EECE 480 Assignment 2

Due date: October 13; hand-in at the beginning of the class.

Objective: To gain familiarity with pn-junction diode band diagrams, parameters and characteristics.

Download a copy of *Bandprof* from the INSTRUCTIONS section of the course website. This program's creator, Dr. William Frensley of UT, Dallas, has kindly made it available for us to rapidly construct band diagrams and to calculate currents in semiconductor devices. A *README* file is also available on the website. Download a copy of the input file *pn.ht2*; change its name to *480_1_your name.ht2*, and then modify the file so that you are describing a silicon diode at 300K with an n-region of width 50 nm and doping density $1 \times 10^{19}\,\text{cm}^{-3}$, and a p-region of width 100 nm and doping density $5 \times 10^{17}\,\text{cm}^{-3}$. The n-region should be on the left, as in Fig. 6.7 of the text book.
To verify the doping profile and geometry, click *Verify*.
To display the equilibrium energy band diagram, click *Simulate*.

1. Show your input file, and the energy band diagram.
2. From the band diagram, estimate $(E_C - E_F)$ in the n-type quasi-neutral region (QNR), and estimate $(E_F - E_V)$ in the p-type QNR.
   Note: the scales of the figure can be changed via the arrows on the top left-hand side.
3. Use the values from Question 2 to estimate n_0 in the n-QNR and p_0 in the p-QNR.
4. Perform your own calculations for n_0 and p_0, based on the known doping densities and intrinsic carrier concentrations (see end of next page for some relevant numerical information).
   If there's serious disagreement between your calculated values and the estimated values from the previous question, speculate as to why this may be so.
5. From the band diagram, estimate the built-in voltage V_{bi}, and the space-charge-region width W.
6. Perform your own calculations for V_{bi} and W.
   If there's serious disagreement between your calculated values and the estimated values from the previous question, speculate as to why this may be so.
7. In the *Bandprof* window, add a potential to one side of the diode to represent a forward bias of 0.8 V. (Activate via [Enter]).
   Activate *Drift-diffusion* in the *Modeling Mode* window of *Bandprof*.
   Show the resulting band diagram, and estimate the junction voltage V_J, and the separation of the quasi-Fermi levels in the space-charge region.
8. Perform your own calculations for V_J and $(E_{Fn} - E_{Fp})$ in the space-charge region.
   If there's serious disagreement between your calculated values and the estimated values from the previous question, speculate as to why this may be so.
9. Perform your own calculation for the electron current ($J_e \times$ Area) in an ideal diode.
   If there's serious disagreement between your calculated value and the *Bandprof* value from the previous simulation, speculate as to why this may be so.
10. Perform your own calculation for the electron current ($J_e \times$ Area) in a diode for which there is no recombination in the p-QNR.
    Any comments on how current is estimated in *Bandprof*?

Notes

1. *Bandprof* uses slightly different values than the textbook for some Si parameters, *e.g.*: $E_g = 1.1245\,\mathrm{eV}$, $\epsilon_r = 11.8$, $N_C = 2.744 \times 10^{19}\,\mathrm{cm}^{-3}$, $N_V = 1.142 \times 10^{19}\,\mathrm{cm}^{-3}$.
   To see these values, click on *Display Parameters* in the *Verify* window, and then click on *Verify.*

2. Information on the Drift-diffusion module can be found by clicking on *Help* in the *Simulation* window and opening one of the dialog boxes.

3. I-V characteristics can be generated from the *Simulation* window by clicking on the *I(V)* tab at the bottom. The device area is displayed at the top of the window.