EECE 480 Assignment 4

Due date: November 17; hand-in at the beginning of the class.

Objective: To gain an understanding of the attributes of HBTs, *i.e.*, gain and high-frequency performance.

Consider an *Npn* $In_{0.61}Ga_{0.39}P$/GaAs HBT of the construction shown in Fig. 9.1. The HBT is operating in the active mode with $V_{BE} = 1.4\,\mathrm{V}$ and $V_{BC} = -1.0\,\mathrm{V}$. The emitter and collector doping densities are $5 \times 10^{18}\,\mathrm{cm}^{-3}$ and $10^{17}\,\mathrm{cm}^{-3}$, respectively. The base has a doping density of $5 \times 10^{19}\,\mathrm{cm}^{-3}$ and a quasi-neutral width of 25 nm.
The cross-sectional area of the emitter is $(2 \times 2)\,\mu\mathrm{m}^2$.

1. Run Bandprof, using the HBT template on the website, for the HBT under the stated conditions. Hand-in the band diagram, and comment on why the particular choice of In mole fraction would be desirable for an HBT.

2. Estimate the current gain β_0, and show your calculations of the relevant currents, *i.e.*, the collector current and the base recombination current.

3. Evaluate the intrinsic, unity-current-gain frequency f_{Ti} and show your calculations of the relevant components, *i.e.*, transconductance, base storage capacitance (consider this to be the only contribution to C_{EB}), C-B junction capacitance.

4. If R_b is due solely to the base spreading resistance, calculate the unity-power-gain frequency $f_{\max}$.

On the following pages is a MATLAB template file that you may wish to use. If you do use this, or any other code, then please include the input file in your answer. If you type the equations into the code, there is no need to hand-write them in your answer.

```
% EECE 480, Assignment 4, 2011
% HBT gain, fTi, fmax
% InGaP/GaAs HBT
% MATLAB template
% completed by (ADD YOUR NAME)
% ADD THE DATE

clear all;
%---physical constants--(be consistent with units)
q= ;
kT= ;
Vth= ;
h= ;
m0= ;
eps0= ;
%--------material constants-------------
%Material 1, n-emitter, In_61Ga_39P
%Material 2, p-base, GaAs
%Material 3, n-collector, GaAs
%Only the properties for GaAs are needed here
mestar= ;
mhstar= ;
Eg= ;
eps= ;
NC= ;
NV= ;
ni= ;
vR = ;        % use the low-doping value
%---------device variables------------
NE= ;
NB= ;
NCC= ;
L= ;    %HBT length (horizontal on Fig. 9.1)
Z= ;    %HBT width (into the page)
WB= ;
VBE= ;
VBC= ;
%----------doping dependant properties (formulae from the book)---------------
mue= ;
De= ;
taue= ;
muh= ;
VbiC= ; %CB built-in voltage
WBC= ;  %CB depletion region depth
n0B= ;
%---------------IC, IB_rec, gain from equations in the book---------
IC= ;
```

```
IBrec= ;
IB=IBrec ;
beta0= ;
%-------------small-sig params (formulae from book)----------
gm= ;
CBEb= ;
Cpi=CBEb;
Cmu= ;
fTi= ;
Bres= ;     %base material resistivity
RBqnb= ;    %resistance of base QNR
Rb= ;       %base spreading resistance
fmax= ;
```