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# EE566 Solid State Devices

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Dept of Electrical Engineering

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## Assignment 6

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### Reading

Chapters 4 & 5 from the textbook.

### **Problem 1<sup>1</sup> (Recombination currents in the space-charge region)**

Consider a forward-biased p-n junction. Sketch the distribution of electron and hole current densities across the junction if there is significant recombination in the space-charge (depletion) region. Assume that the injected hole current is *twice* the injected electron current, and the recombination rate inside the space-charge layer is *half* the recombination rate of electrons in the p-type region.

Demonstrate that the total diode current is given by adding a term that describes the space-charge recombination current to the sum of diffusion currents at the edge of the (space-charge, or) depletion region.

### **Problem 2 (Recombination/Generation currents)**

Sketch the ratios of the space-charge recombination and generation currents to the ideal diode current ( $J_{\text{rec}}/J_{\text{ideal}}$ , and  $J_{\text{gen}}/J_{\text{ideal}}$ ) as a function of the applied bias. Make two plots with multiple plots in each to show the effect of a) doping, and b) temperature on this ratio.

### **Problem 3 (Charge storage and transit times in short-base diodes)**

An ideal short-base Silicon n+-p diode has  $N_d \gg N_a$  and  $N_a = 10^{17}/\text{cm}^3$ . The width of the p-region from the edge of the depletion region to the p-contact is  $W_B = 3\mu\text{m}$ . The area of the diode is  $A = 10^{-5} \text{cm}^2$ . Assume that the n-region is degenerately doped, and use reasonable values of any constants you need.

- Calculate the charge stored in the neutral p-region if  $I = 0.5\text{mA}$  flows through the diode.
- Determine the charge stored in the narrowed depletion region under forward bias.
- How much time does it take a current source of  $0.5\text{mA}$  to cause the diode to switch from an off condition ( $V_a = 0$ ) to the steady state with  $0.5 \text{mA}$  of current?

### **Problem 4 (Solar Cell Device Physics)**

Re-solve the continuity equation for a reverse-biased GaAs p-n junction (doping -  $N_d, N_a$ ) which is illuminated with light which generates  $G_{op}$  electron-hole pairs per unit time to find the photo-generated current. Show that the diffusion currents at the edge of the depletion region are dominated by the optically generated carriers if illumination is strong. Find the optimum bias condition for the p-n junction for maximum photovoltaic conversion.

*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?

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<sup>1</sup> Remember to use proper units and label every figure/plot. Use natural scales such as nm for length, KV/cm for electric fields, and eV for energies. Turn in your answers worked out neatly. Please attach this question sheet to your solution when you turn it in.