EE119 Homework 8: Photodiodes, Solar Cells, and

Professor: Jeff Bokor GSI: Julia Zaks

Due Friday, April 3, 2009

1. Draw a diagram of a p-n junction. Label the p-type material and the n-type material. Draw an arrow in the direction of the built-in E-field and explain why p-n junctions have an e-field. If a photon was absorbed by the p-n junction, In which directions would the electron and hole travel after they have been separated by the photon energy? Clearly label these directions on your diagram.

2. In order to detect light from a Nd:YAG laser at 1064 nm wavelength, what is the maximum energy gap of the detector material?

3. Semiconductor Photodiodes

   For a particular PIN photodiode, a pulse of light containing 5×10^{12} incident photons at wavelength of 1.55 μm gives rise to, on average, 1.5 x 10^{12} electrons collected at the terminals of the device.

   (a) What is the energy incident to the photodiode? What is the quantum efficiency of the photodiode?

   (b) The diffusion length of a charge carrier is the distance that it will travel, on average, before it recombines with another oppositely charged carrier and stops carrying any current. The diffusion length of charge carriers is 0.5 μm in this detector. The detector is roughly a circle with a 0.5 μm radius. (Making the detector any larger would mean that you lose a lot of carriers before they reach electrodes). If the electron diffusion velocity is 7 x 10^6 cm/s, estimate the response time of the detector (do not take drift into account).

   (c) The thickness of the intrinsic layer in the photodiode is typically about 2.5 μm. If the drift velocity of the electrons in this region is 10^7 cm/s, estimate the response time of the detector (do not take diffusion into account).

   (d) Estimate the response time of the detector taking drift and diffusion into account.

4. You've developed a way to make really cheap solar cells that absorb the same fraction of the solar spectrum as silicon. However, the material you're using has a drawback, because it can only generate 0.8 eV of energy per photon absorbed (as opposed to 1.1 eV for silicon).

   (a) What is the maximum generation current for your solar cell material?

   (b) What is the maximum amount of power per area you will get out of your cell?

   (c) What fraction of the total intensity coming from the sun will your solar cell harness?

5. We have a CCD camera with 242 pixels (vertical) by 350 pixels (horizontal), operating at a video frame rate of 30 frames per sec, and each pixel is made with a MOS structure. The size of the CCD is 4.8mm (V) by 6.4mm (H). The CCD is saturated when the incident power density is 0.05 W/cm2 at the wavelength of 630nm. The quantum efficiency at that wavelength is 56%. You can ignore the gap between each pixel.

   (a) The potential well in a CCD pixel will continue to collect all available electronic charges until it is filled with electrons. When this potential well is completely filled with charges, this is the saturation point of the detector and this is the maximum capacity of the potential well. Calculate the maximum well capacity of the CCD (in # of electrons).

   (b) Now, we want to use that CCD to detect radiation from a laser with wavelength of 193nm. The quantum efficiency at that wavelength is 3%, and the maximum well capacity is the same as what you calculated in part (a). What is the saturation power density for this application?