Development of characterisation bench for the analysis of the causes and mechanisms of degradation in Perovskite solar cells in different operating modes, under controlled environments and outdoors.

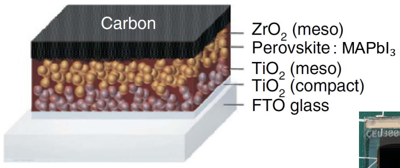
M.-C. Lida[1,2*], M. Var[1], J. Parra[3], S. Narbey[4], F. Oswald[1], A. Migan Dubois[2].

1. Université Paris-Saclay, CEA, CNRS, NIMBE, Laboratoire d'Innovation en Chimie des Surfaces Et Nanosciences (LICSEN), 91190, Gif-sur-Yvette, France
2. Université Paris-Saclay, CentraleSupélec, CNRS, Laboratoire Génie électrique et électronique de Paris (GeePs), 91190 Gif-Sur-Yvette, France
3. École Polytechnique, IPSL, Institut Polytechnique de Paris, ENS, Université PSL, Sorbonne Université, CNRS, Laboratoire de Météorologie Dynamique (LMD), 91128 Palaiseau, France
4. Solaronix SA, rue de l'ouriette 125, CH1170 Aubonne, Suisse

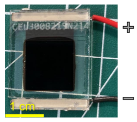
Background and motivations

The emerging technology of Perovskite solar cells (PSCs) has the potential to revolutionise the field of photovoltaics [1]. Obstacles prevent them to reach the market and be largely produced, such as their low stability and the scarce studies published on them [2-6]. Since very few studies have been carried out on advanced characterizations of photovoltaic devices under real-life, outdoor conditions and their associated analyses, the GeePs laboratory and the LICSEN are trying to develop one.

The Perovskite solar cells are manufactured by LICSEN and Solaronix [7, 8]. They contain a carbon-based counter-electrode (under constant illumination) and have shown a power conversion efficiency beyond 20% [9].



Structure of the PSC [7]



PSC

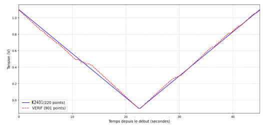
Fabricating the counter-electrode of the PSC with carbon is cheaper than using rare metals like gold or silver. The counter-electrode collects holes and protects the perovskite from moisture, which is harmful for the perovskite.

The GeePs laboratory and the LICSEN are collaborating to establish detailed protocols for characterising PSCs operating in different modes, in indoor and outdoor conditions. It is important that the measurements are comparable in both conditions for a better understanding of the various behaviours of the PSCs observed in those environments. This study will help identifying the causes and mechanisms of Perovskite based solar devices' degradation.

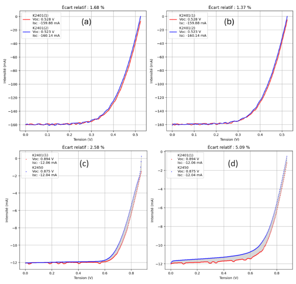
Building characterisation platforms

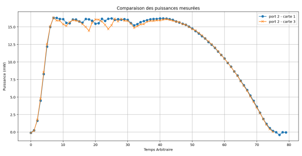
Testing phase

No matter what the operating mode the PSCs are in or the conditions they are undergoing, the instruments measuring their performances must be equivalent.

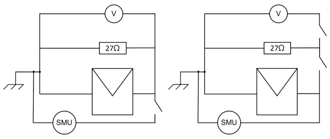


Voltage sweep verification





Maximum Power Point Tracking (MPPT)



Switching measurements with a commutation matrix

A commutation matrix enables the automation of the measures in outdoor conditions.

KEITHLEY Source Measure Units (SMUs) used : 2401, 2450 and 2440.

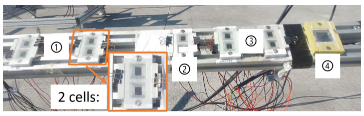
Figure	(a)	(b)	(c)	(d)
KEITHLEY SMU comparison	2401 v 2401	2401 v 2401	2401 v 2450	2401 v 2450
Solar cell	53x18 mm² silicon cell		Masked PSC with a 0.64 cm² active surface	
I-V scan	Reverse	Forward	Reverse	Forward
Relative error	1.68% ✓	1.37% ✓	2.58% ✓	5.09% ✕

Characterisation platforms

The indoor platform for monitoring under controlled AM 1.5G conditions is at LICSEN.

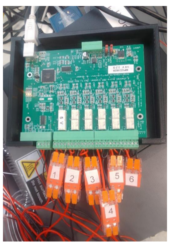
The outdoor platform is located at SIRTA [10, 11] and was developed by GeePs.

Characterisation in real outdoor working conditions

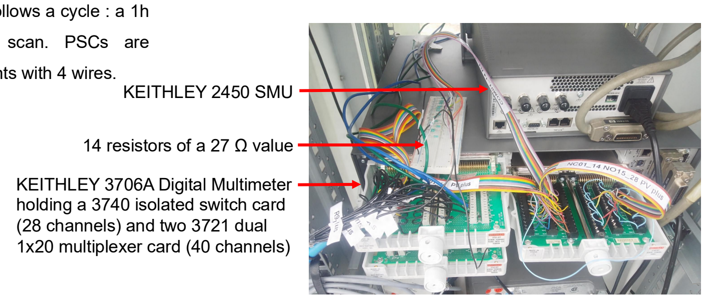


One SMU, ① 4 PSCs on a 27 Ω resistor, ② one open circuit PSC, ④ one temperature sensor (Pt100) and one irradiance sensor are handled by the commutation matrix. MPPT tracking of ③ 4 PSCs is ensured by a µMPPT card and I-V measurements are done by another SMU.

From the sunrise until the sunset, each PSC in either operating mode follows a cycle : a 1h monitoring and an I-V scan. PSCs are connected to the instruments with 4 wires.

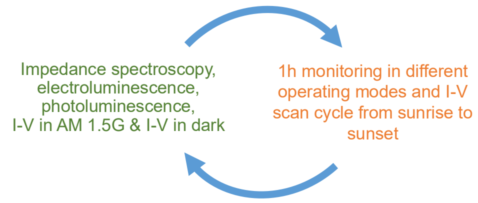


µMPPT card



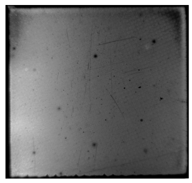
Commutation matrix setup

Punctual measurements



Impedance spectroscopy measurements done at LPICM [12] evaluate the parameters of the PSC's equivalent electrical circuit.

Electroluminescence (EL) and Photoluminescence (PL) are key techniques for detecting defects, impurities, and degradation in solar cells. EL reveals poor recombination areas, while PL provides insights into material quality.



Electroluminescence imaging

Characterisation in indoor controlled environment

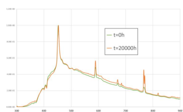
4 cells on a 27 Ω resistor are monitored by a myDAQ (National Instrument) and I-V measurements are done manually with a SMU. 4 cells are operating at MPP with a µMPPT card, which is also used for connecting one open circuit cell and another SMU. Conditions are AM 1.5G.

Hysteresis of the PSCs is less accentuated in indoor controlled conditions than real outdoor conditions.

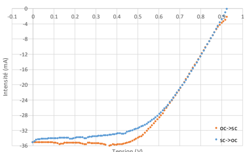
The initial performances of the cells are :

$I_{sc} \approx 35$ mA, $V_{oc} \approx 0.93$ V, FF ≈ 54 %, and $P_{MPP} \approx 18$ mW.

Indoor platform



Solar spectrum stability assessment



PSC I-V scan

References

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