Upscaling of Perovskite-based PV Devices within Project CHEOPS

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By leading the European Horizon 2020 project CHEOPS (low Cost and Highly Efficient phOtovoltaic Perovskite Solar cells), CSEM is committed to bring the promising emerging PV material perovskite closer to the market. To do so, the project focuses on three main axes: development of perovskite/silicon tandem cells, encapsulation and stability, and upscaling.

Energy conversion efficiency of organo-halide perovskite based photovoltaic devices has rapidly advanced over the course of the past few years, reaching values in excess of 20%. However, most of the reported efficiencies are still on small lab-scale devices below 0.3 cm². Therefore, an important effort to upscale such results is needed to demonstrate the commercial viability of this technology. In this sense, CSEM has demonstrated a minimodule with 11.5% efficiency on 12 cm² aperture area [1].

Moreover, perovskite possesses a wide bandgap that fills the requirements as a top absorber in tandem devices in combination with crystalline silicon, offering the potential for very high efficiencies, a route that is also explored by CSEM and its partners in the project.

In terms of scalability, efforts have been made recently at CSEM to go from 0.49 cm² cells to 1.015 cm² cells without a drop in efficiency. In fact, owing to a careful choice of materials and deposition processes, it has been possible to produce 1.015 cm² cells with an efficiency as high as 17% (measured with maximum power point tracking), a record for the simple $CH_3NH_3PbI_3$ absorber. In particular, CSEM's expertise in the deposition of TiOx functional layers by magnetron sputtering has led to the synthesis of very efficient Electron selective contacts.

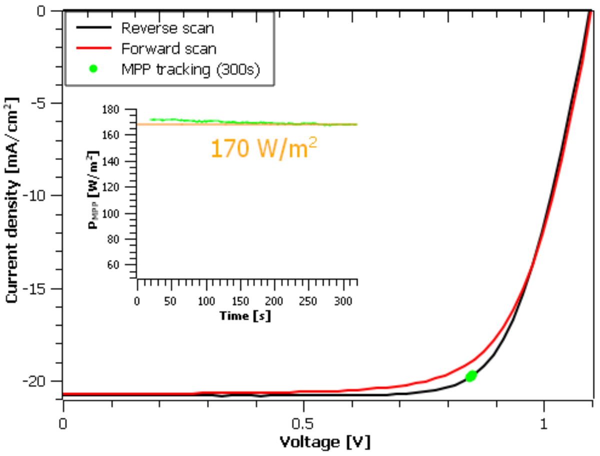

Figure 1: JV characteristics of a perovskite solar cell exhibiting a stabilized power output of 17%. The cell shows the typical hysteresis associated to perovskite solar cells.

These early results already set the necessary base for achieving the ambitious goal of the CHEOPS project, namely manufacturing high efficiency (above 14%) stable modules of at least 15 × 15 cm² in a pre-production environment.

As previously stated, one of the main interest of perovskite absorber is that it can provide a low-cost efficiency boost to existing crystalline silicon solar cells, such as the high efficiency silicon heterojunction cells developed at the CSEM PV-center. Within the frame of CHEOPS, CSEM and EPFL's PV-lab have already successfully demonstrated record breaking tandem cells. Two different tandem architecture are currently investigated: a monolithic integration, where the perovskite top absorber is directly grown on the silicon bottom cell, thus limiting the need for interconnections, and the so-called 4-terminal tandem, where two independently fabricated sub-cells are mechanically stacked together. Recent published results have shown a 20.5% efficiency for the monolithic tandem cell and a 4-terminal-like measurement demonstrating 25.2% [2].

Finally, on the material synthesis level, work is being conducted to implement a perovskite composition that would lead to cells both more stable and more efficient. Namely, a triple cations mixed-halide composition combining Pb, Cs and Br atoms is tested.

Table 1: Comparison between triple-cations mixed halide & "standard" cell.

	Eff. [%]	Voc [mV]	Jsc [mA/cm²]	FF [%]	MPP tracked P density [W/m2]
3-cations	18.74	1175.12	21.54	73.24	171.88
standard	16.88	1094.02	20.81	74.15	167.80

In the coming time, focus will be put on further upscaling these results while improving the stability of the cells. In that respect, specific encapsulation schemes are also under development at CSEM.

This work has received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement No. 653296.

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