Investigation of the ageing behaviour of triple mesoscopic perovskite solar cells under outdoor working conditions

M.Var (maximilien.var@cea.fr)[1,2*], A.Migan-Dubois[3], A.Jaffré[3], J.Parra[4], S.Narbey[5], Y.Bonnassieux[2], F. Oswald[1]

1. Université Paris-Saclay, CEA, CNRS, NIMBE, LICSEN, 91191, Gif-sur-Yvette, France
2. LPICM, CNRS, École polytechnique, Institut Polytechnique de Paris, route de Saclay, 91128 Palaiseau, France
3. Université Paris-Saclay, CentraleSupélec, CNRS, Laboratoire Génie Électrique et Électronique de Paris (GeePs), 91192 Gif-Sur-Yvette, France
4. IPP, IPSL, CNRS, Laboratoire de Météorologie Dynamique (LMD), 91128 Palaiseau Cedex, France
5. Solaronix S.A. Rue de l'Ouriette 129, Aubonne, 1170, Switzerland

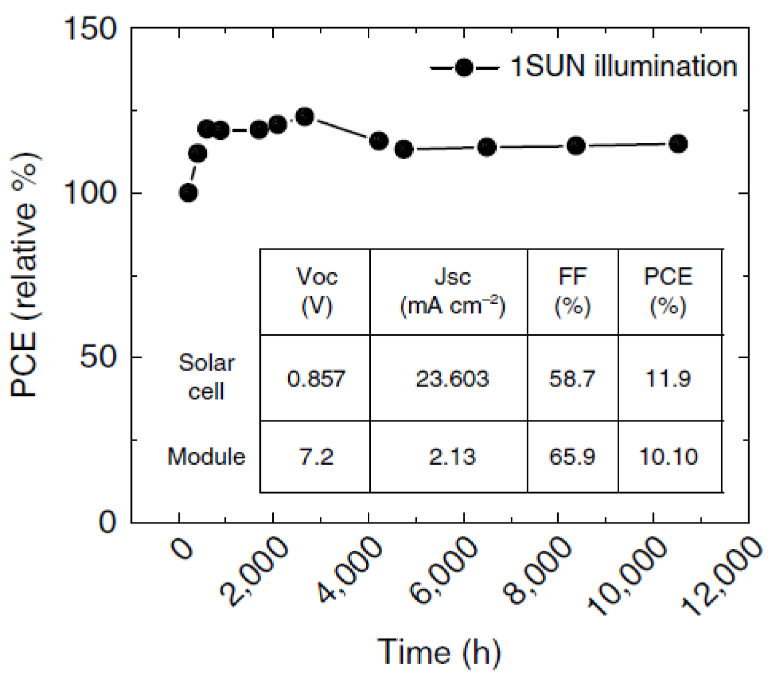
Background and motivations

Perovskite cells (PSCs) are a promising emerging technology, nevertheless, their low stability still prevents them to reach the mass production and market.

Furthermore only few report on real outdoor working conditions can be found

A one-year stable (under constant illumination) perovskite module has been recently published. This device uses a carbon counter electrode that has proven to be an effective method to significantly enhance the device's lifetime, which has nowadays become one of the most prevailing scaffolds for constructing stable PSCs.

Module stability under 1 sun (AM 1.5 G)

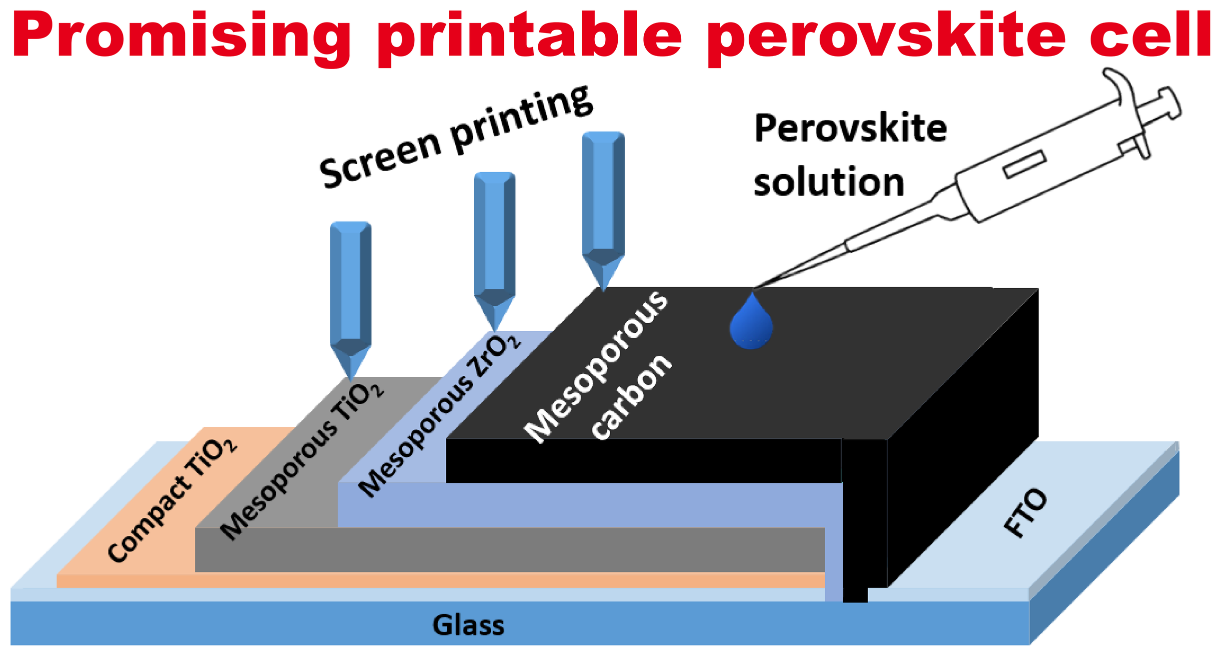


	Voc (V)	Jsc (mA cm⁻²)	FF (%)	PCE (%)
Solar cell	0.857	23.603	58.7	11.9
Module	7.2	2.13	65.9	10.10

doi.org/10.1038/ncomms15684

Since then, carbon electrode-based perovskite solar cells have established themselves as highly promising device architectures for the next generation of photovoltaics with efficiencies over 20% and unprecedented stabilities

Promising printable perovskite cell

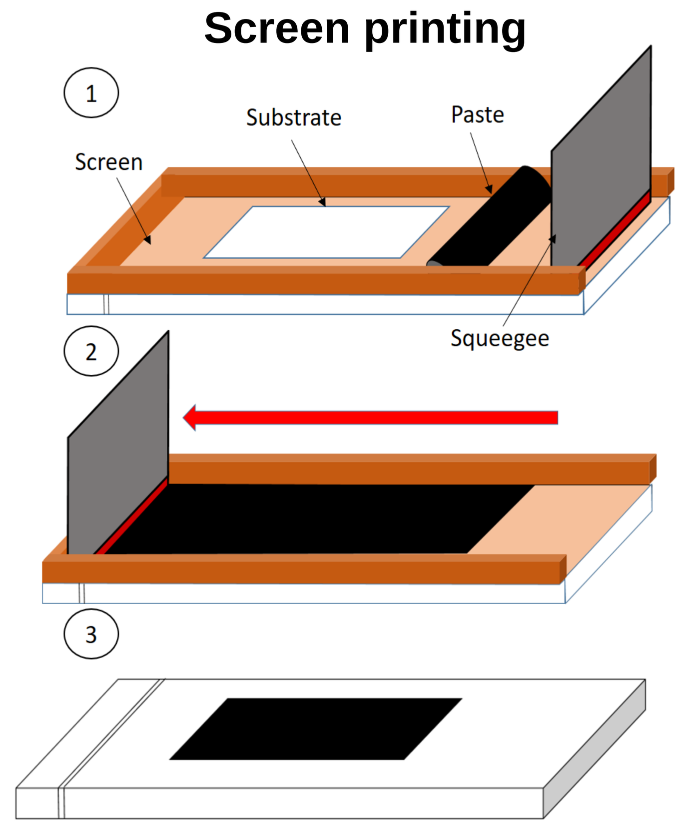


Triple mesoscopic carbon architecture

The carbon counter-electrode eliminates the need for rare metals like gold or silver while serving as hole collector and protecting perovskite from moisture.

Cell manufacturing

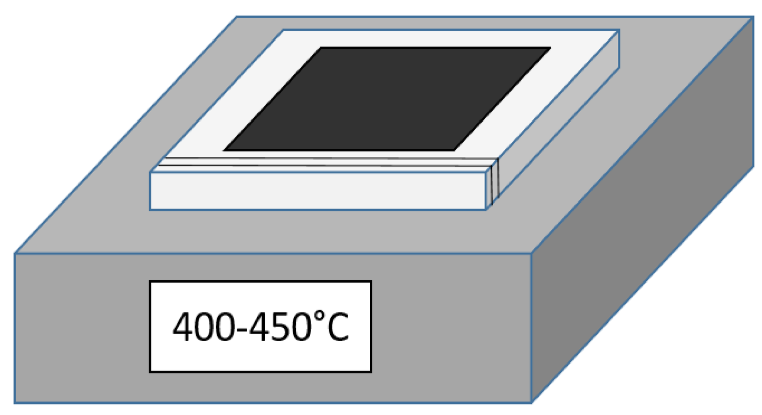
Screen printing



The mesoporous layers are sequentially deposited using screen printing technique, a fast, ubiquitous and inexpensive method. Depending on the mesh size used, ink viscosity and concentration, this technique allows a precise control over the desired thicknesses.

- Compact TiO_2 : 30 nm (by spray coating)
- Mesoporous TiO_2 : 500 nm
- Mesoporous ZrO_2 : 1 µm
- Mesoporous Carbon : 10 µm

Calcination

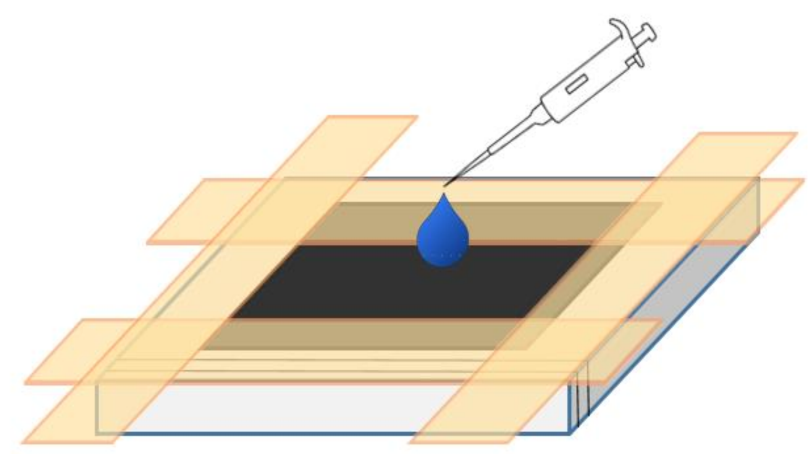


Calcination temperature :

- TiO_2 : 450°C
- ZrO_2 and Carbon 400°C

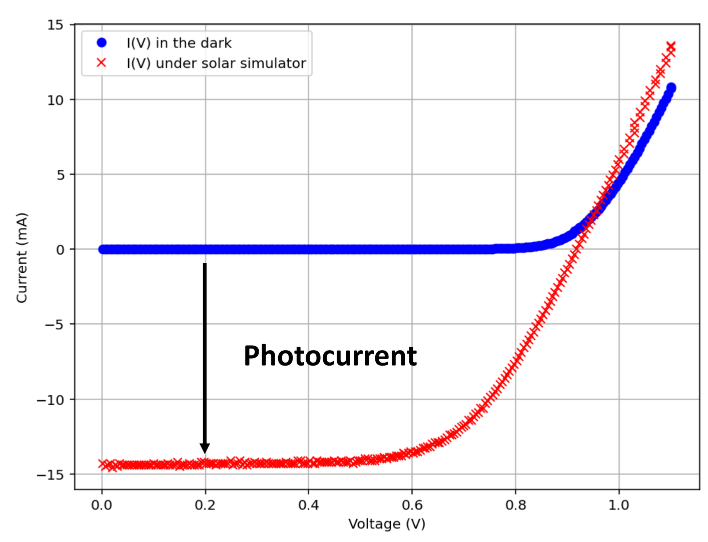
Calcination leads to the cell's inorganic scaffolding

Infiltration of perovskite precursors



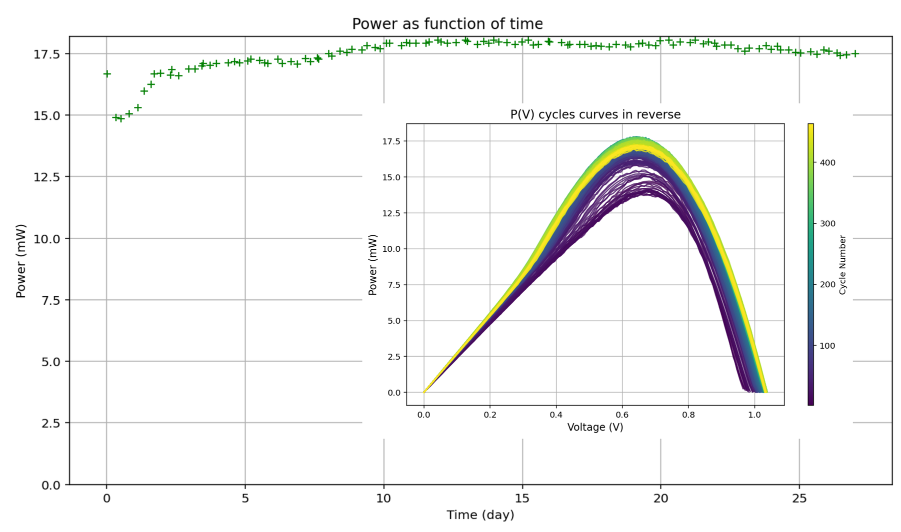
Perovskite precursors are infiltrated into the inorganic scaffold then the cell undergoes an annealing step at 50°C. To achieve optimal performance, both the precursor quantity and crystallization conditions must be carefully optimized.

Characterization in indoor controlled environment

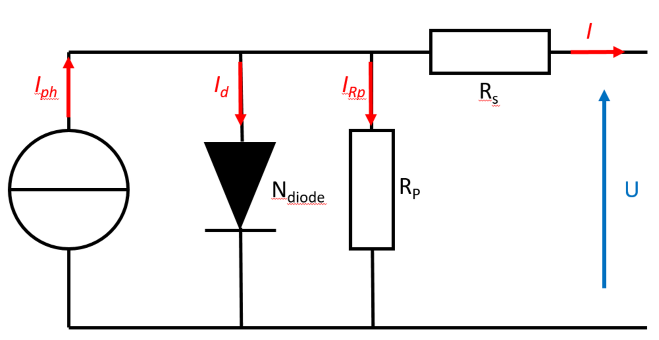


- J_{sc} = 22,34 mA/cm²
- FF = 63,74 %
- V_{oc} = 0,92 V
- η = 13,10 %

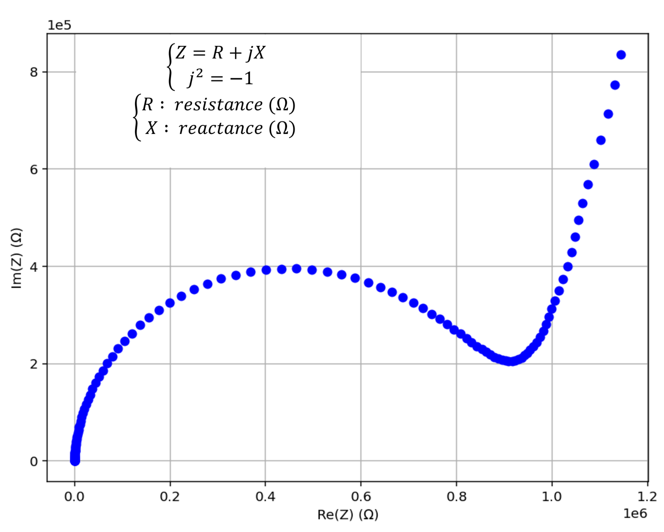
IV under illumination and dark conditions



Maximum power point tracking over time



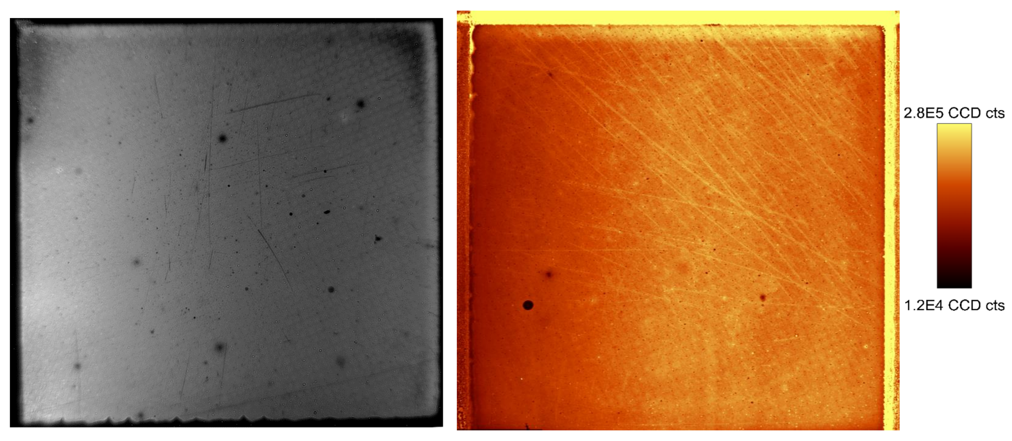
Equivalent electrical diagram of a solar cell



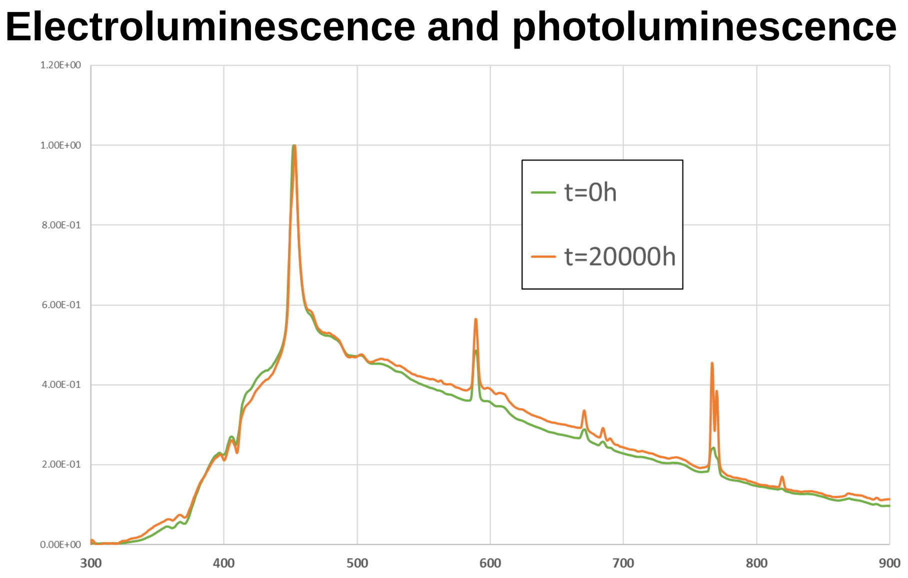
Impedance spectroscopy measurements

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.

Solar simulator : AM1.5G

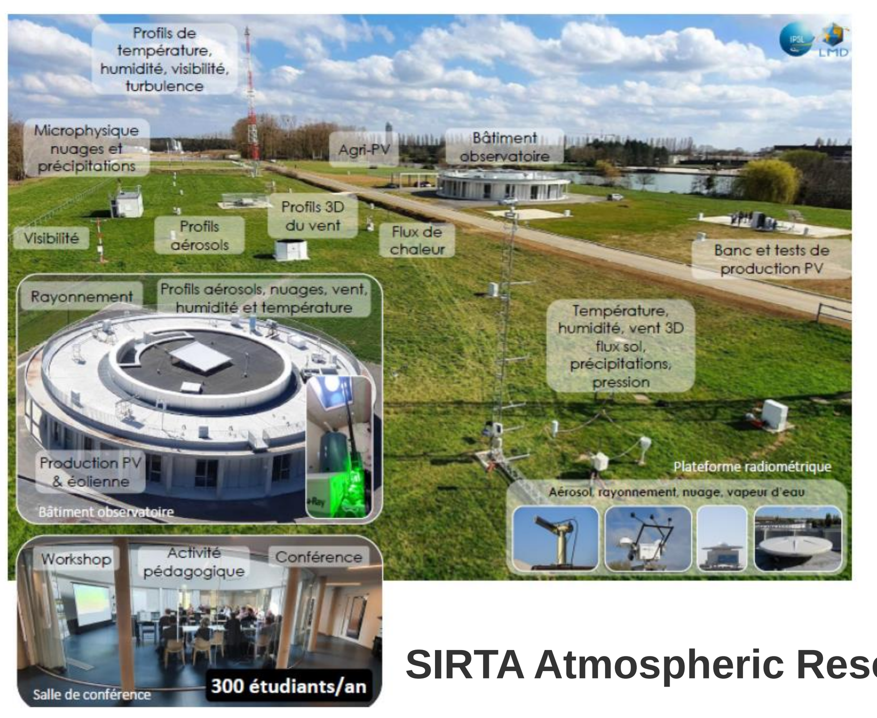


Electroluminescence and photoluminescence imaging

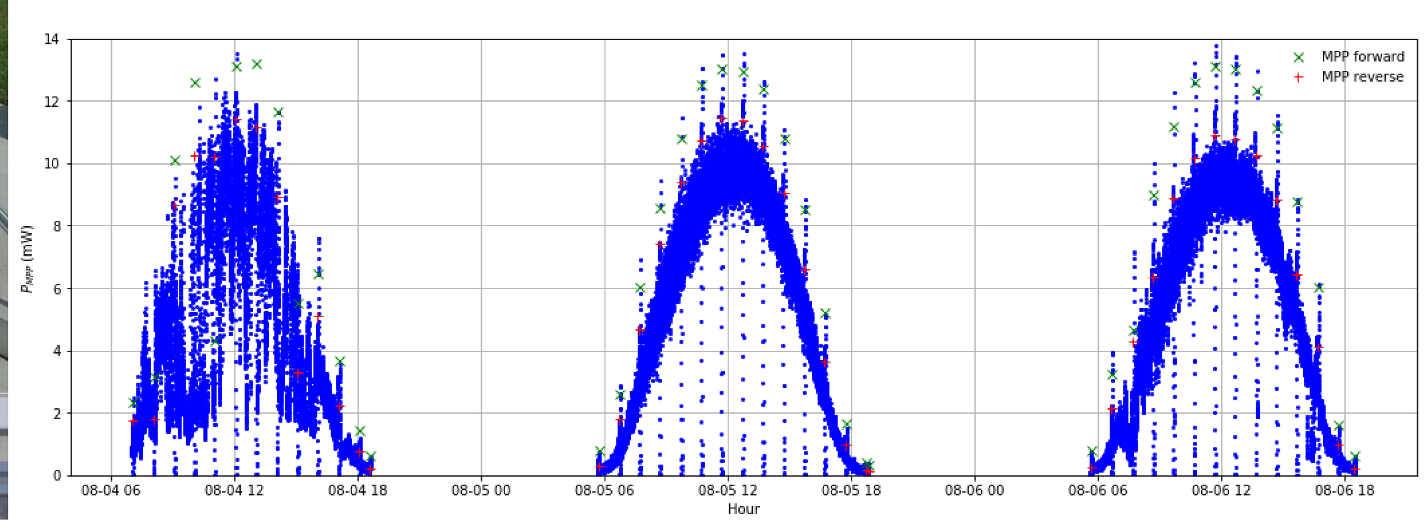


Stability assessment using plasma light solar simulator

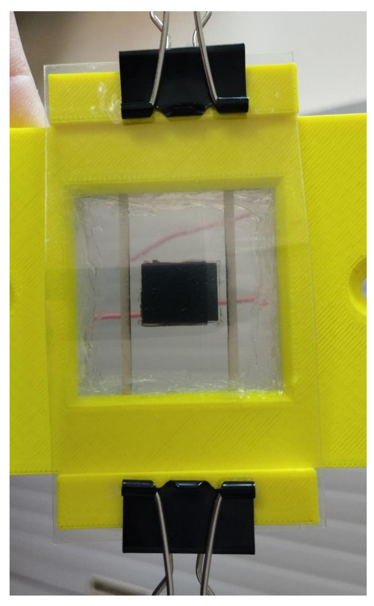
Characterization in real outdoor working conditions and installation



SIRTA Atmospheric Research Observatory and perovskite test bench



Maximum power point tracking in outdoor conditions



Encapsulated cell