ECE 4211 HW5 BJT Design, Heterojunctions, and LEDs 02162017 Due 02212017 **NAME**:\_\_\_\_\_

 Popquiz#2 Diodes and BJTs on Tuesday 02212017 F. Jain

HW3-Q.4. Draw a hybrid  model for a BJT or HBT that you have studied in a prerequisite course. **Calculate any two component** values (in the model) using transistor parameters from the device of Q.2 HW4.

**HW3-**Q.5. Energy band diagram of an N-AlGaAs/pGaAs/P-AlGaAs double heterojunction **diode** is shown below in Fig. 5a (Ffig. 42, page 170 Notes). A single p-n heterojunction is shown in Fig. 5b (Fig. 36 p 163).

## Q.5(a). Modify Fig. 5(a) energy band diagram to represent a heterojunction bipolar transistor by including N-AlGaAs collector in place of p-AlGaAs layer on the right side of the GaAs layer.

HINT: An n-p-n heterostructure bipolar transistor is given on page 237.

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| Fig. 5(a) A double heterojunction. (Fig. 42 Page 170 Notes).  | Fig. 5b. A single heterojunction.(Fig. 36 p 163).  |

**HW5-Q.1 Design specifications***:* Design an n-p-n transistor with a common emitter gain, o = 500. The device cross-section and a typical layout are given in Figure 13. The design is presented in Class Notes (part I) pages 245-254.

Given for guideline purposes are the following device parameters:

Emitter: Base:

Dp,E =20 cm2/sec. Dn,B =40 cm2/sec (diffusion coefficient for electrons)

Hole lifetime p =10 sec Electron lifetime n =2 sec

Emitter area AEB = 2 m x 2 m Base-collector area ABC = 6 m x 6 m

Emitter-collector voltage VCE = 5 Volts



Figure 13. Cross-section and Top view of a n-p-n transistor

Q.1(a) Summarize value of emitter, base and collector doping levels and base thickness tht give a  = 500 per BJT specification.

Q1(b) Name factors that are important in determining the values of the cut-off frequencies fand f.

Q1(c) Name the single most important parameter used in design pass#2 to enhance f to 5.62GHz from 5.26\*107 Hz (almost by a factor of 100).

Q1(d) what is the advantage of using p-SiGe base as opposed to –pSi base and having a nSi- pSiGe-nSi heterojunction bipolar transistor. The main consideration is cut off frequency.

**Q.2 (a).** What is the distance from junction edge (xp) in which electron concentration decays by 1/e? **Circle one**

Ln 2Ln Lp 2Lp

(b) What is the advantage of having a heterojunction such as shown in Fig. 1(a) ? **Circle one**

 Higher injection efficiency improved injection efficiency even if emitter doping is lower than p-side

(c) What happens in an N-AlGaAs/p-GaAs/P-AlGaAs double heterojunction diode of Fig. 1(b) in terms of the recombination of the injected electrons. Can we make p-GaAs thinner than a diffusion length Ln.

YES NO

(d) For a given electron current IEN, which of the two diodes of Fig. 1 will give higher photon density? Assume the junction area A to be same. Thickness of pGaAs in Fig. 1b is smaller than the diffusion length Ln.

 Fig. 1(a) Fig. 1(b)

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| Fig. 1(a). A forward biased N-AlGaAs-p GaAs diode. Fig. 1(b) band diagram of a double heterojunction.  |
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 Fig. 2 shows the energy of injected electrons at a point x on the p-side.

Q.3. (a) If the quantum efficiency q for GaAs is 0.95 and for Si 0.05 how many photons are produced per second for an electron current of 1mA in n-p diodes on the p-side.

Q3(b) Write the mechanism of electrons and holes recombination for Si diode (Fig. 2a) and GaAs diode (Fig. 2b).

Si

GaAs

Q.4(a). Find the energy of emission for points A and B using Figure 22 (on page 303) and Fig. 3a (below).



Fig. 22 page 303. Hint: Point A is the intersection of vertical line through InP. Horizontal line through A on Eg axis gives the energy.

Q4(b) What is the wavelength of emission for points A and B.?

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| D:\_students\xiao\Dr.Jain\bandgap.jpg | Fig. 3a (left)Fig. 3b Lattice constant versus energy gap. |