



**Energy**

National Research Programmes 70 and 71

# Project

Novel generation perovskite devices





## Perovskite – the future of the solar cell

Solar cells made from perovskite are about to break through – the cheap and versatile material is almost made for the efficient generation of solar electricity. However, the new solar cells are not yet robust enough for real use.

Researchers from the Swiss Federal Institute of Technology Lausanne (EPFL) and the University of Fribourg are working on fine-tuning the perovskite technology for use in practice.



Upscaling from a laboratory scale to extensive solar modules is one of the remaining hurdles standing between perovskite solar cells and their industrial mass production. *Source: Final Report*





## At a glance

- Perovskite solar cells are cheap, easy to process and efficient – but are as yet not stable enough during operation.
- Recent developments in the area of Swiss research mean that the objective of producing perovskite solar cells that generate a high output on a lasting basis is within touching distance.
- In order to be successful, the new technology must be compatible with existing industrial manufacturing processes.

Dark-blue panels on red tiled roofs and green meadows – this is the image usually generated upon entering the term “solar energy” in an online search engine. The familiar blue solar cells made from silicon are indeed the most widespread technology for photovoltaics. For some time now, however, it has by no means been the only one. One new technology is about to get out of the starting blocks: the solar cell made from perovskite. This is the collective term for innovative materials whose crystal structure resembles that of the natural mineral also known as perovskite.

Perovskite solar cells have developed quickly. Over the past ten years, their level of efficiency has literally exploded and increased from a modest 3 % to more than 20 %. Perovskites have outstanding properties: they absorb light especially efficiently and are adept at routing the generated electricity. They are cost-effective as well as simple with respect to both production and processing. However, solar cells based on perovskites also have a significant downside: they do not yet work consistently enough and are not sufficiently durable for large-scale use. Researchers from the Swiss Federal Institute of Technology Lausanne (EPFL) and the University of Fribourg are working to improve the stability and efficiency of this promising technology.

## Doping for solar cells

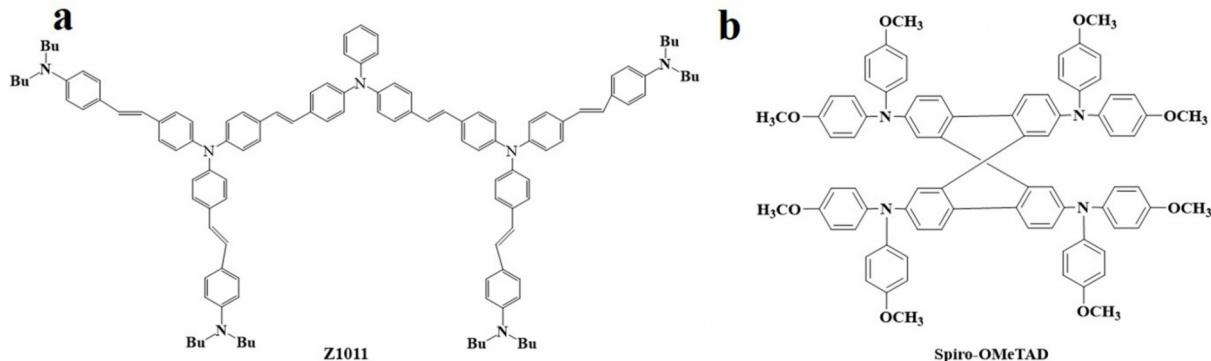
So-called doping is often applied here – an absolutely legitimate means of improving performance in the area of semiconductor technology. This process sees semiconducting materials enriched with a small amount of a foreign element. The progress achieved in this way is striking. For example, by doping a titanium oxide electrode with the element lithium, the researchers increased the performance of a perovskite solar cell by two percentage points to more than 19 %

Upon using neodymium instead of lithium for the doping procedure, the level of efficiency at just over 18 % was not quite as impressive. However – and this is no less important – this solar cell worked for much longer with a high output. The researchers found out that the neodymium atoms worked like a putty and filled in the cracks and fissures in the crystal lattice. This allows for so-called electron traps to be mitigated. These pitfalls disrupt the desired movement of the charge carriers and have a negative impact on the performance of a solar cell. These emerge due to, among other reasons, ultraviolet radiation that attacks the titanium oxide.

In a further study, the researchers replaced the UV-sensitive titanium oxide with another compound: tin oxide. While this is less susceptible to UV light, it has disappointed so far in terms of electrical output. “Doping” was once again the solution here. This time with the element gallium. The result impressed with a good efficiency level of 16.5 % and, in particular, an outstanding resistance to UV radiation.

## Stability thanks to “butterfly molecule”

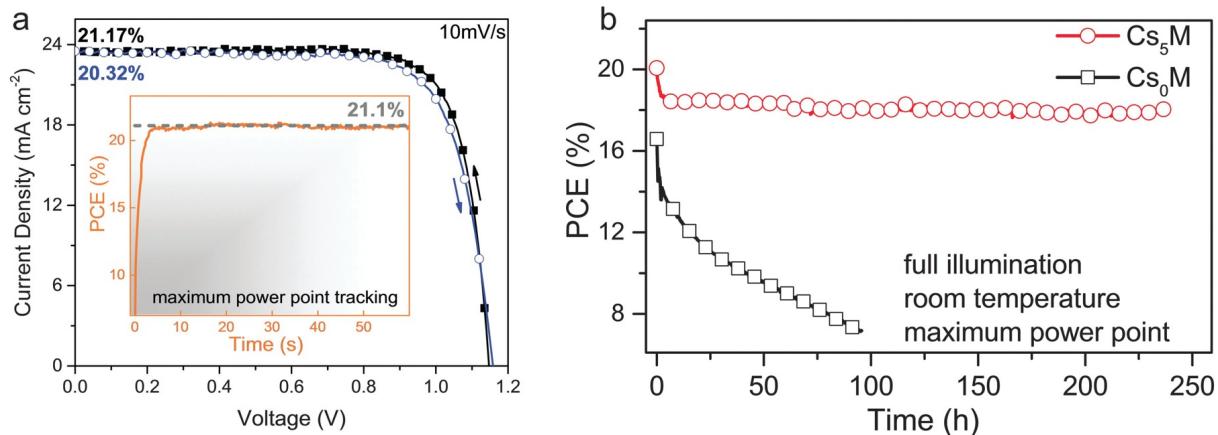
Doping is, however, not always the answer to the challenges faced by perovskite technology. For example, a further development of the EPFL does not use doping at all. It involves an organic compound with molecules that are reminiscent of a butterfly due to their complex form.



Elegant solution – the molecules of this doping-free material distinctively resemble a butterfly.

The rather esoteric-sounding task of this material is to transport “holes” – positive charges that form when electrons are knocked out of their environment via the absorption of light. The organic “butterfly molecules” allow for a similar efficiency level to that achieved by conventional materials. However, they are significantly more stable.

In the cases mentioned so far, the researchers focussed their efforts on improving electrodes and other electricity-transporting layers. Yet among the greatest successes are their developments at the heart of the solar cell – the light-absorbing perovskite. They discovered that the addition of a small amount of caesium to the organic components of the perovskite led to much purer crystals – and a peak level of efficiency of 21.1 %.



The improvement is obvious – the addition of 5 % caesium (red symbols) markedly increases the efficiency and stability of the perovskite cell relative to the variant without caesium (black symbols).

The mixture with caesium also responds more favourably to small inaccuracies in the



manufacturing process. This makes the production of perovskite solar cells with efficiency levels of more than 20 % routine – a breakthrough in terms of reproducibility and a big step towards the industrialisation of this new technology.

## On a direct path to becoming an industrial product

A further important stage on the way towards becoming a marketable product is the step from laboratory-scale solutions to the production of extensive solar modules. The electrical interconnecting of these modules takes place at an industrial level with the help of lasers which engrave insulating dividing lines or channels for pathways into the materials. Whether this industrial process also works for perovskites was unknown until now. With the first laser-produced solar module made from perovskite, the EPFL researchers were able to provide this evidence.

With each innovation, the objective of turning economically viable and highly efficient perovskite solar cells into a reality moves a step closer. And the new cells will not only provide technical support for the energy turnaround, but also make it more aesthetically attractive. This is because the developed materials and processes allow for discreet alternatives to the standardised blue solar cells. Michael Grätzel from the EPFL believes that the chances of a quick introduction of the perovskite solar cell are good. In particular, this is because the new developments can be integrated in existing industrial production chains. Grätzel is convinced that only in this way will Swiss companies and research groups be able to maintain their advantage in this contested international environment.

## Produkte aus diesem Projekt

- High-Efficiency Polycrystalline Thin Film Tandem Solar Cells  
Date of publication: 07.10.19
- Lowtemperature-processed efficient semi-transparent planar perovskite solar cells for bifacial and tandem applications  
Date of publication: 07.10.19
- Controlled growth of  $\text{PbI}_2$  nanoplates for rapid preparation of  $\text{CH}_3\text{NH}_3\text{PbI}_3$  in planar perovskite solar cells  
Date of publication: 07.10.19
- Mechanosynthesis of the hybrid perovskite  $\text{CH}_3\text{NH}_3\text{PbI}_3$ : characterization and the corresponding solar cell efficiency  
Date of publication: 07.10.19
- Perovskite Photovoltaics with Outstanding Performance Produced by Chemical Conversion of Bilayer Mesostructured Lead Halide/ $\text{TiO}_2$  Films  
Date of publication: 07.10.19
- Flash Infrared Annealing for Antisolvent-Free Highly Efficient Perovskite Solar Cells  
Date of publication: 07.10.19
- A Ga-doped  $\text{SnO}_2$  mesoporous contact for UV stable highly efficient perovskite solar cells  
Date of publication: 07.10.19
- Rational Design of Molecular Hole-Transporting Materials for Perovskite Solar Cells: Direct versus Inverted Device Configurations  
Date of publication: 07.10.19
- Molecular Tailoring of Phenothiazine-Based Hole-Transporting Materials for High-  
○ A Novel Dopant- Free Triphenylamine Based Molecular “Butterfly” Hole-Transport Material for Highly Efficient and Stable Perovskite Solar Cells, in Advanced Energy Materials  
Date of publication: 07.10.19
- Not All That Glitters Is Gold: Metal-Migration-Induced Degradation in Perovskite Solar Cells  
Date of publication: 07.10.19
- Highly efficient planar perovskite solar cells through band alignment engineering  
Date of publication: 07.10.19
- Efficient Near-Infrared-Transparent Perovskite Solar Cells Enabling Direct Comparison of 4-Terminal and Monolithic Perovskite/Silicon Tandem Cells  
Date of publication: 07.10.19
- Partial oxidation of the absorber layer reduces charge carrier recombination in antimony sulfide solar cells  
Date of publication: 07.10.19
- Patterning of perovskite–polymer films by wrinkling instabilities  
Date of publication: 07.10.19
- Perovskite Solar Cell Stability in Humid Air: Partially Reversible Phase Transitions in the  $\text{PbI}_2\text{-CH}_3\text{NH}_3\text{I-H}_2\text{O}$  System  
Date of publication: 07.10.19
- Doping of  $\text{TiO}_2$  for sensitized solar cells  
Date of publication: 07.10.19
- Efficient luminescent solar cells based on tailored mixed-cation perovskites

**Performing Perovskite Solar Cells**

Date of publication: 07.10.19

- Spontaneous crystal coalescence enables highly efficient perovskite solar cells  
Date of publication: 07.10.19
- Migration of cations induces reversible performance losses over day/night cycling in perovskite solar cells  
Date of publication: 07.10.19
- Mesoporous  $\text{SnO}_2$  electron selective contact enables UV-stable perovskite solar cells  
Date of publication: 07.10.19
- Enhanced Efficiency and Stability of Perovskite Solar Cells Through Nd-Doping of Mesostructured  $\text{TiO}_2$   
Date of publication: 07.10.19
- Boosting the Efficiency of Perovskite Solar Cells with CsBr-Modified Mesoporous  $\text{TiO}_2$  Beads as Electron-Selective Contact  
Date of publication: 07.10.19
- Effect of Cs-Incorporated  $\text{NiO}_x$  on the Performance of Perovskite Solar Cells  
Date of publication: 07.10.19
- The effect of illumination on the formation of metal halide perovskite films  
Date of publication: 07.10.19
- Room-Temperature Formation of Highly Crystalline Multication Perovskites for Efficient, Low-Cost Solar Cells  
Date of publication: 07.10.19
- Isomer-Pure Bis-PCBM-Assisted Crystal Engineering of Perovskite Solar Cells Showing Excellent Efficiency and Stability

Date of publication: 07.10.19

- High-Efficiency Perovskite Solar Cells Employing a S, N-Heteropentacene-based D-A Hole-Transport material  
Date of publication: 07.10.19
- Novel p-dopant toward highly efficient and stable perovskite solar cells  
Date of publication: 07.10.19
- A novel one-step synthesized and dopant-free hole transport material for efficient and stable perovskite solar cells  
Date of publication: 07.10.19
- Incorporation of rubidium cations into perovskite solar cells improves photovoltaic performance  
Date of publication: 07.10.19
- High-Performance Regular Perovskite Solar Cells Employing Low-Cost Poly(ethylenedioxythiophene) as a Hole-Transporting Material  
Date of publication: 07.10.19
- A vacuum flash-assisted solution process for high-efficiency large-area perovskite solar cells  
Date of publication: 07.10.19
- Cesium-containing triple cation perovskite solar cells: improved stability, reproducibility and high efficiency  
Date of publication: 07.10.19
- Entropic stabilization of mixed A-cation  $\text{ABX}_3$  metal halide perovskites for high performance perovskite solar cells  
Date of publication: 07.10.19
- Ionic Liquid Control Crystal Growth to Enhance Planar Perovskite Solar

Date of publication: 07.10.19

- Dopant-free star-shaped hole-transport materials for efficient and stable perovskite solar cells  
Date of publication: 07.10.19
- Dopant-Free Donor (D)-π-D-π-D Conjugated Hole-Transport Materials for Efficient and Stable Perovskite Solar Cells  
Date of publication: 07.10.19
- Enhanced electronic properties in mesoporous TiO<sub>2</sub> via lithium doping for high efficiency perovskite solar cells  
Date of publication: 07.10.19

Cells Efficiency

Date of publication: 07.10.19

- Closing the Cell-to-Module Efficiency Gap: A Fully Laser Scribed Perovskite Minimodule With 16 % Steady-State Aperture Area Efficiency,  
Date of publication: 07.10.19
- Zinc tin oxide as high temperature stable recombination layer for mesoscopic perovskite/silicon monolithic tandem solar cells  
Date of publication: 07.10.19
- Perovskite solar cells hit 21.1 % efficiency and record reproducibility  
Date of publication: 07.10.19

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All information provided on these pages corresponds to the status of knowledge as of 10.05.2019.