## Mandatory assignment 2 - J0 simulations and introduction to Quokka 2.2.5

This assignment is separated into two parts: First we perform simulations of the various saturation current prefactors in a 1D solar cell using (cmd-)PC1D, then we will investigate the impact of $J_{0,front}$ and $J_{0,rear}$ on the silicon solar cell using the conductive boundary approximation as implemented in Quokka 2.2.5.

Suggested reference material (see fronter page):

[1] Kimmerle, et al, *Precise parameterization of the recombination velocity at passivated phosphorus doped surfaces*. Journal of Applied Physics, 119(2), 25706. (2016)

[2] Fell, A., *A Free and Fast Three-Dimensional/Two-Dimensional Solar Cell Simulator Featuring Conductive Boundary and Quasi-Neutrality Approximations*. IEEE Transactions on Electron Devices,. (2013).

[3] Fell, A., et al. *Input Parameters for the Simulation of Silicon Solar Cells in 2014.* IEEE Journal of Photovoltaics, (2015)

Quokka 2.2.5 manual: https://www2.pvlighthouse.com.au/resources/quokka2/QM2/Quokka%20manual.htm

**Part 1: Simulating emitter recombination:**

Here we will simulate $J_{0e}$ from a series of different experimental emitter profiles, which can be found as PC1D input files under the "Simulation files" section on the Fronter page.

Use the parameterization in Eq. (1) in Ref. [1] above to define the front surface recombination velocity parameter $S_p$ based on the surface doping concentration $N_{surf}$. Use a fixed charge density of $Q_f = 10^{12}$ cm$^{-2}$ and values for planar surfaces and the SiOxNy/SiNx passivation stack given in Table I in the paper. Assume no bulk SRH or rear surface recombination.

a) Simulate the emitter saturation current $J_{0e}$ and sheet resistance $\rho_{sheet}$ of each file (simplest to do using cmd-PC1D6 and a prm-file setup using the *J0e_calc_n_type_emitter.exc* excitation settings file). Plot $J_{0e}$ as a function of $\rho_{sheet}$ and compare to Fig. 4 in Ref. [1].
b) Use only doping profile *AKprofile1.dop* and the value found for $J_{0e}$ above. Then assume a photogenerated current under illumination of $J_{ph} = J_{sc} = 38.5$ mA/cm$^2$. Why can we assume that the solar cell will be well described by the single diode equation in this case, with $J_{0e} \approx J_{01}$? Using the single diode equation with no series or shunt resistance contributions, calculate $V_{oc}$, $FF$ and the conversion efficiency $\eta$. Repeat the calculation using PC1D simulations and compare your results (you will have to adapt the thickness/reflectance/illumination intensity to obtain a similar $J_{sc}$ value).
c) Add more recombination pathways in your diode by adding bulk recombination ($\tau_{0n} = \tau_{0p} = 50\ \mu s, E_t - E_i = 0$ eV) and rear side recombination (Uniform p-type BSF with $d_{BSF} = 5\ \mu m, N_A = 10^{18}, S_{0n} = S_{0p} = 1e6$ cm/s). What are now the contributions to $J_{01}$ in the forward-biased diode in the dark ($J_{0e}$, $J_{0base}$, $J_{0BSF}$) assuming that the cell still behaves as a single, ideal diode? How does the simulated IV curve under illumination compare to that predicted by the single diode equation in this case? If there is a difference, can you find an explanation for why this is the case?

**Part 2: Simulating a PERC (Passivated emitter and rear cell) solar cells with relevant input parameters using Quokka 2.5:**

Download and install Quokka 2.5 and Matlab Compiler Runtime from PV Lighthouse:

https://www2.pvlighthouse.com.au/resources/quokka2/quokka%202.aspx

and solar cell parameter files from the solar cell library:

https://www2.pvlighthouse.com.au/resources/Solar%20cell%20library/Solar%20cell%20library.aspx

Use the "commercial PERC cell" parameter file as a starting point for doing simulation. Make a schematic diagram of the simulation domain and important parameters that are used. Simulate the following and include the results in you report:

a) The IV curve of the cell and the IV parameters $J_{sc}$ $V_{oc}$, $FF$ and $\eta$.
b) The spatial distribution of excess charge carriers under $J_{sc}$, $V_{oc}$ and maximum power point conditions.
c) An overview of the various power loss mechanisms (various resistive and recombination contributions) using the buildt-in FELA analysis.
d) How would the results change if you instead use the first emitter profile from part 1 in the cell? Assume an SRV of $S_p = 10^7$ cm/s for the contacted part of the emitter.
e) Perform a 1-parameter (or 2-parameter) variation of your own choice, e.g. by changing the contact pitch. How does the IV parameters and power loss mechanisms change with your parameter change?