6th EUROREGIONAL WORKSHOP ON PHOTOVOLTAICS

22nd – 24th June 2026

Tržaška cesta 25, Ljubljana, Slovenia

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BOOK OF ABSTRACTS

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UNIVERSITY OF LJUBLJANA
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About this publication

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About the workshop

Photovoltaics has long been one of the rapidly advancing technologies, now establishing itself as a swiftly developing global energy source. We are witnessing the historically fastest adoption of a new energy source. Whether it will become the dominant energy source will be revealed in the coming years.

5th workshop

The Euroregional workshop is intended to gather experts together with PhD students. It is organised as a forum of global R&D trends. You will get the chance to meet researchers from across the Europe, get to know their research projects and share the common issues and challenges.

The workshop consists of the following sessions:

1. **Perovskite solar cell fabrication and characterization,**
2. **Tandem solar cells,**
3. **Performance, reliability, and sustainability of photovoltaic devices and systems,**
4. **Energy yield modelling in solar cells and PV systems,**
5. **Indoor and outdoor monitoring of PV cells, modules and systems,**
6. **Power electronics and other BoS components,**
7. **Big-data approach in the field of photovoltaics.**

Sponsor

PI-KEM

http://www.pi-kem.co.uk/

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Program

Monday, 22nd June

12:00 – 13:00	***Registration & Lunch***	
13:00 – 13:15	**Opening of the workshop**	
	Session 1	
13:15 – 13:35 INVITED	Jarla Thiesbrummel University of Potsdam, Germany	The impact of ion migration on the efficiency and stability of perovskite solar cells
13:35 – 13:55 INVITED	Miloš Dubajić University of Cambridge, United Kingdom	Structural heterogeneity in lead halide perovskites across spatial and temporal length scales
13:55 – 14:15 INVITED	Sarah Gillespie AMOLF, Amsterdam, Netherlands	Quantifying ionic processes in perovskites using frequency-domain photoluminescence
14:15 – 14:30	Enrique H. Balaguera Universidad Rey Juan Carlos Madrid, Spain	Rapid mapping of degradation pathways through current transients in perovskite solar cells
14:30 – 15:00	***Coffee Break***	
	Session 2	
15:00 – 15:20 INVITED	Stoichko Dimitrov Queen Mary University of London, United Kingdom	Antisolvent bath approach for printing perovskite solar cells at scale
15:20 – 15:40 INVITED	Juanita Hidalgo New York University, USA	From end-of-life to recycling: enabling a sustainable lifecycle for halide perovskites
15:40 – 16:00 INVITED	Tom Aernouts IMEC, Genk, Belgium	Efficient Structures And Processes for Upscaling of Perovskite Modules and Tandems
16:00 – 16:15	Ramashanker Gupta Charles University Prague, Czech	Advancing perovskite solar sells through environmentally sustainable solvent processing
16:15 – 16:30	PI-KEM, United Kingdom	Sponsor presentation
16:30	**Poster session** ***Beer & Pizza***	

Tuesday, 23rd June

9:00 – 9:15	**Opening of the SLO-PV conference** *Marko Topič*	
9:15 – 10:00 PLENARY	Rutger Schlatmann Helmholtz-Zentrum Berlin, Germany	Photovoltaics as the innovative driving force of energy transition – everywhere and for everyone
10:00 – 10:30	***Coffee break***	
	Session 3	
10:30 – 10:50 INVITED	Chiara Barretta PCCL Leoben, Austria	Selecting encapsulant materials for perovskite/crystalline silicon tandem solar modules
10:50 – 11:10 INVITED	Aleksandra Djurišić Ruđer Bošković Institute, Zagreb, Croatia	Photo/electrochemical reactions and the degradation halide perovskites
11:10 – 11:30 INVITED	Marko Remec Helmholtz-Zentrum Berlin, Germany	Indoor insights for outdoor stability
11:30 – 11:45	Arslan Ali LPVO, UL FE, Ljubljana	Encapsulation of perovskite solar cells
11:45 – 12:00	Žan Ajdič LPVO, UL FE, Ljubljana	Insights from mass indoor stability testing of single-junction perovskite solar cells
12:00 – 13:00	***Lunch***	
	Session 4	
13:00 – 13:20 INVITED	Maximiliano Senno University of Valencia, Spain	Accelerated and Outdoor Stability Testing of High-Efficiency Vacuum-Processed Perovskite Solar Cells
13:20 – 13:40 INVITED	Viktor Škorjanc Helmholtz-Zentrum Berlin, Germany	Influence of surface PbI2 on coevaporated perovskite reproducibility
13:40 – 14:00 INVITED	Erica Magliano CNR Istituto di Struttura della Materia, Roma, Italy	Additive-free co-evaporation of FAPbI3 enabled by sequential FAI sources for improved phase stability and film quality
14:00 – 14:15	Jovan Lukić University of Belgrade, Serbia	Halogen bonding interfacial engineering in perovskite solar cells
14:15 – 14:30	Fernando Solorio Soto LPVO, UL FE, Ljubljana	SnO2/ZnO bilayer for stable perovskite solar cells
14:30 – 15:00	***Coffee break***	

	Session 5	
15:00 – 15:20 INVITED	Bart Macco TU Eindhoven, Netherlands	Spatial ALD of ZnO:Al passivating contacts: from interface physics to scalable doping strategies
15:20 – 15:40 INVITED	Catarina Ferreira University of Southern Denmark, Odense	Optical design and optimization of non-absorbing colored multilayer coatings for building-integrated photovoltaics
15:40 – 16:00 INVITED	Abhisek Chakraborty CHOSE, Tor Vergata University of Rome, Italy	Best practices for measuring performance and stability of indoor photovoltaic devices
16:00 – 16:15	Matej Hyvl Institute of Physics, Academy of Sciences of the Czech Republic, Prague	Microscopic and macroscopic studies of perovskite degradation: linking stability and crystallographic orientation
16:15 – 16:30	Matija Pirc LPVO, UL FE, Ljubljana	Perovskite Solar Cells for indoor IoT – A Full Year Monitoring Study
16:30	**LPVO tour** (departure from the registration desk) Perovskite fabrication facility Perovskite stability setups WLED and BCLED Outdoor testing field	
19:00	***Workshop dinner at Pod vrbo*** Ziherlova ulica 36, 1000 Ljubljana	

Wednesday, 24th June

	Session 6	
9:00 – 9:20 INVITED	Patricia Schulze Fraunhofer ISE, Germany	Fully-textured perovskite/silicon tandem solar cells
9:20 – 9:40 INVITED	Quentin Jeangros CSEM, Neuchâtel, Switzerland	Towards scalable and durable perovskite/silicon tandem and triple junction solar cells
9:40 – 10:00 INVITED	Suzana Kralj PV-Lab EPFL, Neuchâtel, Switzerland	From fast laser deposition to sustainable solar sells
10:00 – 10:15	Manas R. Samantaray CHOSE, Tor Vergata University of Rome, Italy	Wide-Bandgap Perovskite Solar Cells for Underwater Photovoltaics: From Experimental Demonstration to Simulation-Guided Device Engineering
10:15 – 10:30	Miha Kikelj LPVO, UL FE, Ljubljana	Degradation monitoring of tandem solar cells
10:30 – 11:00	***Coffee break***	
	Session 7	
11:00 – 11:20 INVITED	Martin Ledinsky Institute of Physics of the Czech Academy of Sciences, Prague	Universal formation mechanism of halide perovskite thin films
11:20 – 11:40 INVITED	Karen Forberich HI-ERN, Erlangen, Germany	High-throughput experimentation and use of artificial intelligence for materials research
11:40 – 12:00 INVITED	Jorge Pascual Mielgo University of Valencia, Spain	Solution and interface engineering to overcome limitations in tin-based perovskite photovoltaics
12:00 – 12:15	Stjepan Dolić Ruđer Bošković Institute, Zagreb, Croatia	Differences in the degradation pathways of 2D lead- and tin-based perovskite compositions
12:15 – 12:30	Kristijan Brecl LPVO, UL FE, Ljubljana	Outdoor cross-location stability comparison of perovskite solar cells
12:30	***Lunch***	

ABSTRACTS

Monday, 22nd June 2026

The impact of ion migration on the efficiency and stability of perovskite solar cells

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Abstract

Mobile ions play a crucial role in metal halide perovskites, shaping the device physics of perovskite-based devices such as solar cells or memristors. Although the importance of mobile ions in metal halide perovskites has long been recognised, a comprehensive understanding of ion migration and the various factors influencing it is still lacking. In this talk, I will discuss how mobile ions impact both the efficiency and the operational stability of perovskite solar cells. I will show how reversible and irreversible ionic losses impact the device performance, and point out possible strategies to reduce this impact. Finally, I will cover lateral ion migration, and show the importance of considering ion migration in three dimensions when characterising and modelling perovskite solar cells.

Structural heterogeneity in lead halide perovskites across spatial and temporal length scales

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Abstract

In this talk, I will present our recent results and insights into the factors governing structure–property relationships in 3D bulk halide perovskites. We argue that the origin of their macroscopic properties lies in structural dynamics, in particular correlated octahedral tilts that give rise to fluctuating nanodomains. I will show how different chemical compositions at the A and X sites modify their local structure and affect these tilting correlations, and I will propose alternative strategies to control them.

I will also present our recently developed 4D time-resolved hyperspectral PL imaging, a technique that provides simultaneous temporal and spectral resolution at the diffraction limit. This allows us to identify charge transfer from band edges to sub-gap states in regions under tensile strain, providing a unified link between local structural fluctuations, nanoscale strain and macroscopic properties.

Quantifying Ionic Processes in Perovskites using Frequency-Domain Photoluminescence

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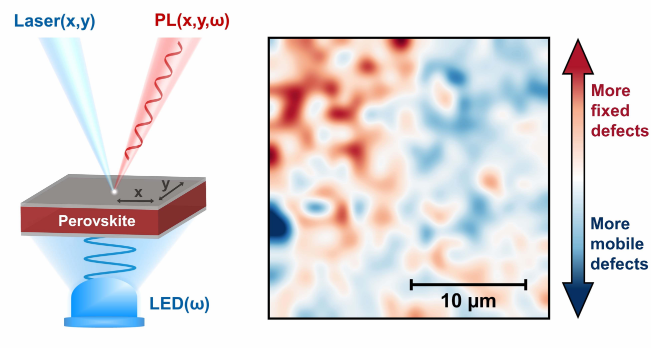
Abstract

The widespread commercialization of halide perovskites in semiconductor technologies is still hindered by their inherent instability, which primarily arises from mobile ionic processes in the material[1]. However, ionic reactivity is not always detrimental; ions are responsible for "perovskite healing" and self-optimization. Understanding the influences of different ionic species is therefore crucial for enhancing perovskite photovoltaic performance, and can open up new technological pathways which exploit the beneficial ionic effects. To directly quantify these ionic processes, we present a fully optical characterization technique called "intensity-modulated photoluminescence spectroscopy" (IMPLS)[3]. IMPLS can be regarded as an optical analogue of impedance spectroscopy (IS): the PL phase shift and amplitude are collected as a function of excitation frequency and fitted to models to extract useful information. Specifically, we extract ionic diffusion coefficients (D_{ion}~10^{-10} cm^2/s), quantify ion-mediated losses, and spatially differentiate regions with relatively more mobile ions across perovskite films (see figure)[4]. IMPLS has several key advantages over IS: it can be performed on samples without electrical contacts, and can probe both local and global features. Ultimately, IMPLS is a valuable tool for research and in-line processing to assess material quality and stability.

Keywords: Halide perovskites, ion migration, photoluminescence, impedance



References

[1] J. Thiesbrummel et al, *Nat. Rev. Chem.* **10** 179-195 (2026)
[2] S.C. Gillespie et al, *ACS Energy Lett.* **10**, 3122–3131 (2025)
[3] S.C. Gillespie et al, *ACS Energy Lett.* **11**, 3330–3339 (2026)

Rapid mapping of degradation pathways through current transients in perovskite solar cells

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Abstract

Perovskite solar cells are strong candidates for next-generation industrial photovoltaics. However, the operational stability of such devices remains a critical barrier to massive and large-scale commercialization. Thus, estimating their losses and correcting them as early as possible is essential to advance this technology. In this work, we introduce a rapid methodology to monitor degradation mechanisms through the analysis of current transient responses under real-world operational conditions. The approach exploits time-resolved electrical measurements acquired during controlled voltage sweeps (commonly used for efficiency estimation) to capture dynamic variations associated with device ageing. Such transient traces provide direct insights into time-dependent effects occurring within the device, including reversible ionic redistribution and irreversible material degradation. To interpret the measured responses, we employ physics-based equivalent circuits that enable the separation of ionic/electronic effects related to transport, recombination and charge collection. Our proposed method significantly reduces characterization time while preserving sensitivity to the relevant degradation mechanisms, in comparison to Impedance Spectroscopy. The results demonstrate that current transient analysis offers a powerful and efficient route to access operational stability information, bridging the gap between fast laboratory characterization and realistic device behavior, as well as guiding the design of more stable perovskite samples for photovoltaic applications.

Keywords: Perovskite solar cells, transient analysis, equivalent circuits, ionic effects, Impedance Spectroscopy.

Antisolvent bath approach for printing perovskite solar cells at scale.

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Abstract

Scaling up perovskite solar cell printing is critical for commercialization, yet achieving high-quality films under industrial conditions remains challenging, particularly due to limited control over crystallization, especially using more sustainable green solvents. At the laboratory scale, spin coating combined with anti-solvent treatment has delivered high efficiencies by enabling precise control of nucleation and crystal growth. In contrast, large-area printing requires alternative deposition techniques, like slot-die coating, and anti-solvent treatment is often considered incompatible with these methods, leading to reliance on gas-flow-assisted drying. This approach demands changes in solvent systems, moving away from optimized lab-scale formulations and reducing control over intermediate pre-perovskite phases that can benefit high-quality crystal growth and optimal orientation.

Here, we introduce a dynamic anti-solvent bathing method for scalable perovskite printing. Results across multiple compositions, including $CsFAPbI_XBr_{1-X}$, $CsFAPbI_3$, $MAPI_3$, and $CsPbI_3$, show that this approach enables high-quality film formation, in most cases under ambient conditions and using green solvents. This method can be preceded by gas flow assisted drying. The anti-solvent bath can be used to facilitate targeted solvent or ions extraction, promoting effective crystallization. In situ GIWAXS and photoluminescence spectroscopy, in addition to NMR and FTIR reveal the crystallization mechanisms and suggest that pairing anti-solvent bathing with targeted additives could enhance film quality for high-performance devices.

From End-of-Life to Recycling: Enabling a Sustainable Lifecycle for Halide Perovskites

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Abstract

Lead halide perovskites solar cells, including single-junction and tandem, are advancing toward commercialization as low-cost, high-efficiency photovoltaic technologies. However, limited operational lifetimes under environmental stressors, even with encapsulation, remain a major challenge. Chemical and structural instability hinders deployment, motivating the need for both stabilization strategies and sustainable end-of-life solutions. Our lab addresses these challenges by investigating the intrinsic and extrinsic mechanisms that drive end-of-life behavior across a wide range of perovskite compositions which reflects the complexity of their mixed chemistries. Our work is organized along two directions. First, we investigate degradation pathways in situ, examining the coupled effects of humidity, oxygen, and composition.(1) Using synchrotron-based in-situ GIWAXS, we track structural evolution under controlled environmental exposure to uncover mechanistic pathways driving instability. Second, we explore aqueous-based recycling strategies and their connection to degradation. Because perovskites readily degrade in humid environments, water can serve as a green solvent for material recovery. We systematically study different compositions and additives to decouple solute-solvent interactions and optimize recovery yield and purity. By connecting degradation mechanisms with recycling pathways, this work establishes design principles for energy materials. While focused on halide perovskites, this framework is broadly applicable to other material systems facing sustainability challenges.

(1) Hidalgo et al. J. Am. Chem. Soc. 2023, 145, 45, 24549–24557

Efficient Structures And Processes for Upscaling of Perovskite Modules and Tandems

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Abstract

The unprecedented fast rise of power conversion efficiency (PCE) of perovskite-based solar cells (PSC) in recent years has created a vast worldwide research activity in this material class for photovoltaic and other opto-electronic applications. Several materials compositions and device architectures have been described and best reported PCE's yield recently more than 27%. Also improved stability under specific conditions has been shown for specific architectures. Whereas all these results indicate a high potential for this novel solar technology, further steps must be taken to convince industry and even the whole PV community that perovskite-based photovoltaics can really emerge from the lab into industrially applicable solar module processing. Our R&D program works actively on the upscaling of perovskite solar modules with scalable processes up to sizes of 35x35 cm^2.

Similarly, the perovskite PV technology has boosted the tandem research whereby perovskite cells and modules are placed on top of other PV devices like Si or CIGS solar cells. Impressive lab scale results exceeding 34% PCE have been reported. New challenges arise when this needs to be upscaled to full wafer or module size. It will be discussed how we approach these challenges.

Advancing Perovskite Solar Cells Through Environmentally Sustainable Solvent Processing

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Abstract:

In the current landscape of photovoltaic research, $FAPbI_3$-based perovskite solar cells have achieved remarkably high efficiencies. Till date even without formamidinium-based perovskites, respectable power conversion efficiencies are still challenges; however, challenges related to commercialization and large-area fabrication remain, particularly from an environmental perspective. This study presents a sustainable and high-performance fabrication strategy for $FAPbI_3$-based perovskite solar cells (PSCs) by integrating a green solvent-assisted two-step deposition method with 4F-PEAI interfacial engineering. The adoption of dimethyl sulfoxide (DMSO) and isopropanol (IPA) as environmentally friendly solvents not only aligns with green chemistry principles but also facilitates the formation of highly crystalline and uniform α-FAPbI3 films. This method provides a safer and scalable alternative to conventionally used comparatively less toxic solvents such as dimethylformamide (DMF), thereby supporting environmentally accountable large area photovoltaic manufacturing.

Furthermore, the incorporation of 4F-PEAI as a surface passivation layer plays a pivotal role in enhancing device performance. Structural and optical characterizations, including X-ray diffraction (XRD), scanning electron microscopy (SEM), and UV–visible spectroscopy, confirm enhanced film morphology, increased crystallinity, and reduced trap densities in treated devices. As a result, photovoltaic performance shows a significant improvement, with 4F-PEAI-modified devices achieving a power conversion efficiency (PCE) of 19.61%, compared to 15.2% for untreated devices.

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ABSTRACTS

Tuesday, 23rd June 2026

Photovoltaics as the innovative driving force of energy transition – everywhere and for everyone

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Abstract

In this introductory presentation, current insights will be presented on the relation between outdoor and indoor tests and real life performance , for high efficieny single and multijunction solar cells . In parallel, it will also be demonstrated how the exceptionally fruitful and stable relation between the partner groups in Ljubljana and Berlin enabled a number of high-impact contributions to the field and what we expect to do next.

Selecting Encapsulant Materials for Perovskite-Crystalline Silicon Tandem Solar Modules

Chiara Barretta[1*], Petra Christoefl[1], Marcel Kuehne[2], Markus Franke[2], Frans Op den Buijsch[3], Roland Milatz[3], Lisa Champault[4], Quentin Jeangros[4], Quiterie Emery[5], Mark Khenkin[5], Carolin Ulbrich[5], Gernot Oreski[1,6]

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Abstract

Perovskite-silicon tandem solar cells are among the most promising next-generation PV technologies due to their very high conversion efficiencies. However, transferring these devices from cell to module level is still limited by encapsulation challenges. In contrast to conventional crystalline silicon devices, tandem cells are considerably more sensitive to thermal and mechanical stress, while currently available encapsulation materials were mainly developed for processing at higher temperatures and for less delicate cell architectures.

To support material selection for tandem module lamination, a screening methodology was developed with particular focus on the thermo-mechanical processing range relevant for perovskite stability. In total, 22 encapsulation films, including commercial and experimental materials, were investigated with regard to softening and melting behaviour, onset of crosslinking, viscosity under lamination conditions, thermal dimensional changes, optical properties, and chemical composition. Based on these results, a comparative scoring approach was applied to identify suitable candidates and highlight critical material limitations.

The study shows that low thermo-mechanical stress and high dimensional stability are essential requirements for tandem integration, whereas high viscosity or pronounced anisotropic shrinkage may induce stresses that can damage or delaminate the perovskite-based layer stack. Although none of the tested films fulfilled all desired criteria, several materials displayed promising combinations of low-temperature processability, limited deformation, and acceptable optical performance. The proposed methodology provides a practical basis for selecting and further developing encapsulation materials for perovskite-silicon tandem modules.

Photo/electrochemical reactions and the degradation halide perovskites

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Abstract

Perovskite solar cells have achieved remarkable efficiencies, but they still suffer from degradation under operational conditions, namely illumination, bias, and elevated temperature. While these reactions are accelerated with exposure to moisture and oxygen, they can still occur in inert atmosphere. The degradation reactions include not only iodide oxidation (which then drives ion migration), but also reactions involving organic cations which can result in a multitude of reaction products from secondary reactions driving irreversible decomposition. These reactions affect both 3D and 2D perovskites, and they have been less well understood in 2D perovskites. In this presentation, we will discuss the degradation reactions which affect organic cations, with the focus on the 2D perovskites (Ruddlesden-Popper and Dion-Jacobson), which are commonly used in high performance perovskite solar cells in 3D/2D structures to improve stability.

Indoor Insights for Outdoor Stability

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Abstract

Record small area single-junction perovskite solar cells (PSCs) have shown power conversion efficiencies exceeding 27% [1]. The main research focus has now shifted from efficiency optimization towards achieving better long-term operational stability, preferably reaching silicon solar cells lifetimes. The first years-long outdoor datasets reveal a pronounced seasonality in single-junction PSCs. Those seasonal changes in performance make stability assessments using conventional methods and metrics challenging.

By analyzing the data of the longest available time series, a 5-year long outdoor experiment, we attribute performance changes to different factors: (I) seasonal changes in the solar spectrum, (II) unconventional temperature-dependent behavior of aged PSCs and (III) perovskite metastability, particularly the light-soaking effect.

These effects are not only present in single-junction PSCs, but also in perovskite-based tandem devices. In a two-terminal tandem device, the series connection between the sub-cells makes assessment of the outdoor stability even more difficult compared to single-junction devices as tandem performance depends significantly on the current matching of the sub-cells. We show how additional indoor characterization, using controlled spectral and temperature conditions, can help us understand and evaluate device outdoor behavior. Combining long-term outdoor studies and indoor experiments will provide a base for improved device lifetime projections.

[1] Best Research-Cell Efficiency Chart, NREL: https://www.nrel.gov/pv/cell-efficiency.html

Encapsulation of Perovskite Solar Cells

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Abstract

Metal halide perovskites (ABX_3) have emerged as highly promising candidates for the next generation of photovoltaic (PV) technologies due to their exceptional optoelectronic characteristics, low fabrication costs, and compatibility with scalable manufacturing processes. Despite these advantages, the long-term operational stability of perovskite solar cells (PSCs) remains a significant challenge, primarily due to substantial degradation when exposed to environmental stressors such as moisture and oxygen. Therefore, effective encapsulation methods are essential for the successful commercialization of PSCs in practical applications. In this work, an external encapsulation approach is employed in which PSCs are laminated between two glass layers, utilizing cross-linked Polyolefin Elastomers (POE) as the primary encapsulant, while Polyisobutylene (PIB) serves as the edge sealant. The effectiveness of the encapsulation is evaluated through periodic measurements of PV parameters and damp heat experiments. The results demonstrate that the lamination process does not adversely affect device performance, as the PV parameters remain intact after encapsulation, indicating the preservation of the initial cell characteristics and the absence of encapsulation-induced degradation.

Insights from mass indoor stability testing of single-junction perovskite solar cell

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Abstract

Perovskite solar cells are a relatively new technology with significant potential, as their efficiency is already comparable to that of conventional silicon solar cells. However, to reach the market, their long-term stability must exceed at least 20 years, which is currently not the case.

In this contribution, we present the effect of moisture, light, perovskite composition, and bias voltage on the long-term stability of our typical FACs PSCs in a p-i-n configuration. By exposing cells to different conditions, we determine the most critical factors causing cell degradation. Testing many solar cells under specific conditions allows us to statistically support the results obtained and identify degradation trends, rather than reporting only on the champion devices.

Accelerated and Outdoor Stability Testing of High-Efficiency Vacuum-Processed Perovskite Solar Cells

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Key words: perovskite, solar cell, vacuum deposition, Close space sublimation (CSS), wide bandgap perovskites

Abstract

Vacuum-processed perovskite solar cells (PSCs) are emerging as a scalable alternative to solution-based approaches, offering improved reproducibility and solvent-free fabrication. However, stability studies on vacuum-processed devices remain limited, highlighting the need for systematic accelerated and outdoor testing protocols. In this presentation, encapsulated devices fabricated using different vacuum-based techniques are discussed, with particular focus on their indoor and outdoor stability. Co-evaporated inverted (p–i–n) FAMAPbI devices achieved average efficiencies of 21–22% and retaining 80% of the initial efficiencies after 300 h at 65 °C under ISOS-L2 conditions. In addition, two-step deposition methods, including sequential evaporation and close-space sublimation (CSS), demonstrated remarkable accelerated indoor stability, retaining more than 85% of their initial efficiency after 1000 h at 65 °C and more than 80% after 1000 h at 85 °C under MPPT operation. Finally, the presentation will also cover the development of our outdoor ISOS-O2 testing setup, where co-evaporated MAPI and FAMAPI devices have been monitored over the last two years to assess their performance under real operating conditions.

Influence of surface PbI_2 on coevaporated perovskite reproducibility

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Abstract

Perovskite coevaporation is an upscalable deposition technique, particularly important in the context of textured perovskite-silicon tandem solar cells as it allows for conformal coverage of textured silicon bottom cells.[1] However, coevaporation processes can suffer from poor reproducibility.[2] In this study, we analyze the phases present in coevaporated $FA_{0.8}Cs_{0.2}Pb(I_{0.8}Br_{0.2})_3$ perovskite films prepared by two nominally equivalent processes (labeled as *Process 1* and *Process 2*) using in-situ grazing-incidence wide angle x-ray scattering (GIWAXS) measurement during post-deposition annealing. We show that films from both processes are stable for prolonged annealing time (20 min) at elevated temperature (180 °C). The key difference between the two films is the presence of PbI_2 phase. For *Process 1*, the PbI_2 (001) peak integral increases during the annealing, while perovskite (110) peak integral stabilizes after an initial spike (Figure 1a,b). *Process 2* shows no PbI_2 peak, and the perovskite peak integral keeps increasing during the annealing. Angle-dependent GIWAXS measurement indicates that the PbI_2 phase in *Process 1* is located at the perovskite film surface (Figure 1c). We link the formation of the PbI_2 phase at the film surface to reduced FAI incorporation for higher film thicknesses, which varies unintentionally between deposition runs. Achieving improved control of this key parameter thus appears to be crucial for enhanced reproducibility.

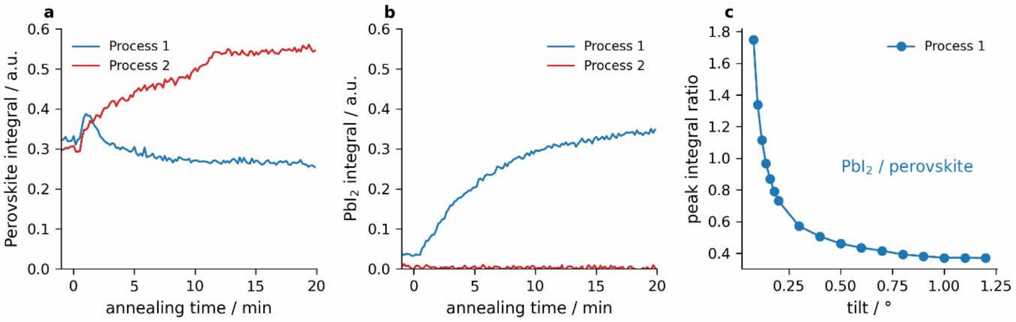

Fig. 1: GIWAXS measurements on coevaporated perovskite. a, Perovskite (110) peak integral during annealing at 180 °C. **b**, PbI_2 (001) peak integral during annealing at 180 °C. **c**, Ratio of PbI_2 and perovskite peak in angle-dependent measurements.

1 Roß, M. *et al. Advanced Energy Materials* 11, 2101460 (2021)
2 Mahmoud, M. A. A. *et al. J. Mater. Chem. A* 13, 42281–42288 (2025)

Keywords: perovskite, coevaporation, tandem solar cells

Additive-Free Co-Evaporation of FAPbI3 Enabled by Sequential FAI Sources for Improved Phase Stability and Film Quality

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Keywords: Thermal Co-Evaporation, FAPI, perovskite, organic decomposition.

Abstract

Achieving high uniformity over large areas and reproducibility across batches remains one of the main challenges for the industrial upscaling of perovskite solar cells. Vapor-phase deposition offers a promising route to overcome these limitations by decoupling film formation from solvent-driven instabilities and enabling precise control over thickness and composition.

In this work, we investigate the additive-free co-evaporation of formamidinium lead iodide ($FAPbI_3$), addressing the intrinsic instability and decomposition of formamidinium iodide (FAI) during processing. By implementing a sequential use of multiple FAI sources, we mitigate precursor degradation and achieve improved compositional stability during deposition. This strategy enables the growth of thick and homogeneous perovskite films with enhanced morphology. Furthermore, the introduction of an intermediate annealing step promotes grain growth and improves crystallinity, particularly for thicker layers. A systematic study of substrate temperature identifies 60 °C as the optimal condition to stabilize the photoactive α-phase while suppressing the formation of the δ-phase. The role of the hole transport layer is also examined, revealing a trade-off between phase stabilization and reproducibility. Optimized devices based on PTAA achieve a power conversion efficiency of 18.5% along with improved operational stability, demonstrating the potential of vapor deposition for scalable and reliable perovskite manufacturing.

Halogen bonding interfacial engineering in perovskite solar cells

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Abstract

Hybrid metal halide perovskites have become among the most promising semiconductor materials for photovoltaic applications. However, despite achieving high power conversion efficiencies, their long-term stability under operating conditions remains a critical challenge. A key source of instability arises at the interfaces between the perovskite layer and charge transport materials, particularly metal oxides. In this work, halogen bonding (XB) via 1,4-diiodotetrafluorobenzene (TFDIB) is used to engineer the interface of the TiO_2 electron transport layer and perovskite, leading to enhanced operational stability of perovskite solar cells. This approach is further complemented by incorporating an iodo-functionalized Zn–phthalocyanine as a modulator for the hole transport layer, which improves interfacial passivation and increases power conversion efficiency. Together, these results highlight the effectiveness of halogen bonding as a strategy for improving both the stability and performance of hybrid photovoltaic devices.

SnO_2/ZnO bilayer for stable perovskite solar cells

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Abstract

Perovskite solar cells (PSCs) are emerging as strong contenders in the photovoltaic (PV) market, with certified power conversion efficiencies reaching 28%.[1] Yet their long-term stability continues to limit practical deployment. In addition to absorber engineering, the design of adjacent charge transport layers is critical for suppressing metal-ion migration and mitigating interfacial degradation pathways.[2-3] A promising approach to enhance devices stability is through incorporating layers deposited by atomic layer deposition (ALD), whose self-limiting growth enables the formation of compact, pinhole-free electron transport layers (ETLs) directly on the perovskite surface.[4] In this work, we show that the use of ALD SnO2/ZnO bilayers, together with thermally evaporated C60, combines the higher power efficiency of SnO2 with the improved stability offered by ZnO. The long-term stability improves by a factor of 2–3 compared to our reference cells, achieving a t80 of over 1000 hours in the best case. This has been confirmed by analyzing multiple devices across several batches. Techniques, such as TEM, XPS, EQE, and PLQY, were used to elucidate the role of ALD ZnO films in improving stability.

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Spatial ALD of ZnO:Al Passivating Contacts: From Interface Physics to Scalable Doping Strategies

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Abstract

Atomic layer deposition (ALD) offers unmatched control over ultrathin films and interfaces, making it highly attractive for advanced photovoltaic device architectures. In this contribution, we focus on Al-doped ZnO (ZnO:Al) as a passivating contact for silicon solar cells.

ZnO:Al provides a novel promising route toward indium-free electron-selective contacts, combining efficient carrier transport with surface passivation. The underlying device physics will be discussed, including the role of doping, interface quality, and transport through the oxide, in relation to recent results demonstrating efficiencies exceeding 24%.

A central theme of this work is the scalability of such contacts. While batch ALD has a proven track record in scaling ALD for solar cells, we highlight that spatial ALD offers intrinsic advantages for doping control. In particular, the continuous and decoupled precursor supply enables new doping strategies, such as co-injection and sub-saturated growth, which can lead to improved dopant incorporation and activation compared to conventional supercycle approaches.

Finally, the implications for silicon–perovskite tandem solar cells are discussed, where the proposed use of a degenerately-doped transparent conductive oxide as the silicon cell front contact opens very natural integration schemes with the tunnel recombination junction of the perovskite top cell.

Optical design and optimization of non-absorbing colored multilayer coatings for building-integrated photovoltaics

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Abstract

Photovoltaic (PV) modules for building integration necessitate to fulfil the usual technical requirements – such as low cost, long-term stability, and high power conversion efficiency – while aesthetically harmonizing with the building architecture and its surrounding environment, which can be achieved through coloration. However, traditional coloration techniques typically employ absorbing dyes and pigments in front of the PV modules, therefore compromising their efficiency. To overcome such a drawback, increased attention has been devoted to the use of structural colored elements that rely on optical effects occurring in nanometer thin structures to produce vivid colors with low optical losses. In this work, particular attention will be devoted to the design of planar thin-multilayer elements made from non-absorbing dielectric materials that can be placed in front of PV cells and modules to colorize them without severely affecting their efficiency. Here, we will start by exploring simpler periodic structures – Distributed Bragg Reflectors – and later move toward more complex configurations obtained by inverse design optimization to reproduce a broad gamut of colors on request. Experimental validation of the design methodologies here proposed is finally caried out through fabrication and characterization of PV mini-modules with selected target colors, showing a remarkable agreement between theoretical predictions and experiments.

Keywords: Colored photovoltaics, Inverse design, Multilayer structures, Structural colors, Building-integrated photovoltaics

Best Practices for Measuring Performance and Stability of Indoor Photovoltaic Devices

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Abstract

Indoor photovoltaics (IPV) is emerging as a key technology for powering the Internet of Things, wireless sensors, and consumer and medical electronics by harvesting ambient light energy inside homes and buildings. Despite rapid progress, the field has long lacked standardized testing conditions, making it difficult to compare performance data across laboratories and industrial settings worldwide.

In this invited talk, I will present the outcomes of a landmark consensus effort involving researchers and engineers from more than 60 institutions and companies. Together, we have developed best practice recommendations for evaluating indoor photovoltaic performance and establishing baseline stability tests. Our recommendations draw on recent experimental data, published literature, technical specifications from standards organizations, curated lighting databases, and existing regulations.

The proposed framework begins with the selection of a single reference artificial light source, followed by structured guidance on measurement system setup, and a step-by-step protocol for conducting measurements and stability tests. All procedures are consolidated into three practical checklists designed for adoption in both academic and industrial contexts.

This work aims to promote accurate, reproducible measurement of solar cells and modules under indoor lighting conditions, enabling meaningful comparability across the global IPV research community.

Microscopic and Macroscopic Studies of Perovskite Degradation: Linking Stability and Crystallographic Orientation

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Abstract

Organic halide perovskites have achieved remarkable power conversion efficiencies, exceeding 35% in tandem and 27.3% in single-junction devices. However, long-term operational stability remains the primary barrier to commercialization. While macroscopic degradation trends are well documented, the microscopic origins of instability and their relation to crystallographic structure are still insufficiently understood.

In this work, we combine macroscopic ageing studies with grain-resolved correlative atomic force microscopy and electron backscatter diffraction to investigate degradation in perovskite thin films. Time-resolved AFM reveals heterogeneous surface evolution, ranging from intact grains to partially and fully degraded grains. By correlating morphological changes with crystallographic orientation, we show that degradation is strongly orientation dependent. These results provide direct microscopic evidence that crystallographic orientation controls the environmental stability of perovskite thin films.

Perovskite Solar Cells for indoor IoT – A Full Year Monitoring Study

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Abstract

The growing need for self-sustaining power sources for small electronics, internet of things (IoT) devices in particular, has made indoor photovoltaics (IPV) a market with substantial promise, and perovskite solar cells (PSCs) are a compelling candidate technology. To better characterize how PSCs behave in realistic indoor settings, an indoor monitoring system has been built that holds four solar cells at their maximum power points while continuously recording both their output and the surrounding conditions and periodically performs J-V scans. The setup tracked three PSCs alongside one crystalline silicon cell (c-Si SC), each roughly 1 cm² in active area, across a full year. Pairing the resulting daily yields with the energy budgets of several wireless standards suggests that one 1 cm² PSC suffices to run an IoT node that communicates over a short-range, low-power link on most days – a conclusion verified with a working prototype. On a handful of days annually, though, even maximum power point tracking cannot be sustained, which argues for incorporating modest energy storage capability. Tilt experiments revealed gains of 36% at the optimal angle and losses of 72% at the worst, measured against horizontal placement. Over the year, the leading PSC delivered 148.8 mWh/cm² versus 46.0 mWh/cm² for the c-Si cell – a threefold margin – while preserving most of its performance.

ABSTRACTS

Wednesday, 24th June 2026

Fully-Textured Perovskite/Silicon Tandem Solar Cells

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Abstract

For highest efficiency potential and compatibility with industrial silicon surface texture, our work focusses on the fabrication of perovskite top solar cells that conformally coat µm-sized random pyramid silicon texture. For that purpose, the hybrid co-evaporation/ wet chemical route is applied to ensure controlled perovskite thin film formation over relatively large silicon pyramids. Similarly, suitable deposition methods for selective contacts are chosen. Resulting perovskite interfaces to the hole and electron selective contacts are studied in detail and suitable passivation schemes are proposed. Supported by opto-electronic simulation and device characterization, we gain insights into the underlying working mechanisms and find that the large improvement in V_{OC} and FF of the applied passivation approach at the perovskite/C_{60} interface is driven by a field-effect reducing interfacial recombination and increasing electron concentration within the perovskite bulk, which enhances conductivity. Based on these findings, we were able to reach a certified power conversion efficiency of 31.6% for fully-textured perovskite/silicon tandem solar cells. In addition, highlights on Fraunhofer ISE's current work on scaling and triple-junction solar cells will be presented.

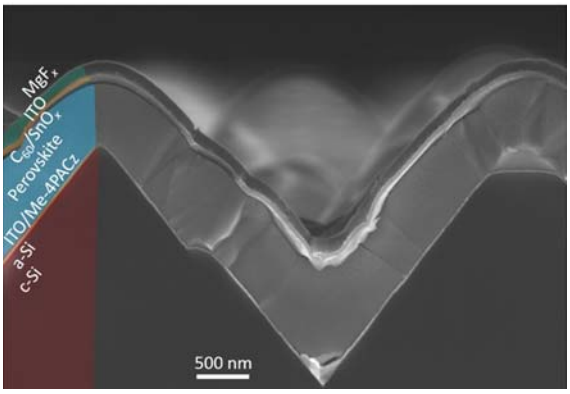

Fig.1: Cross-sectional scanning electron microscopy image of a perovskite top solar cell on a µm-sized textured silicon bottom solar cell.

Towards scalable and durable perovskite/silicon tandem and triple-junction solar cells

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Abstract

This contribution will provide an overview of the latest results from CSEM and EPFL PV-Lab on 2-terminal perovskite/silicon tandem and perovskite/perovskite/silicon triple-junction solar cells, with a particular focus on scalability and durability.

Developments of industry-compatible manufacturing techniques will be discussed, with emphasis on the perovskite absorber and front-side metallisation. In particular, replacing the thermally evaporated metallisation grid of lab-scale devices with a screen-printed electrode will be shown to induce only minimal performance losses thanks to the favourable thermal budget of the perovskite absorber: power conversion efficiencies above 33% are maintained. The use of low-silver-content metallisation pastes will also be demonstrated to have only a marginal impact on device performance, thereby improving sustainability. The applicability of screen printing for the metallisation of record-efficiency (>30%) perovskite/perovskite/silicon triple-junction solar cells will also be addressed [1].

From a durability perspective, cell- and module-level modifications leading to improved resilience to thermal cycling and light soaking at elevated temperature stress will be presented. These results will be complemented by a concise overview of the key degradation pathways that need to be mitigated to extend the operational lifetime of perovskite-based multi-junction solar cells.

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From Fast Laser Deposition to Sustainable Solar Cells

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Abstract

Metal halide perovskites (MHPs) enable perovskite/silicon tandem solar cells with efficiencies exceeding 34%, but scalable fabrication remains a key challenge. While solution processing dominates, physical vapor deposition (PVD) approaches are still underexplored. Here, we demonstrate pulsed laser deposition (PLD) as a single-source PVD technique to form the inorganic scaffold in a hybrid sequential process. A PbI_2:CsBr (10:1) layer is deposited at rates >100 nm min^{-1}, ten times faster than conventional PVD methods. Structural and morphological analyses confirm stoichiometric transfer, polycrystalline films, and porous structures. Subsequent solution conversion yields $Cs_xFA_{1-x}Pb(Br_yI_{1-y})_3$ absorbers with tunable bandgaps. Proof-of-concept tandems demonstrate efficiency 25.9%, highlighting the potential of laser-based vapor deposition for high-throughput tandem fabrication.

In parallel, we address sustainability challenges associated with the material utilization and high consumption of ITO-coated glass substrates. We introduce a simple acetone-based reuse method that preserves substrate quality without harsh chemicals. Life cycle assessment shows reduced CO_2 emissions with repeated reuse, while devices maintain efficiency over multiple cycles. These results together demonstrate a pathway toward scalable and more sustainable perovskite solar cell research.

Key words: pulsed lased deposition, rapid deposition, sustainability

Wide-Bandgap Perovskite Solar Cells for Underwater Photovoltaics: From Experimental Demonstration to Simulation-Guided Device Engineering

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Abstract

Autonomous underwater sensors, marine monitoring platforms, and Internet-of-Things (IoT) systems require compact and sustainable power sources; however, underwater solar energy harvesting is fundamentally constrained by strong spectral filtering and photon-flux attenuation in water [1,2]. Since water strongly absorbs red and near-infrared wavelengths while transmitting blue–green light more effectively, wide-bandgap photovoltaic absorbers are particularly attractive for underwater operation [3].

In this presentation, I will discuss our recent progress on perovskite solar cells for underwater photovoltaics, combining laboratory-scale experiments with simulation-guided device engineering. First, I will present the experimental demonstration of perovskite solar cells operating in seawater and deionized water environments. The fabricated device achieved a power conversion efficiency of 14.29% under standard illumination in air and delivered power densities of 10.49 and 11.88 mW cm^{-2} at a depth of 10 cm in seawater and deionized water, respectively. External quantum efficiency measurements further revealed that the spectral response of the perovskite solar cell remains largely preserved within the 400–800 nm wavelength range underwater, whereas conventional silicon solar cells experience significant degradation in the infrared region due to strong water absorption. Building upon these experimental findings, I will also present recent simulation studies exploring wide-bandgap and environmentally friendly lead-free perovskite absorbers for next-generation underwater photovoltaic systems. The simulations investigate the impact of underwater spectral filtering, operating conditions, and interface engineering on photovoltaic performance under depth-dependent underwater illumination. The results indicate that wide-bandgap absorbers exhibit improved spectral compatibility with underwater environments, while optimized interfacial engineering can enhance carrier selectivity and suppress recombination losses under low-irradiance operation.

Overall, this work highlights the potential of spectrally matched wide-bandgap perovskite photovoltaics for next-generation underwater energy harvesting and autonomous marine sensing applications, while providing insights into the design of photovoltaic technologies specifically optimized for underwater environments.

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Degradation monitoring of tandem solar cells

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Abstract

We developed a bi-chromatic (470nm and 940nm) LED stability testing setup with integrated photoluminescence (PL) and electroluminescence (EL) imaging capabilities, which utilize for accelerated ageing, stability testing and in-situ characterisation of perovskite-silicon tandems. In our work we focused on studying the effects of sub-cell current mismatch (CMM) on the degradation rate of the perovskite sub-cell (and tandem as a whole) on encapsulated 4 cm^2 tandems. The samples were subjected to 1-sun illumination and kept at a constant temperature of 25°C at their MPP, initially at current matched conditions ($J_{ph\_PK} = J_{ph\_SI}$). After MPP stabilised, the IR light intensity was cycled periodically ensuring current mismatches up to ± 4 mA/cm^2 all while keeping the blue light intensity constant and ensuring constant excitation of the perovskite sub-cell. Additionally, we performed periodical (1h) in-situ electrical characterisation using the pulsed *I-V* method effectively "freezing" the ionic distribution within the perovskite sub-cell therefore probing the *I-V* corresponding to the current operating point. Additionally, periodic luminescence images (PL/EL) at different electrical biases were captured as well, in order to track the spatially resolved degradation of the perovskite sub-cell in real time. Our preliminary results show that in addition to a decrease in key perovskite/tandem performance metrics (I_{SC}, FF) degradation is faster albeit masked in the silicon limited phase, showing strong correlation with the increase of sub-cell CMM, whereas in the perovskite limited phase an initial increase in the overall power can be observed. This becomes more prominent with larger CMM and prolonged time under illumination owing to an increased mobile ion density, which is confirmed by increased variance during MPP tracking and a clear deflation of the bias dependent pulsed *I-V*s. Owing to periodic luminescent images we can correlate the decrease in the I_{SC} to an overall degradation of parts of the absorber as well as deterioration of the ETL/HTL interface leading to reduced extraction of photogenerated charge carriers.

Universal Formation Mechanism of Halide Perovskite Thin Films

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Abstract

Using in situ photoluminescence (PL) and GIWAXS measurements, we studied the formation of halide perovskite (HP) thin films prepared by various deposition methods. Based on the results, we divide the growth into two stages. In the first stage, rapid grain growth observed by GIWAXS is accompanied by a proportional increase in PL intensity. In the second stage, the growth rate significantly decreases and the PL signal is strongly quenched. This indicates that once grains start to coalesce, highly defective grain boundaries are formed, leading to a rapid decrease in PL.

The same behaviour was observed for solution-processed, evaporated, pizza-oven deposited (EPFL), and pulsed laser deposited (University of Twente) films. A deeper understanding of this universal formation mechanism provides a unique opportunity to improve optoelectronic quality during the deposition, leading to higher open circuit voltage on the device level. Precisely timed passivation targeting grain boundaries is key to minimizing defect densities, and in situ PL can effectively guide this process, as will be demonstrated for evaporated films in-situ passivated by KCl.

Keywords: Formation of halide perovskites, photoluminescence, GIWAXS, defects, grain boundaries

High-throughput experimentation and use of artificial intelligence for materials research

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Abstract

Machine learning has become a ubiquitous tool in materials research, yet its impact depends critically on access to large, consistent, and well-annotated experimental datasets — a persistent bottleneck in photovoltaics research. I will present our infrastructure for the automated fabrication, characterization, and degradation testing of organic and perovskite solar cells, and how it integrates with a workflow for the automated storage of measurement data and associated metadata in a FAIR database.

Building on this data foundation, I will present an example in which we use input parameters — such as processing conditions or molecular features — to predict key device properties such as power conversion efficiency (PCE), average visible transmittance (AVT), and operational lifetime. For instance, we predict the open-circuit voltage from the absorption spectrum [1]. I will also present an example of how we infer device parameters — such as absorption cross section, mobility and recombination constants — by combining current-voltage, transient absorption and absorptance measurements [2].

Finally, I will demonstrate an inverse-design workflow, in which perovskite solar cells were optimized in a closed loop, employing molecular features obtained from DFT calculations [3]. For this we employ Bayesian optimization based on Gaussian process regression, which guides the selection of subsequent experiments. Starting from an initial dataset of 149 molecules, 48 new HTL molecules were synthesized and tested in two batches, reaching PCE values of up to 26.2%.

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Solution and interface engineering to overcome limitations in tin-based perovskite photovoltaics

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Abstract

Metal halide perovskites offer a vast compositional landscape, within which tin-based compounds have emerged as the most promising alternative to the dominant lead systems. Their narrower bandgap and favorable optoelectronic properties position them as strong candidates to surpass the performance of conventional lead-based devices, with reported power conversion efficiencies approaching 18%. Despite this potential, their poor reproducibility and complex processing conditions have limited their interest and adoption across perovskite photovoltaic laboratories. This talk will show how a detailed understanding of solution and interface chemistry provides critical insight into these limitations, enabling innovative strategies to overcome the intrinsic constraints of current systems and outlining the directions to realize the potential of tin-based perovskite photovoltaics.

Differences in the degradation pathways of 2D lead- and tin-based perovskite compositions

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Abstract

This work presents a comparative analysis of the stability and degradation mechanisms of two-dimensional (2D) Ruddlesden–Popper halide perovskites, focusing on lead-based and tin-based compositions containing 2-thiopheneethylammonium (TEA) and 4-fluorophenethylammonium (FPEA) spacer cations. While 2D perovskites are generally more stable than their 3D counterparts, fundamental differences between lead-based and tin-based materials remain insufficiently understood.

We demonstrate that lead-based 2D perovskite compositions exhibit higher environmental stability but undergo degradation due to the chemical instability of organic cations which has been confirmed by detection of outgassing of volatile species such as NH_3. In contrast, Sn-based perovskites degrade more rapidly yet follow fundamentally different pathways since organic ammonium halide cations (TEA^+/$FPEA^+$) do not show evidence of chemical decomposition. This difference is attributed to the fact that Sn^{2+} cation oxidation dominates degradation in tin-based systems, while iodide oxidation and organic cation decomposition govern Pb-based materials.[1]

Furthermore, the influence of spacer cation choice is highlighted. TEA-based Sn perovskites exhibit improved stability over FPEA analogues. Additive engineering using $SnCl_2$ and 3-phosphonopropionic acid (3PPA) is also shown to enhance stability by suppressing Sn^{2+} oxidation and passivating defects.[2],[3]

These findings provide critical insight into degradation pathways in 2D perovskites and offer strategies for improving the stability of lead-free tin-based perovskite materials for optoelectronic applications.

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Outdoor cross-location stability comparison of perovskite solar cells

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Understanding the impact of climate on the operational stability of perovskite solar cells (PSCs) is essential for their successful deployment in real-world photovoltaic applications. To investigate climate-dependent degradation mechanisms, a coordinated outdoor experiment was initiated on 14 April 2026 across three European test sites representing different Köppen–Geiger–Photovoltaic (KGPV) climate conditions: Jaén, Spain, Berlin, Germany, and Ljubljana, Slovenia.

Identical measurement systems have been installed at all locations. Each site hosts four substrates containing six perovskite solar cells each. All devices originate from the same fabrication batch and were manufactured and laminated at the Laboratory of Photovoltaics and Optoelectronics (LPVO) in Ljubljana, ensuring consistent device quality across the study. The cells are continuously operated at their maximum power point (MPP), while environmental parameters including air temperature, solar irradiance, and solar spectrum are monitored simultaneously.

Preliminary observations from the first three months of operation indicate clear differences in device behaviour between the test locations. The PSCs deployed in Jaén show the first signs of power loss, whereas no measurable degradation has yet been observed at the Berlin and Ljubljana sites. These initial findings coincide with the higher temperatures recorded at the Spanish location and suggest that temperature may be a key driver of early-stage outdoor degradation.

This experiment represents one of the first harmonized cross-location outdoor studies designed to assess PSC stability under distinct climatic conditions. As the monitoring campaign continues, the collected dataset will enable a systematic evaluation of the relative influence of temperature, irradiance, spectral variations, and other environmental factors on perovskite solar cell degradation, providing valuable insights for future reliability assessment and lifetime prediction models.

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ABSTRACTS

Poster

Data-driven theoretical, experimental, and machine learning study of perovskite optoelectronic properties for green energy applications

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Abstract

Perovskite materials have emerged as highly promising candidates for next-generation optoelectronic and photovoltaic applications, owing to their tunable bandgaps, strong optical absorption, and high carrier mobility. However, a comprehensive understanding of the relationship between their structure and optoelectronic performance remains incomplete. This work presents an integrated theoretical, experimental, and machine learning approach to investigate the optoelectronic properties of selected perovskite materials. First-principles density functional theory (DFT) calculations are performed using Quantum ESPRESSO to predict key structural, electronic, and optical parameters. Experimental characterization, including X-ray diffraction (XRD), UV–Vis spectroscopy, and photoluminescence measurements, is carried out to validate and complement the computational results. Machine learning models are then developed on the combined dataset to uncover hidden structure–property relationships and accelerate the identification of high-performance materials. This data-driven framework is expected to contribute to the rational design and optimization of perovskite-based optoelectronic and solar cell devices.

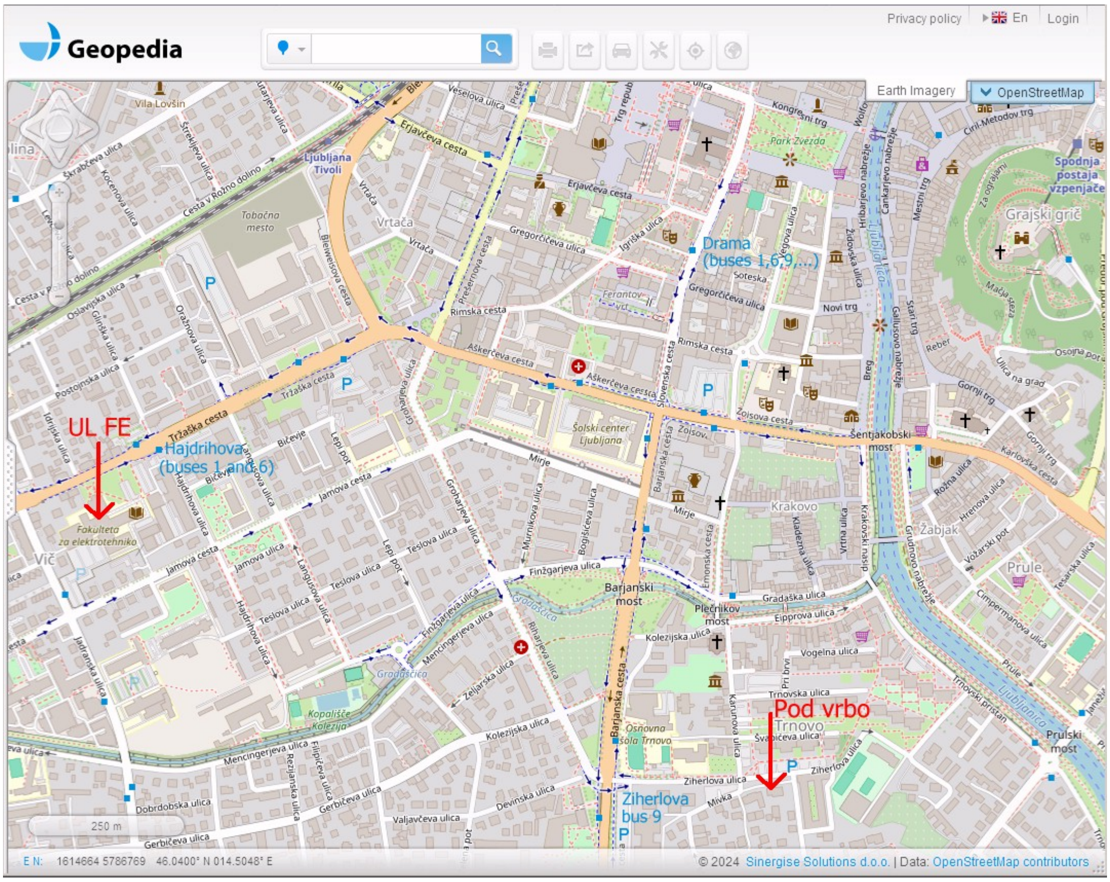
Keywords: Perovskite materials; Density Functional Theory (DFT); Experimental characterization; Machine learning; Data-driven materials discovery; Structure–property relationships.

Free WiFi connection

SSID: **FE-Guest**
User name: **pv01**
Password: **6818**

Workshop dinner

Tuesday dinner will be in restaurant **Pod vrbo** (literally *under the willow tree*).
Time: **19:00**
Transport:
- by walking: Due to close distance (1.4 km) we recommend walking. Go to the street south of the faculty (Jamova cesta, parallel with Tržaška road), turn left in the direction of center. At fourth crossing (about 500 m) turn right to Groharjeva street (ulica). Follow it to the end (600 m) where it turns left to Barjanska road (cesta). When you cross the road, you are on Ziherlova street. After 280 m the restaurant is on the right.
- by public transport: At the crossing with Barjanska road there is station Ziherlova, served by bus 9, which runs through the center and the main bus/railway station. You can switch with many other buses incl. 1 and 6 at Drama (two stations away).



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