

---

# EE566 Solid State Devices

Spring 2008

Dept of Electrical Engineering

University of Notre Dame

Instructor: Debdeep Jena ([djena@nd.edu](mailto:djena@nd.edu), x8835)

---

## Assignment 6

Posted: 03/08/2008

Due: 03/14/2008

**Reading:** Chapters 5 & 6 of the Textbook (Muller/Kamins/Chan: MKC) + Class Notes.

### **Problem 1\* (Generation and Recombination processes)**

We discussed in class that in the depletion region of a p-n junction, generation processes occur under reverse bias, and recombination processes occur at forward bias. These two processes form the basis of many useful devices based on semiconductors. Consider a p-i-n junction made of a semiconductor of bandgap  $E_g$  and intrinsic carrier density  $n_i$  (at 300 K) for this problem. The doping densities are  $N_D$ ,  $N_A$ , and the i-region thickness is  $W$ . You can simplify the problem by assuming that the i-region thickness is much more than the depletion regions in the n & p type regions.

- What is the reverse-bias leakage current density for the p-i-n junction if generation in the i-region is neglected?
- What is the additional leakage current density due to generation? What physical process leads to this generation? How can it be experimentally verified?
- Now let photons of energy larger than  $E_g$  be incident uniformly in the i-region such that they lead to the generation of  $G_{opt}$  electron-hole pairs per second per unit volume (unit:  $\text{cm}^{-3}\text{s}^{-1}$ ). Find the third component of the reverse-bias current that flows in the device. Explain how this device can be used as a photodetector. Look for published papers that describe such photodetectors where similar structures have been used, and explain why the i-region helps.

### **Problem 2 (Generation-recombination currents)**

Problem 5.10, **MKC** (keep your approach dimensionally correct to make life easier – not a trivial problem).

### **Problem 3 (Recombination currents in the space-charge region)**

Problem 5.12, **MKC** (Label your sketches carefully, this is a qualitative question).

### **Problem 4 (p-n junction switching: design problem)**

Problem 5.14, **MKC**.

### **Problem 5 (Charge storage and transit times in short-base diodes)**

Problem 5.18, **MKC**.

### **Problem 6 (Solar Cell Device Physics)**

Consider a *single* junction solar cell in operation, with  $G_{op}$  being the generation rate of carriers. The open-circuit voltage  $V_{OC}$  is defined as the voltage at which the current through the cell is zero. Similarly, the short-circuit current  $I_{SC}$  is defined as the current flowing through the cell when the applied bias across it is zero. From your knowledge of diode current flow mechanisms, find the bias voltage  $V_{max}$  for the cell at which the conversion of solar power in to electric is *maximized*. Plot the minority carrier profiles inside, and around the edges of the depletion region when the cell is biased at  $V_{bias}=0$ ,  $V_{max}$ , and  $V_{OC}$ .

*Sketch* the solar spectrum (intensity vs wavelength) on the earth's surface, and outside the atmosphere. Explain why, to convert the radiation into electrical energy with the *highest efficiency*, one needs to use p-n junctions made of *multiple* semiconducting materials (the so-called multi-junction cells). What is the highest efficiency reported till date for a semiconductor solar cell?

In general, make sure you are comfortable with the chapter-end problems of MKC Chapters 5 & 6.

---

\* Remember to use proper units and label every figure/plot. Turn in your answers worked out neatly. Please attach this question sheet to your solution when you turn it in.