University of Delaware
Department of Electrical and Computer Engineering
ELEG620: Solar Electric Systems
Homework #4

Introduction

The goal of this homework is to understand the design trade-offs and interactions in a solar cell. A simple design can be done using the closed form diode equations, but calculations of the optical properties and short circuit require computer calculations, and hence we will use a solar cell design program to calculate the solar cell efficiency.

Note that for the PC1D files, you may not vary any of the parameters in PC1D, except as specified in the homework. As output, please save the PC1D *.prm files **in the PC1D directory**. Please make sure to name the *.prm files such that they can be readily identified when we look for them, and note in your report what they are called. When you have finished the homework, please copy and save the entire PC1D directory to another, higher level directory labeled with you name, zip the directory and submit zipped directory.

Problem #1: Closed Form Equations vs computer calculations

Calculate J_0, J_{sc} (using the constant generation approximation) and V_{oc} for the parameters in Basic_Solar_Cell.prm. Compare J_0 (which you will have to calculate from other results in PC1D), J_{sc} and V_{oc}. How close are they, and what accounts for the differences? Change the emitter doping profile in PC1D to a Gaussian and repeat the comparison

Problem #2: Solar Cell Optimization

For the parameters in Basic_Solar_Cell.prm (expect using a Gaussian emitter profile), design a solar cell by changing the emitter doping and thickness and base thickness, assuming a Gaussian profile. The minimum emitter thickness is 0.2 microns, and the maximum is 5 microns.

a) What are the solar cell device parameters (emitter doping and emitter and bases thickness) which give maximum efficiency? Physically explain your results and justify why the maximum occurs at the values it does.
b) How is the optimum thickness altered if the top surface recombination velocity is increased to 10,000 cm/sec? (You do not need to give specific numbers). Explain physically and check your physical explanation using PC1D.
c) Which physical effects are not included in the calculations?

Problem #3: Back Surface Field

To reduce the effects of a rear recombination velocity, a back surface field (BSF) is implemented, consisting of a thin heavily diffused region at the rear of the solar cell. Include a BSF into PC1D, and do an optimization for the thickness and doping. The maximum BSF thickness is 3 microns.

a) What are the optimum BSF parameters? Physically explain the trade-offs in the BSF design.

b) From the energy band diagram or a solar cell with a back surface field, explain how the surface passivation works.

Problem #4: Base doping and minority carrier lifetime

The base doping is initially set to 1 Ohm-cm material, which is a typical value for a commercial solar cell. Increasing the base doping, assuming the minority carrier lifetime remains relatively unchanged, would ideally increase the open circuit voltage.

c) Explain physically why increasing the base doping ideally increases Voc, both in terms of Fermi-levels and physically.

d) In practice, Voc does not continue to increase with doping because the minority carrier lifetime degrades as the doping is increased. Using the "moderate case" in the figure below, determine an optimum base doping by changing the minority carrier lifetime as you change the doping. What is the optimum base doping?