Energy yield modeling of Perovskite/Silicon tandem solar cells under real operating conditions

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1. Introduction

Perovskite Silicon (PK/c-Si) tandem solar cell are experiencing rapid development, with an actual record efficiency of 34.85% [1]. This efficiency is obtained for a two terminals device and under standard test conditions (STC) However, STC are not representative of real world conditions. Therefore, it would be useful to look at the annual electricity generation (at various locations) as the new performance metric, rather than the efficiency under STC.
Regarding the electrical architecture, in two terminals (2T) tandem cells, the sub cells are connected in series. This implies a current constraint. The aim of this work is to quantify the impact of the current matching (CM) constraint on the energy yield of 2T PK/c-Si tandem solar cells, under real operating conditions, using a complete multiphysics model.

2. Model description

2.1. Optical approach

For each hour, SMARTS software and PVGIS are used to simulate the solar spectrum at a desired location for each hour of the year. The sun position with respect to the solar cell system is calculated (polar and azimuthal angles). The absorption along the wavelength in each layer is obtained using RayFlare [2], an optical simulator, which relies on a combination of ray and wave optics. Coupling the absorption and incident spectrum gives the power and photons density absorbed as a function of wavelength for each sub-cell.

2.2. Electrical model and thermal balance

For each hour, an ideal electrical model, based on the Shockley-Queisser article [3], is established to obtain the electrical characteristics of the cell.
Regarding the thermal part, under steady-state conditions, the heat balance described in article [4] is used to calculate the cell equilibrium temperature. The latter is fed back into the electrical balance to obtain the electrical characteristics of the cell at its real temperature.

3. Preliminary results (with a focus on the optical effects)

The tandem cell architecture from [5], which can obtain a STC efficiency up to 30.8% [6], is shown in (Figure 1a). It was simulated under STC with CM constraint, and in Lyon, France with or without the CM constraint. The cell harvesting efficiency is calculated for these three cases (Figure 1b).
If we remove the CM constraint, under real conditions in Lyon, this cell is resilient to daily and yearly variations in solar spectrum, irradiance and temperature. However, with the CM constraint, there is a decrease of 0.9% in harvesting efficiency.

4. Conclusion

In this resume, we introduced a multiphysics model which calculates the energy yield of PK/c-Si tandem solar cell under real operating conditions at a chosen location. Some preliminary results were shown, with a focus on the impact of the CM constraint on the cell performance.
In perspective, we would like to develop a more enhanced electrical model, and consider material properties variations along the temperature. We hope to discuss some of these elements during the presentation of our work.

5. References

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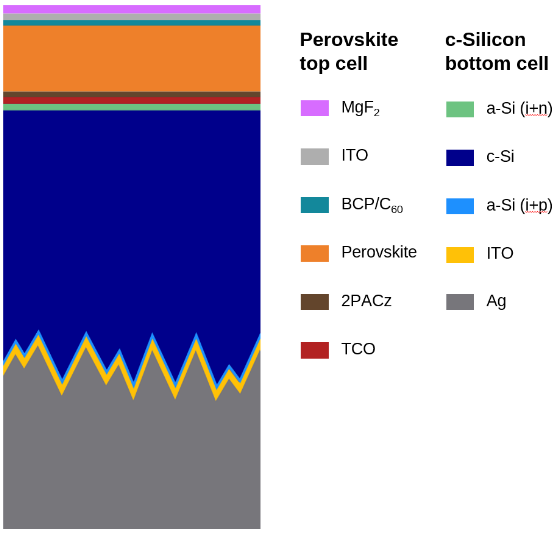
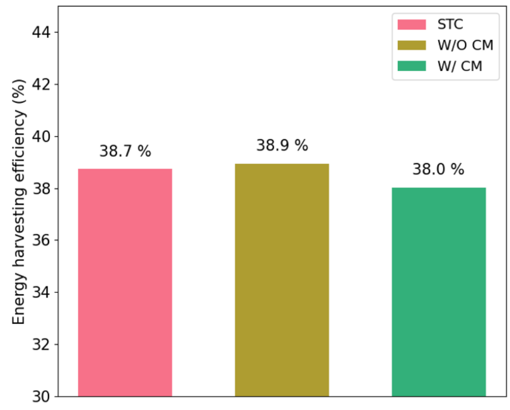


(a)



(b)

Fig. 1: (a) Tandem solar cell architecture used for simulation, (b) Harvesting efficiency of the device under STC and in Lyon with and without current matching constraint

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