Mandatory assignment 1 – Simulation of a Cu2O / Si tandem solar cell using PC1Dmod

This assignment will teach you how to define material parameters, device structure and excitation settings using PC1Dmod and extract relevant results. We will not do the complete multijunction cell directly in one simulation, but instead simulate the cell as two separate single junction cells.

Top (Cu_2O) cell:

We will first assume that the entire top cell can be made as a Cu2O homojunction (this has been shown to be difficult to achieve experimentally). We will therefore assume that the material can be doped n- and p-type as we like. Other than this you should try to find realistic material parameters for Cu2O. One suggestion might be:

- Config file "configfile_original_PC1D5.cfg" (disable advanced Si-specific models)
- Cell area 1 cm^2
- Cell thickness: 2 µm
- P-type base doping: $N_A = 1 \times 10^{16}$ cm^{-3}
- Uniform emitter profile with thickness 0.3 µm. N-type emitter doping: $N_D = 1 \times 10^{19}$ cm^{-3}
- Electrical band gap: 2 eV
- Refractive index (assumed constant): 2.6
- Intrinsic carrier density $n_i = 1 \times 10^4$ cm^{-3} (Just a guess for now, can be improved if you find numbers for N_C and N_v for Cu_2O.
- Absorption coefficient: Use external file, data from Ref [1] (see link or download from Fronter. Remember that $\alpha = 4\pi/k$, where k is the extinction coefficient). Disablee free-carrier absorption
- SRH lifetime 500 ns (from Ref [2]). Disable auger and intrinsic recombination
- Constant mobility of 39.6 cm^2/Vs (measured at MiNaLab). Set this value for both electrons and holes.
- We assume that we have been able to passivate the front and rear surfaces somewhat, reducing the surface recombination to S = 1000 cm/s
- Perfect antireflection coating on the front side, 5% contact shading
  can be modelled as a constant 5% reflectance at all wavelengths
- 0 % internal reflection on rear surface (perfect coupling of light to the cell below)
- No series or shunt resistance
- Excitation settings based on "one-sun_updated.exc" (AM1.5G, 0.1 W/cm^2), from -0.5V to +1.5V

Bottom (Si) cell:

Use the "PVcell_simple" template for the bottom cell (but you are encouraged to investigate how the cell can be changed to improve the performance). The most important change you need to make is in the optical excitation settings. How much light will pass through the top cell. How will the incoming spectrum be, and what is the total intensity?

- Calculate the incoming spectrum based on the incoming spectrum file from the top cell, and assuming that the intensity at each wavelength is reduced to $I = I_0 \exp(-\alpha W)$, where α is the absorption coefficient in the top cell material and W is the top cell thickness. Assume perfect optical coupling between the two cells (no reflectance). Alternatively, this can also be calculated using OPAL 2 [3].

Report: Plot the IV and IQE curves for the two cells, and create a table for J_{sc}, V_{oc}, FF and the conversion efficiency for each cell. State any assumptions or changes you made along the way. What is the total efficiency of the tandem cell, given that they can be operated individually (4-terminal connection)?
(Voluntary bonus question: If the two cells are connected in series (2-terminal device) the current will always be limited by the smallest of the two, and the voltage of each cell will change according to this limitation. What is the total efficiency in this situation?)

[1] Malerba, C., et al (2011). Absorption coefficient of bulk and thin film Cu2O. Solar Energy Materials and Solar Cells, 95(10), 2848–2854. https://doi.org/10.1016/j.solmat.2011.05.047
[2] Viet Pham, et al (2013). Photocarrier generation in CuxO thin films deposited by radio frequency sputtering. Applied Physics Letters, 102(3), 32101. https://doi.org/10.1063/1.4788680
[3] https://www2.pvlighthouse.com.au/calculators/OPAL%202/OPAL%202.aspx