EE566 Solid State Devices

Spring 2008
Dept of Electrical Engineering
University of Notre Dame
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2nd Mid-Term Exam
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Problem (20 Points): HBT Device Physics

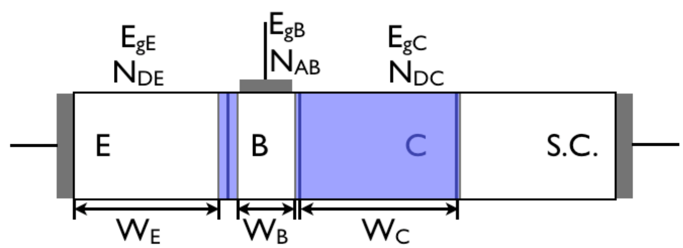

Figure 1.

The Figure above shows the cross section of a n-p-n HBT. The shaded regions are depleted, and the figure indicates the situation at equilibrium ($V_{BE} = V_{CB} = 0$ V). The effective thicknesses of the layers in the emitted, base, and collector are indicated, along with the respective doping densities and bandgaps. Assume that $E_{gE} > E_{gB}$, the HBT has a short base, the collector is doped lightly [$N_{DC} << (N_{AB}, N_{AB})$], and the sub-collector (S.C.) is doped heavily. The two heterojunctions are abrupt (neglect any "spike" effects of the bands). Assume the saturation velocity of electrons is v_{sat}, the diffusion constants $D_n = D_p = D$ of electrons and holes are equal throughout the device, and the carrier lifetimes are $\tau_n = \tau_p = \tau_0$ everywhere.

Answer the following questions:

a) Sketch a charge-field-band diagram of the device in the forward-active mode (B-E forward biased, C-B reverse biased). Assume that the widths of the two depletion regions do not change appreciably. Show the Fermi levels (& quasi-Fermi levels) clearly. Also show the minority carrier concentrations. (**5 pts**)

b) Identify the regions where the highest generation & recombination occurs in the HBT based on the band diagram. (**1 pts**)

c) Find the emitter injection efficiency γ_E, the base transport factor α_T, and the current gain β_F of the HBT based on what we have covered in the class. (**3 pts**)

d) Generation current component has not been considered in the class for understanding HBT performance. Calculate the generation current density in the forward-active mode at low injection condition, and explain qualitatively what effect it might have on the HBT performance (on the three components of the current). (**5 pts**)

e) How can you reduce the generation current? (**1 pts**)

f) Assume that the onset of the Kirk effect occurs at a current density $J_{kirk} \approx qN_{DC}v_{sat}$. What should be the *minimum* bandgap of the collector such that the effective low-injection generation current (from part d) is smaller than the Kirk current threshold? Express it in terms of all given quantities. (**5 pts**)

NOTE:
Draw sketches with proper LABELS!! (wherever the situation demands). State your approximations clearly, and use your intuition to cut down on the math.