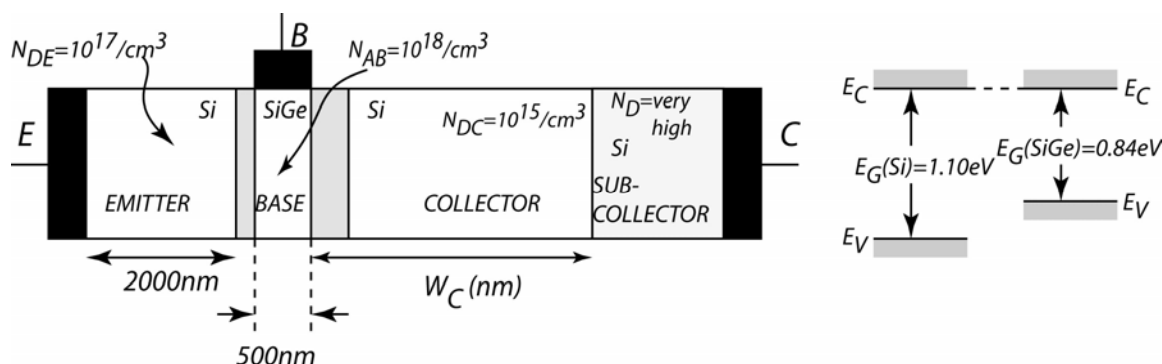


EE566 Solid State Devices

Spring 2006
 Dept of Electrical Engineering
 University of Notre Dame
 Instructor: Debdeep Jena (djena@nd.edu, x8835)

2nd Mid-Term Exam 04/10/2006

Problem(20 Points)



Consider the SiGe HBT shown above. The E/B Si/Si_xGe_{1-x} heterojunction is abrupt. Note the doping densities carefully, and neglect bandgap narrowing. Further, let us assume for this exam that the conduction band offset ΔE_C between Si and Si_xGe_{1-x} (used in the base) is zero eV as shown. Assume T=300K. Use the following parameters for your calculations – do not use data from other sources:

$$\epsilon_s = 11.7\epsilon_0 \mid \epsilon_0 = 8.85 \times 10^{-14} \text{F/cm} \mid \mu_n = 1500 \text{cm}^2/\text{V}\cdot\text{s} \mid \mu_p = 450 \text{cm}^2/\text{V}\cdot\text{s} \mid \tau_n = \tau_p = 0.5 \mu\text{s} \mid n_{iE}^2 = 10^{20}/\text{cm}^6 \mid v_{sat} = 1 \times 10^7 \text{cm/s}$$

- Make two sketches of the band-diagrams of the HBT: one at equilibrium ($V_{BE} = V_{CB} = 0$ Volt), and the second in the forward-active mode ($V_{BE} = 0.7$ Volt, $V_{CB} = 5$ Volt). Show the Fermi/quasi-Fermi levels. It is not necessary to calculate anything for this part. (2 Points)
- Make three sketches of the minority carrier distributions across the HBT in the three modes of the HBT operation - forward-active, saturation, and cutoff. It is not necessary to calculate anything for this part. (2 Points)
- Find the emitter injection efficiency γ_E , base transport factor α_T , and the corresponding current gain β_F . (5 Points)
- What is the maximum collector width W_C such that it is totally depleted at $V_{CB} = 0$ Volt? Make reasonable assumptions. Set the collector width at this value. (2 Points)
- It is given that the unity-gain cutoff frequency f_T of this transistor is limited by one of the two transport processes – base transit time, or collector transit time. Show which one dominates (calculate them in ps units). What is the f_T of this HBT (express it in GHz)? (4 Points)
- What change would you suggest to increase the f_T of this HBT? Support your suggestion. (3 Points)
- During normal operation, what problem is likely to be encountered due to the low doping in the collector? Can you suggest a way to fight this effect? (2 Points)

NOTE:

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