Homework 4 – due May 16, 2019 by 5pm

Reading: Read Chapter 6 (skip 6.4), 7.2, 7.3, and 7.5 in Muller & Kamins, as well as HEMTs handouts

1. Consider the structure illustrated in the figure below. The i-AlGaAs contains a delta-doped layer a distance $\delta$ from the AlGaAs/GaAs interface. The doping in the delta layer is $n_d = 4 \times 10^{12}$ cm$^{-2}$. This results in a 2DEG in the GaAs near the AlGaAs/GaAs interface. Calculate the sheet charge $n_s$ in the 2DEG for $\delta = 30$ Å and $\delta = 40$ Å, and draw band diagrams (conduction band only) of these structures. What happens as the delta layer is brought closer to the GaAs? What advantages and disadvantages are there in doing this in a HEMT? Make the following assumptions: $\phi_b$(AlGaAs/Au) = 0.9 V, the conduction band at the AlGaAs/GaAs interface drops .03 eV below the Fermi level regardless of $n_s$, all the electrons from the delta layer go either to the 2DEG or to the metal, and use $\Delta E_c$ calculated in the previous homework set.

![Diagram of structure](image)

2. (a) Calculate $\beta$ for a GaAs n-p-n bipolar transistor. The properties of the transistor are as follows: $N_{de} = 2 \times 10^{17}$ cm$^{-3}$, $N_{ab} = 1 \times 10^{17}$ cm$^{-3}$, $N_{dc} = 1 \times 10^{17}$ cm$^{-3}$, $\mu_n = 4500$ cm$^2$/V$\cdot$s, $\mu_p = 400$ cm$^2$/V$\cdot$s, $\tau_n = \tau_p = 1$ ns, and $w_B = 0.3$ μm

(b) Now solve the same problem, except that the GaAs emitter is replaced with Al$_{0.2}$Ga$_{0.8}$As (assume heterojunction is graded so that there is no spike in the conduction band) and the doping in the base $N_{ab}$ is increased to $1 \times 10^{18}$ cm$^{-3}$. By what factor has your $\beta$ improved?

3. If the device in problem 2(a) is biased at $J_C = 0.25$ mA/cm$^2$ and $V_{CE} = 6$ V, draw the band diagram and electric field profile in the device. If $V_{CE}$ is increased, which part of the device will break down (i.e. where is the maximum electric field in the device)? How might you redesign the device to improve breakdown?