

Assignment 5

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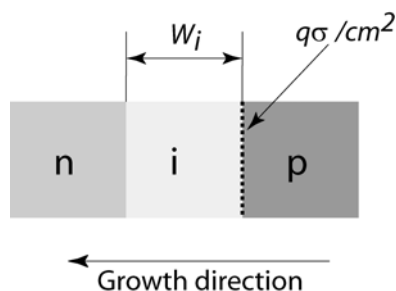
Due: 03/05/2007

Reading

Class notes + Chapters 5 & 6 of Muller/Kamins/Chan (MKC).

Problem 1 (The strange p-(i)-n junction)

Here is a real-life problem in dealing with junctions, especially if you are a great device engineer at the hands of a not-so-great crystal grower (they are known to be a strange lot!). Suppose you asked the MBE grower to grow you a GaAs *p-i-n* junction. Since the grower was paranoid that zinc, the acceptor dopant, might diffuse into the *i*-layer, he dropped the temperature after the *p*-layer, and waited for all the excess zinc to be pumped away before doing on to grow the *i*-layer (thickness W_i), followed by the *n*-layer. When he gave the sample to you, you performed a *C-V* measurement and found that the depletion capacitance is the same as the normal *p-n* junction, i.e., as if there was NO *i*-layer at all! The reason is that while he was waiting for the zinc to be pumped away, oxygen, a donor, incorporated in the crystal and formed a sheet of density σ/cm^2 at the *p-i* interface (see Figure).



a) Derive an algebraic relation between the doping densities N_D , N_A , $q\sigma$, and W_i which will explain the capacitance. To do this, you *have* to sketch the charge, field, and band diagram. Assume $N_D=N_A$ for simplicity. Neglect Gummel correction.

b) Next, calculate a numerical value of W_i . Assume $N_D=N_A=10^{17}/cm^3$, and $q\sigma=5 \times 10^{11}/cm^2$.

Problem 2

Calculate the electron and hole energy eigenvalues in a $L=8$ nm AlGaAs/GaAs quantum well (assume an infinite barrier height). If electrons & holes in the ground states of the well recombine radiatively, what is the color of the emitted light?

Problem 3¹ (Currents in long-base p-n junctions - practice)

Problem 5.11, **MKC**.

Problem 4 (Long and Short base p-n junction currents)

We will henceforth call the heavily doped side of an asymmetrical p-n junction as the *EMITTER*, and the lightly doped side the *BASE*, to prepare for the jargon used in bipolar transistors. Consider an ideal n^+p junction made of GaAs ($N_D=2 \cdot 10^{17}/cm^3$, $N_A=10^{15}/cm^3$) at 300K. Assume that the minority carrier lifetime of electrons in the p-side and holes in the n-side is $\tau_n=\tau_p=0.2\mu s$. Look up data sheets for anything else you might need.

- Calculate the saturation current density J_0 for the diode (current density is $J=J_0[\exp(V/V_{th})-1]$).
- Sketch the minority and majority carrier profiles outside the depletion region at zero bias, and at a forward bias of $V=0.5$ Volt. Label length scales (diffusion lengths, etc).
- Calculate and sketch the electron and hole current components (both diffusion and recombination) outside the depletion region as a function of distance at this forward bias. Which carriers (minority or majority) dominate the current flow on each side of the junction?
- Redo parts a) to c) for a *short-base* diode, with the *total* base width (thickness of the p-side) $W_B=2\mu m$. Verify that $W_B < L_n$, where L_n is the minority carrier diffusion length in the base. Make reasonable approximations (linearize slow exponentials, etc) to simplify the problem.
- Finally, what we are waiting for – when is the current larger – for long base or short base? Can you explain intuitively why this must be so?

¹ Remember to use proper units and label every figure/plot. Use natural scales such as nm for length, KV/cm for electric fields, and eV for energies. Turn in your answers worked out neatly. Please attach this question sheet to your solution when you turn it in.