ECE 59500: Spring 2019
Theory and Practice of Solar Cells: A Cell to System Perspective

Take Home Midterm Exam
Due 5:00 PM Friday, April 19 at Wang Hall 3055

NAME: ______________________________

Student ID: ______________________________

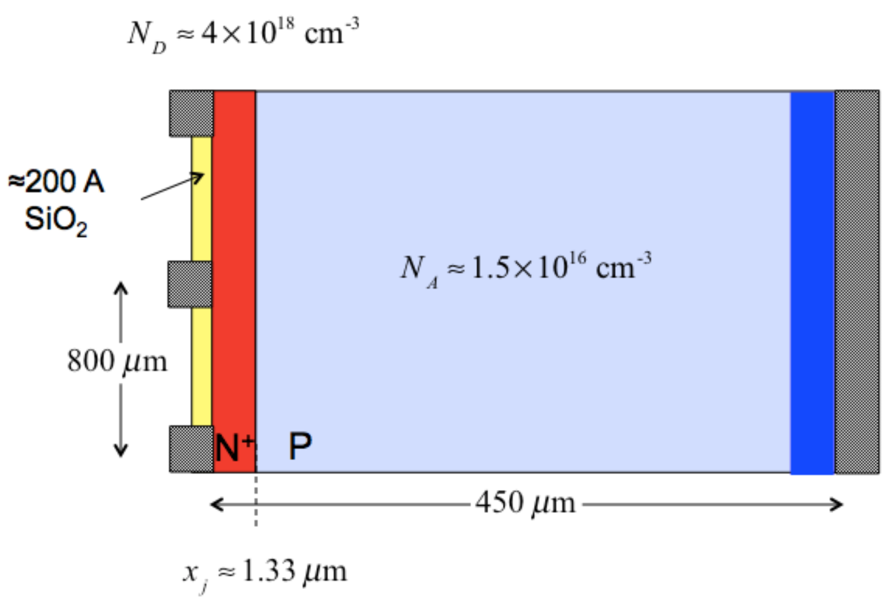
This is a closed book exam. You are permitted to consult any reference book, paper, etc. (although you will probably do better if you do not). You are not permitted to discuss this exam with anyone until after you handed it in.

I certify that this exam is my work and my work alone and that I have received NO help from anyone on it.

Signed: ______________________________

Date: ______________________________

This exam concerns a simple, 1D model of the PERL cell as summarized in the figure below.



You should assume $T = 25\,°\text{C}$ and $n_i\left(25\,°\text{C}\right) = 0.86\times10^{10}$ cm^{-3}. You will need a value for the diffusion coefficient and for some lifetime parameters. Explain how you get them and cite your sources.

1) PN junction analysis is often based on the assumption of "low-level injection." For the P-type base layer of the PERL cell, this means $\Delta n << p_0 = N_A$. Check the validity of this assumption.

1a) For the PERL cell at open-circuit voltage, $V_{oc} = 706\ \text{mV}$. Is the P-type base in low-level injection at V_{oc} ?

1b) An open-circuit voltage of 744 mV has been achieved in the HJ-IBC cell. If this V_{oc} could be obtained in the PERL cell, would it be in low-level injection at V_{oc}?

2) The dark current is described by $J_D = J_0\left(e^{qV_D/k_BT} - 1\right)$, where the saturation current density, J_0, has components from the top surface/contact, the top N-layer, the P-layer, and the bottom surface/contact:

$$J_0 = \left[J_{0p}(t\text{-c}) + J_{0p}(\text{n-Si})\right] + \left[J_{0n}(\text{p-Si}) + J_{0n}(\text{b-c})\right].$$

In the 25% PERL cell, $J_0(25\ °\text{C}) = 50\ \text{fA}$. It is thought that for this cell, the contributions from minority carrier holes in the N-layer contact/surface and the N-layer itself is $J_{0p} = \left[J_{0p}(t\text{-c}) + J_{0p}(\text{n-Si})\right] = 15\ \text{fA}$. Answer the following two questions.

HINT: You can adapt expressions presented for the P-type base in Lecture 3: Design of Si Solar Cells.

2a) Assume that all of the minority hole recombination is due to holes recombining at the top contact/surface. **What it the average surface recombination velocity?** (The average surface recombination velocity is the average accounting for recombination at the metal contact and at the oxidized Si surface.)

2b) Is this number reasonable? Compare it to the value expected if the oxide-passivated portion of the N-layer had a recombination velocity of 0 cm/s. (Assume that metal grid covers 2% of the top surface.)

2c) Assume that all of the minority hole recombination is due to holes recombining in the N-layer. **What it the minority hole lifetime**?

2d) Compare the lifetime you deduced in 2c) to the upper limit lifetime due to radiative and Auger processes. The radiative lifetime is $\tau_R = 1/BN_A$ and the Auger lifetime is $\tau_A = 1/C_nN_D^2$. What do you conclude?