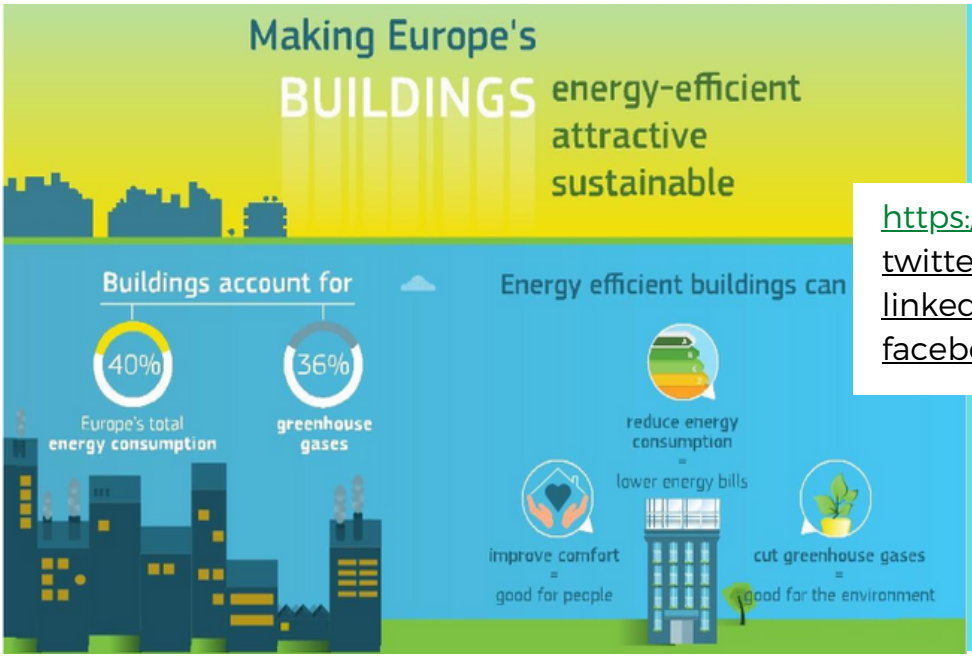
CITYSOLAR

ENERGY HARVESTING IN CITIES WITH TRANSPARENT AND HIGHLY EFFICIENT WINDOW INTEGRATED MULTI-JUNCTION SOLAR CELLS

Welcome to the third issue of CITYSOLAR Newsletter. You will find relevant information about the Project and its progress on developing innovative transparent and highly efficient window integrated multi-junction solar cells.

We hope you enjoy reading the newsletter and we invite you to share your thoughts, ideas and suggestions through our social media at the links below:



https://www.citysolar-h2020.eu
twitter.com/CITYSOLAR_H2020
linkedin.com/company/citysolar-eu
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NEW PEOPLE IN THE PROJECT

Prof. David Tanenbaum joined in September 2022 the CITYSOLAR network as a visiting Professor at University of Southern Denmark. David is Professor at Pomona College in California, and has longstanding experience in the field of organic and perovskite solar cell manufacturing and characterization, including extensive work on stability, also via the ISOS community.
Welcome David, great to have you onboard!

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CITYSOLAR NETWORK EVENTS

8th World Conference on Photovoltaic Energy Conversion (WCPEC)

September 26–30, 2022. Milano, Italy
https://www.wcpec-8.com

CITYSOLAR was represented by CNR-ISM and University of Rome Tor Vergata at the The 8th World Conference on Photovoltaic Energy Conversion (WCCPEC), which took place from 26–30 September 2022 in Milano.

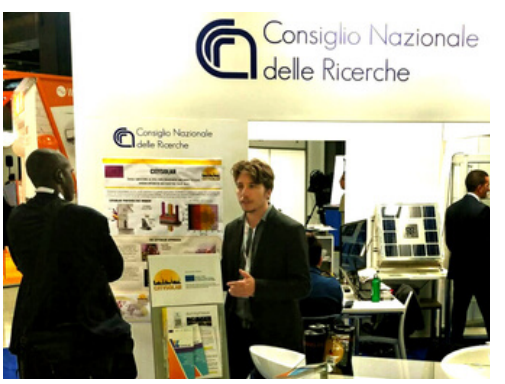
Here CITYSOLAR presented their progress on semi-transparent perovskite photovoltaics, describing a new transparent perovskite solar module with record high performance values.

The CITYSOLAR poster at the conference could be seen through a semi-transparent CITYSOLAR PV module, lighting up LEDs on the side of the frame.

The presentation gathered great attention, and also demonstrated the large potential for CITYSOLAR transparent PV technology to relevant industrial stakeholders, research institutions, and the broader public.

The WCPEC, held every fourth year, is firmly established within the PV community as the event for the greatest minds and experts in various PV sectors to meet, discuss, exchange ideas, and network.

The CITYSOLAR Project was presented at the 8th World Conference on Photovoltaic Energy Conversion in Milan, Italy.



CITYSOLAR NETWORK EVENTS

CITYSOLAR Midterm Review meeting with European Commission

September 8-9, 2022, Rome, Italy

https://www.citysolar-h2020.eu/news-and-events

On September 8-9th, University of Tor Vergata hosted the **CITYSOLAR Midterm Review meeting** together with the project officer from the **European Commission**.

At the Midterm Review meeting, the progress in each work package on project management, exploitation, dissemination and communication, OPV and perovskite PV cells and module development, light management strategies, tandem PV integration along with material, thin film and device characterization was discussed, facilitating valuable feedback from the EC officer.

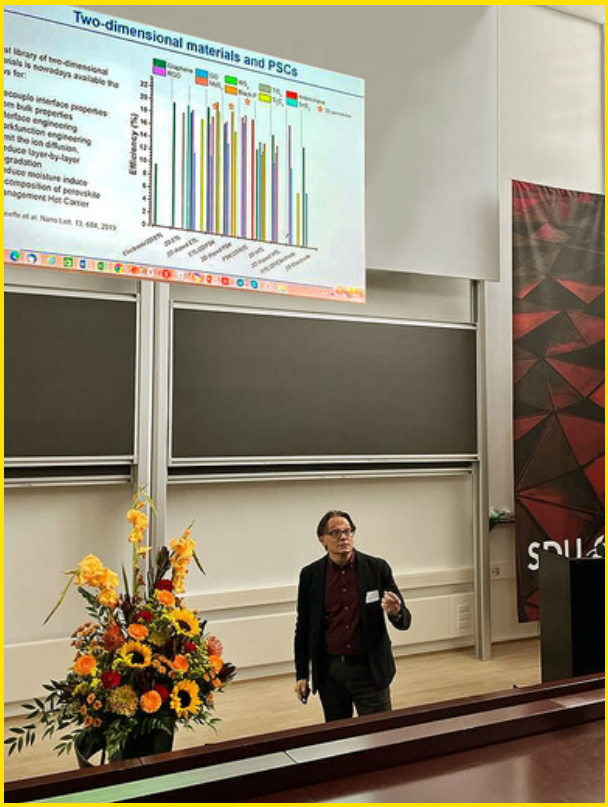
The positive conclusions and plans for second half of the CITYSOLAR project was followed by a fantastic CITYSOLAR social dinner, with all project partners.

CITYSOLAR NETWORK EVENTS

International Summit on Organic and Hybrid Photovoltaics Stability

International Summit on Organic and Hybrid Photovoltaic Stability (ISOS-13)

September 27-30, 2022. Sønderborg, Denmark
https://event.sdu.dk/isos13



On September 27-30 CITYSOLAR partner University of Southern Denmark (SDU) hosted at the campus in Sønderborg, Denmark, the **International Summit on Organic and Hybrid Photovoltaic Stability** (ISOS-13) that included talks from key scientists in the field, including also several industrial presentations and on-site demonstrations.

The ISOS-13 Summit had talks from several CITYSOLAR partners, include Prof. Aldo Di Carlo and Prof. Christoph Brabec, discussing amongst other the work and progress of the CITYSOLAR project to the community.

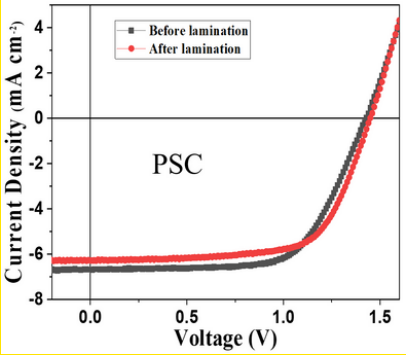
The conference was concluded by a great social trip with the electric ferry to the island of Ærø, an Island in Denmark that is CO2 neutral and 100% supplied by renewable energy!

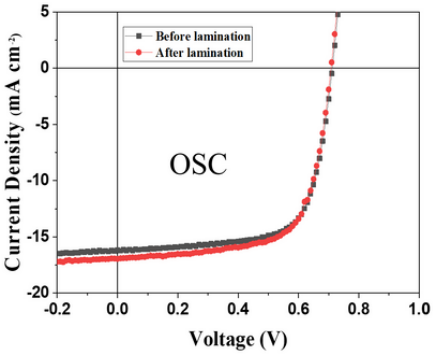
Participants of the the International Summit on Organic and Hybrid Photovoltaic Stability in the campus hall of the University of Southern Denmark (SDU), Sønderborg, Denmark.

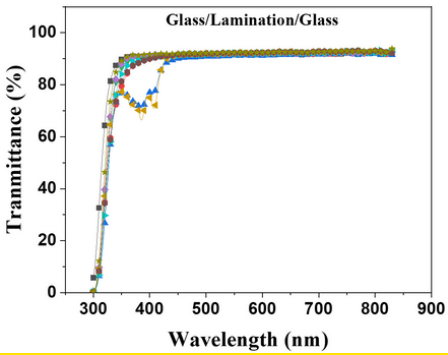
LAMINATION STUDIES TO PRODUCE PEROVSKITE-ORGANIC TANDEM SOLAR CELLS

A variety of lamination materials have been tested and characterized to determine viable solutions for combining perovskite and organic solar cells produced in laboratories at CHOSE and FAU into a four terminal tandem structure at SDU with minimal impact on transparency (AVT), color rendering (CRI), and power conversion efficiency (PCE) of the individual component cells. Several UV curing adhesives, epoxies, and pressure cured materials have been demonstrated to be compatible for both glass and PET substrate materials.

Solar cells on glass substrates survive these processes are successfully bonded to each other to create the first demonstration of our transparent tandem cells in the CITYSOLAR project.



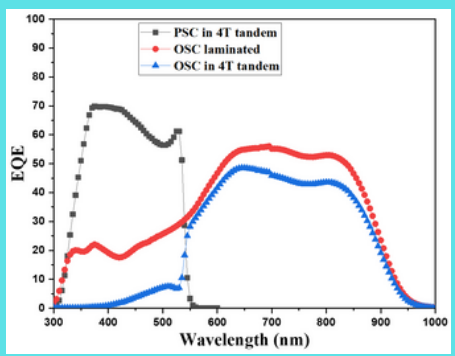


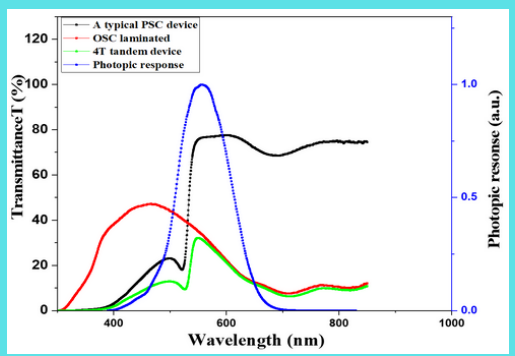


The successful lamination enables our prototype tandem cells to be characterized. These first generation four terminal cells have good PCE in a current matching stacked tandem configuration. The quantum efficiency (EQE) is as expected for the component cells.

The transmittance will be improved as light management schemes are incorporated in future generations of tandem solar cells.

4T tandem cell





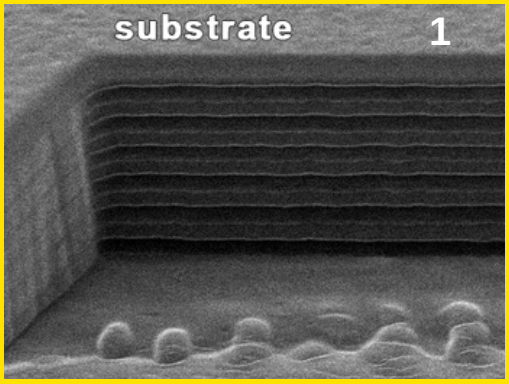
ADVANCED LIGHT MANAGEMENT WITH DISTRIBUTED BRAGG REFLECTORS (DBRS)

In a conventional opaque solar cell, the back metal contact reflects light back to the absorbing layer, which essentially increases the optical path length and output current of the device. For transparent solar cells, however, the lack of back reflection from an opaque metal contact sets the need for more advanced light management.

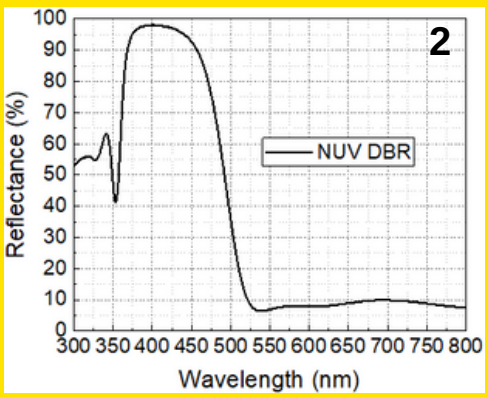
At SDU CAPE, researchers have developed highly transparent wavelength-selective Distributed Bragg Reflectors (DBRs) that are designed to reflect near ultraviolet or near-infrared light back into the CITYSOLAR top perovskite or bottom organic cells, respectively, while still offering high transparency and light outcoupling in the visible region.

Guided by optical simulations, multiple layers of high and low refractive index oxide thin films are deposited by reactive sputtering. The precise control of thicknesses and composition of individual layers allows the construction of DBRs with high performance, e.g. near ultraviolet DBRs with a transmittance loss of <10% in the visible region and reflectance of >90% at the wavelength range matched with the perovskite absorbers.

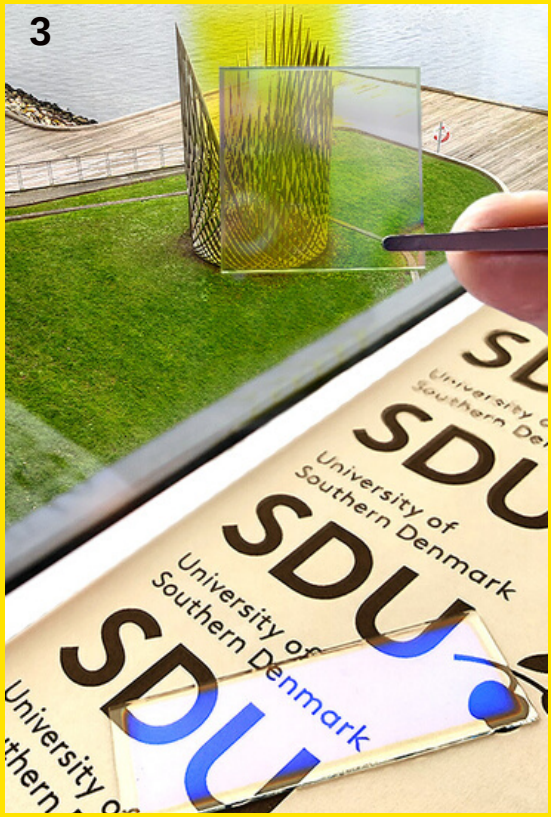
One key feature of the DBRs that is crucial for their excellent optical properties is the smooth surfaces derived from the amorphous nature of both oxide films. When they are stacked together, the interfacial roughness is <1 nm, measured by energy dispersive x-ray reflectivity at the "CNR-ISM SpecX Lab", and also confirmed by Helium-ion microscopy micrographs.



1. Cross-section image of the CITYSOLAR DBR stack.



2. Optical reflectance spectrum of the DBR for near UV perovskite absorbers.



3. Photograph of a DBR stack.

HOW SCALABLE ARE SEMI-TRANSPARENT PV SOLAR CELLS?

The CITYSOLAR consortium advanced a study to industrialize the deposition of semi-transparent perovskite solar cell over a large area with the aim of easily applying it in building façades. The big challenge is the development of a low temperature process (below 100˚C), performed in ambient atmosphere, utilizing an automated scalable technique. The research study successfully reached the aim and it has been published in Solar RRL journal.

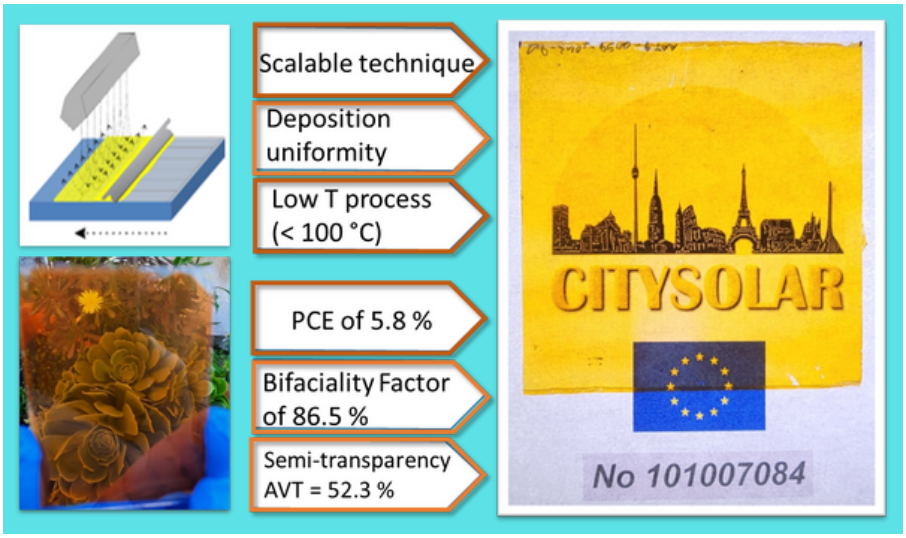
Semi-Transparent Blade-Coated FAPbBr3 Perovskite Solar Cells: A Scalable Low-Temperature Manufacturing Process under Ambient Condition

Jessica Barichello, Diego Di Girolamo, Elisa Nonni, Barbara Paci, Amanda Generosi, Minjin Kim, Alexandra Levtchenko, Stefania Cacovich, Aldo Di Carlo, Fabio Matteocci-
Solar RRL journal, November 30, 2022
https://doi.org/10.1002/solr.202200739

Perovskite photovoltaics (PVs) is an emerging PV technology that attracts interest thanks to an unprecedented combination of properties, including the ease of the bandgap tunability. The feasibility to deploy wide bandgap absorbers (>2.2 eV) leading to high average visible transmittance (AVT) is particularly intriguing for building-integrated PVs, in particular for smart windows, façades, and agrivoltaics. However, research on this topic is still at the initial stage. Uniform coverage and morphology control of bromide perovskite film are the main issues to tackle..

Herein, a systematic study on the development of FAPbBr3-based semi-transparent perovskite solar cell (ST-PSC) is presented by replacing spin-coating as the main deposition technique used for the device fabrication. To tackle this topic, the blade coating technique is employed to obtain a manufacturing flow performed at low temperature in the air environment. AVT of 52.3%, and bifacial factor of 86.5%.

Moreover, scalable and uniform FAPbBr3 deposition on 300 sq.cm. substrates is presented for the first time. The combination of low temperature, scale-up capability, and air processing along with promising PV performances represent a feasible platform for the future exploitation of PSC in building integrated photovoltaic.



Scientific Publications

Ferromagnetic Behavior and Magneto-Optical Properties of Semiconducting Co-Doped ZnO

Antonio Di Trolio, Alberto M. Testa and Aldo Amore Bonapasta. CNR.
Nanomaterials, 2022
https://doi.org/10.3390/nano12091525

ZnO is a well-known semiconducting material showing a wide bandgap and an n-type intrinsic behavior of high interest in applications such as transparent electronics, piezoelectricity, optoelectronics, and photovoltaics. This semiconductor becomes even more attractive when doped with a few atomic percent of a transition metal.

In the present review, we discuss the magnetic and magneto-optical properties of Co-doped ZnO thin films by considering also the significant improvements in the properties induced by post-growth irradiation with atomic hydrogen. We also show how all of these properties can be accounted for by a theoretical model based on the formation of Co-VO complexes and the concurrent presence of shallow donor defects, thus giving a sound support to this model to explain the RT-FM in ZCO ffects, making this material one of the most important representatives of so-called dilute magnetic semiconductors (DMSs).

Design of Highly Efficient Semitransparent Perovskite/Organic Tandem Solar Cells

Daniele Rossi, Karen Forberich, Fabio Matteocci, Matthias Auf der Maur, Hans-Joachim Egelhaaf, Christoph Brabec and Aldo Di Carlo. UNITOV, CNR, FAU.
Solar Rapid Research Letters, 2022
https://doi.org/10.1002/solr.202200242

Solar cells transparent in the visible range are highly requested for integration in see-through photovoltaic (PV) applications. The development of advanced transparent PV can fully exploit the tandem technology, where the top cell absorbs the near-ultraviolet solar spectrum while the bottom absorbs the near-infrared part.

Herein, a possible implementation of this tandem structure composed of a high-bandgap halide perovskite solar cell and a low-bandgap organic solar cell, is considered. Electro-optical simulation results based on parameters calibrated on experimental data show that an efficiency of 15% can be achieved with an average visible transmittance above 50%. This can be obtained considering the halide perovskite with mixed chlorine and bromine anions, a nonfullerene-based bulk heterojunction, a well-calibrated light management, and a three-terminal configuration of the tandem.

Scientific Publications

Organic photovoltaic modules with new world record efficiencies

Andreas Distler, Christoph J. Brabec, Hans-Joachim Egelhaaf.
Progress in Photovoltaics, 2022
https://doi.org/10.1002/pip.3336

During the last years, the development of new active materials has led to constant improvement in the power conversion efficiency (PCE) of solution-processed organic photovoltaics (OPV) to current record values above 17% on small lab cells. In this work, we show the developments and results of a successful upscaling of such highly efficient OPV systems to the module level on large areas, which yielded two new certified world record efficiencies, namely, 12.6% on a module area of 26 sq.cm. and 11.7% on a module area of 204 sq.cm.

The decisive developments leading to this achievement include the optimization of the module layout as well as the high-resolution short-pulse (nanosecond) laser structuring processes involved in the manufacturing of such modules. The new developments and their implementation into the production process of the record OPV modules are described in detail, along with the challenges.

Stimulated Self-Healing of Formamidinium Lead Tri-bromide Perovskite under Soft-X-Ray Irradiation

Valeria Milotti, Stefania Cacovich, Daniel Ory, Davide Raffaele Ceratti,
Jessica Barichello, Fabio Matteocci, Aldo di Carlo, Polina M. Sheverdyaeva,
Philip Schulz, and Paolo Moras. CNR, IPVF, EDF, EDF, CNRS, UniToV.
Submitted, 2022

Hybrid organic inorganic halide perovskites are emerging as photoactive materials for a new generation of photovoltaics, thanks to their tunable electronic and optical properties. Their stability under external stresses such as light bias or reactive extrinsic chemical species requires improvement before their widespread commercial application can truly begin.

In this work, we employ X-ray photoelectron spectroscopy and photoluminescence imaging to investigate decomposition and self-healing of formamidinium lead tri-bromide (FAPbBr3) under ion bombardment and X-ray irradiation. Significantly, we observe an X-ray stimulated recovery in the perovskite's optoelectronic properties proportional to the amount of damage, fueled by migration of formamidinium and bromine ions within the material. This self-healing effect has the potential to greatly extend the lifetime of perovskite-based devices.

CITY SOLAR

ENERGY HARVESTING IN CITIES WITH TRANSPARENT AND HIGHLY EFFICIENT WINDOW INTEGRATED MULTI-JUNCTION SOLAR CELLS

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Project website: https://www.citysolar-h2020.eu

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