Given $c_b \approx 5\times10^{-15} cm^3$/sec in Si at 300 K, and assuming $\tau \leq 1$ msec due to recombination at R-G centers, does one have to worry about carrier recombination via the band-to-band process in nondegenerately doped Si at room temperature? Explain.

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Problem 3 - (8 points total).

Inter-band impact generation of electron-hole pair in a high electric field is one of the many hot carrier effects. We will perform a simple calculation to estimate the equivalent electron temperature of a hot electron.

Assume that the initial energy supplied by an energetic electron to form an electron-hole pair is $1.5E_g$, where E_g is the band gap of Silicon.

a) Compute the effective electron energy at room temperature (4 points)

b) Calculate the equivalent electron temperature $T_{electron}$ for the electron that initiated the electron-hole pair generation (4 points)