Exercise Series 14

Exercise 1: Tandem cells

Consider two solar cells in tandem, a and b, that are not interconnected monolithically (two terminals for the whole stack of the two cells) but as a 4-terminal (two terminals for each cell, so four in total) tandem device, such that the *I*-*V* curves of each cell could be measured independently of the other one:

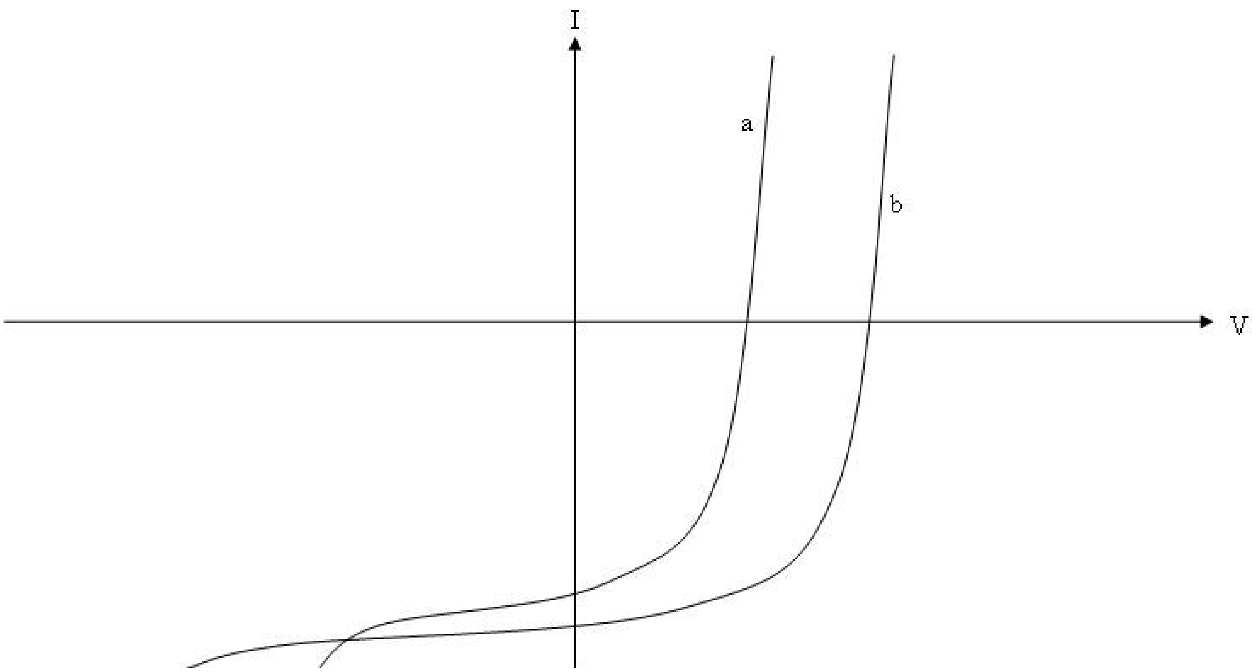

Figure 1: *I*-*V* curves of two solar cells a and b that are used together in a tandem device.

a) Which cell is the top/bottom cell and why?

Imagine now that you interconnect the two cells monolithically.

b) Draw the *I*-*V* curves of the cell [ab] (or [ba] according to your answer a)).

c) Which cell is the limiting one and why?

Additional readings on new tandem devices:
III-V on Silicon: IEEE JPV, 2016.
http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=7460224
Perovskite on Silicon: JPCL 2016, 7.
http://pubs.acs.org/doi/abs/10.1021/acs.jpclett.5b02686

Exercise 2: Thin Film module

By building not only small test cells but whole modules, one interconnects stripes of solar cells in series by laser scribe as shown in figure 2.

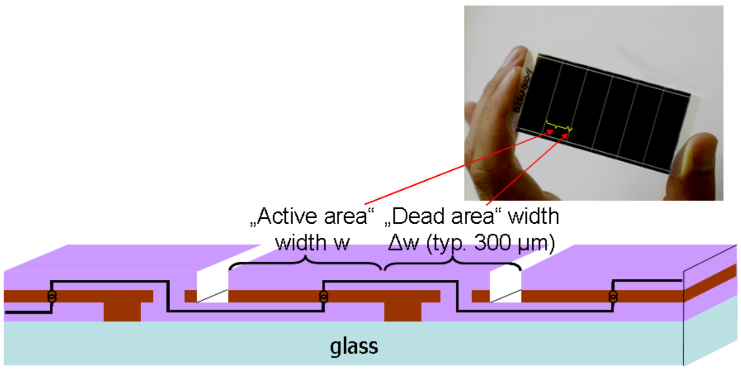

Figure 2: : Single solar cell stripes interconnected in series by laser scribe.

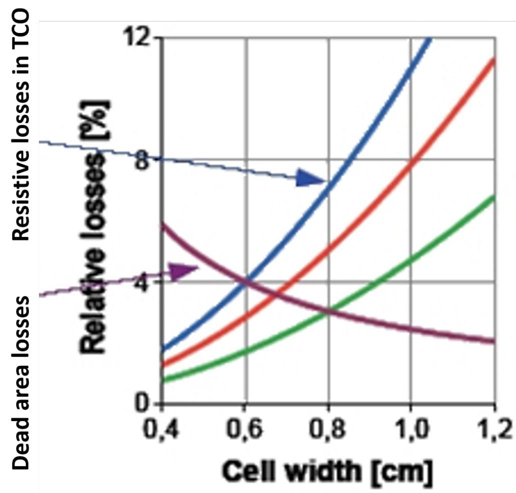

Figure 3: : Larger cells have higher serial resistancies in the TCO, but less dead material.

a) Why is it recommended to separate a module into several smaller stripes?

b) Two opposite effects lead to an optimum width w for given Δw as can be seen in figure 3: On one hand, the laser scribe region Δw is 'dead' material, i.e. no current is produced there. Thus, the wider the cell is (large width w), the lower the relative losses due to the dead area Δw. On the other hand, too large stripes (large width w) lead to a drop of efficiency due to serial resistivity of the TCO.
Find the analytical formula for $w(\eta_{\text{max}})$.
The following approach is recommended:

- Calculate the relative power loss $\frac{\Delta p_{\text{i}}}{p}$ due to dead zones.
- Calculate the relative power loss $\frac{\Delta p_{\text{ii}}}{p}$ due to the series resistance introduced by the top-TCO. Therefore, calculate first the current at each position of a cell, then the mean current square in a cell, and finally the power loss. Consider hereby the sheet resistance R_{sheet} with $R_{\text{s}} = R_{sheet} \cdot \frac{\Delta x}{\Delta y}$ the resistance for a layer of width Δy and a length Δx (current flows in x direction) and where R_{s} is the series resistance.
- Minimize the sum of the power losses.

Exercise 3: Solar Cell technologies

In this exercise, we review 9 different semiconductor solar cell technologies:

a) Al-BSF cells

b) PERC solar cell

c) Interdigitaded back contacted (IBC) solar cell

d) Standard silicon heterojunction (SHJ, or ”HIT” for Heterojunction with Intrinsic Thin film) as Sanyo trademark) solar cell

e) Perovskite solar cell

For each technology,

- draw the solar cell structure (layer stack, materials and typical thickness for each layer),
- draw the band diagram
- mention the advantages and drawback of each technology,
- state the efficiencies of these cells on lab scale and for a typical module (if available).