AMANDA – A Materials Acceleration Platform for solution processed semiconductor research

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part of JÜLICH Forschungszentrum

in cooperation with FAU Friedrich-Alexander Universität Erlangen-Nürnberg, HZB Helmholtz Zentrum Berlin

What we do….

Photovoltaics

Core Competencies

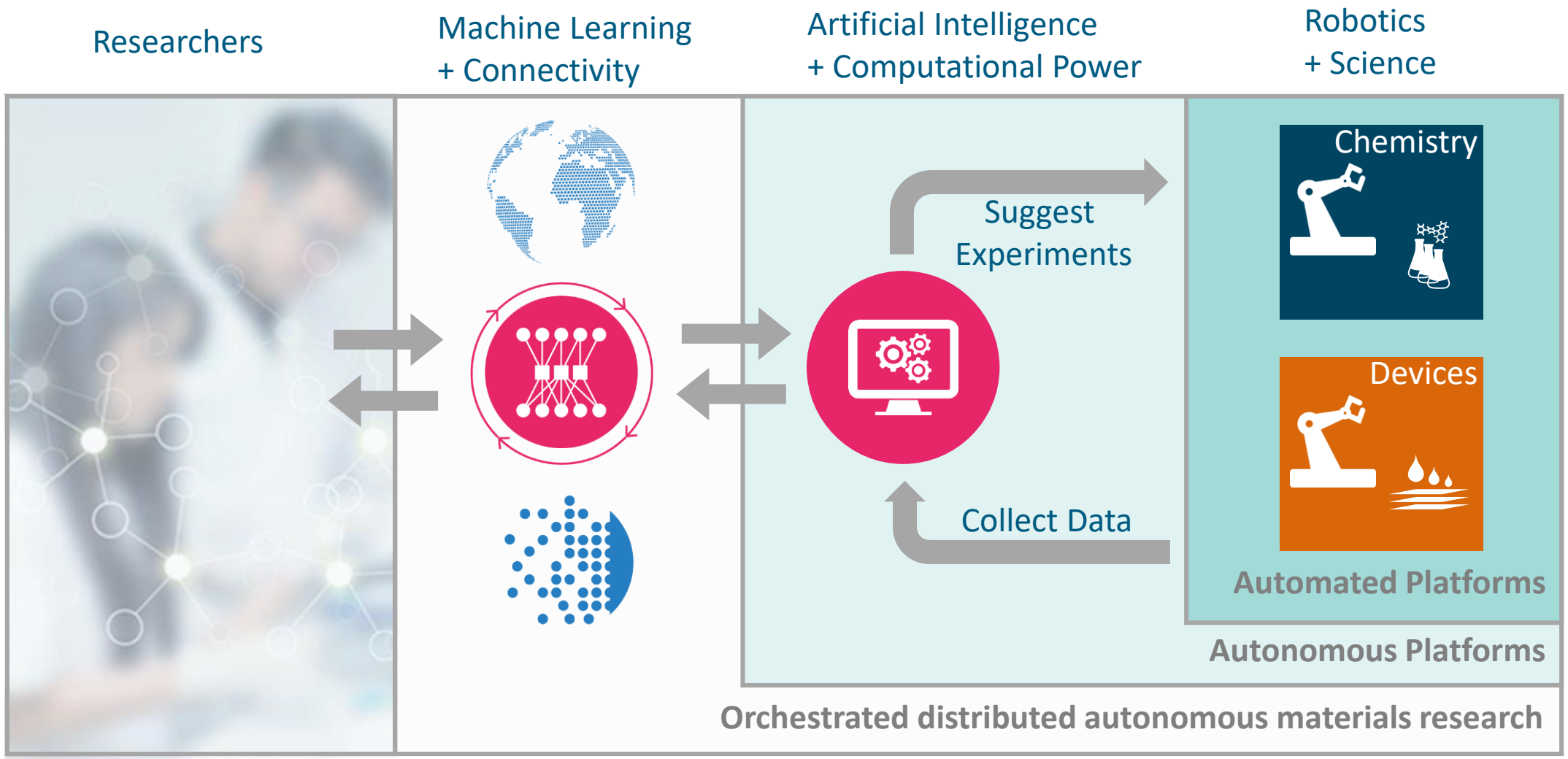
- Physics of Photovoltaics
- PV-Systems & Failure mechanisms
- Materials Science & Development
- Solution processable Semiconductors
- Imaging IR Methods

Big Data

Big Data Methods

- Automation & Robotics
- Artificial Intelligence & Machine Learning
- Data Bases
- FAIR Data

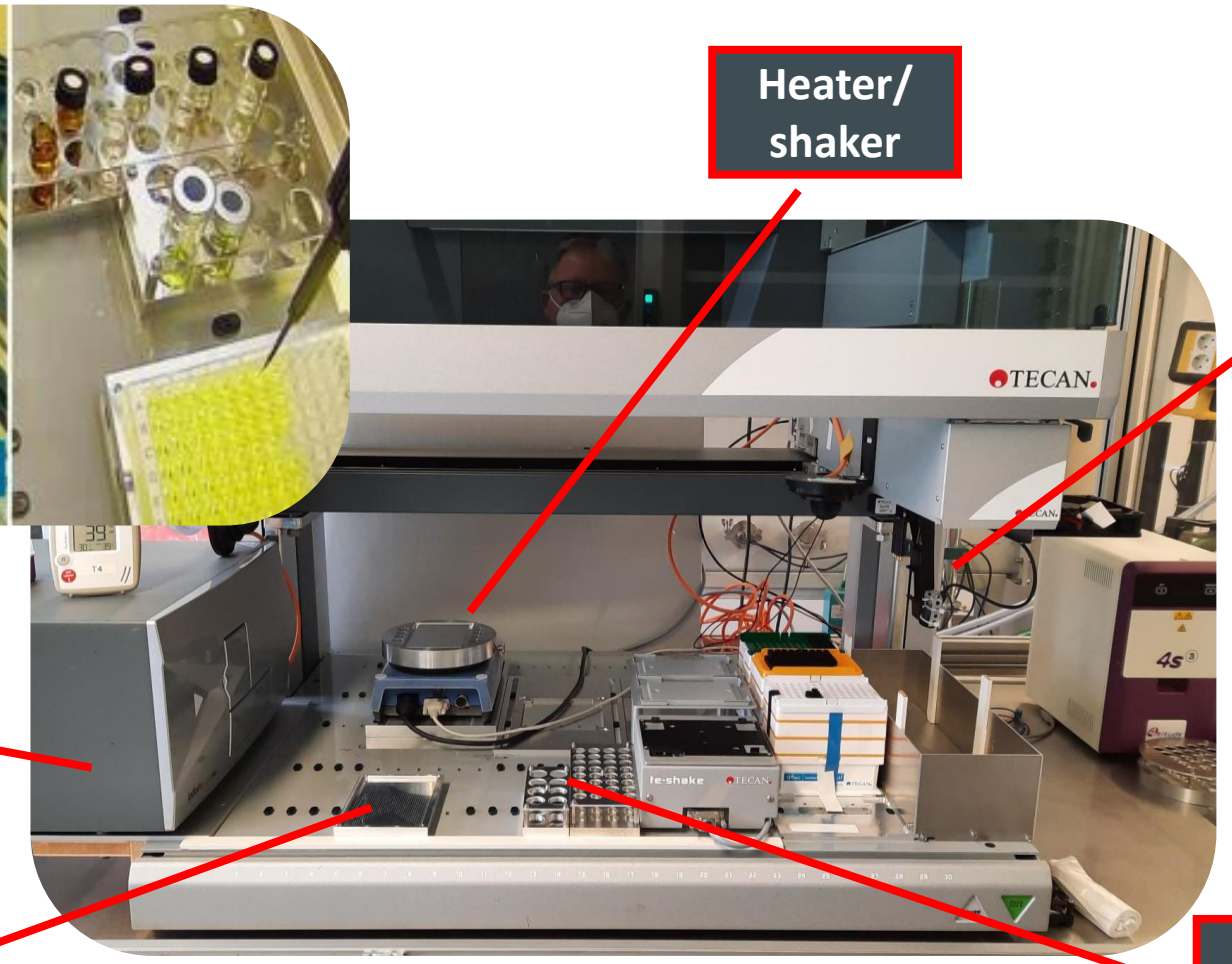
Virtual Access Platform for Materials Discovery



10x Acceleration of the discovery of complex functional materials

Synthesis and Ink Formulation

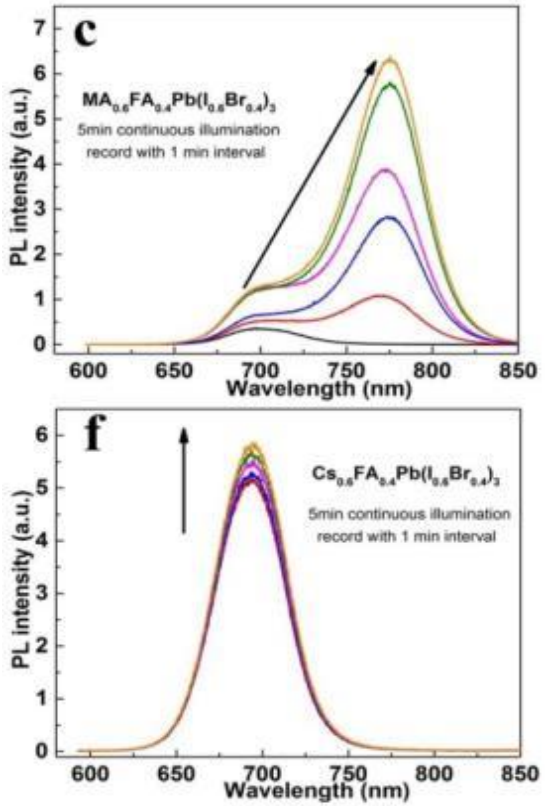
Automated Pipetting System and Spectrometer => Synthesis and Drop-casting



Automated Synthesis and Characterization of Perovskites

ADVANCED ENERGY MATERIALS

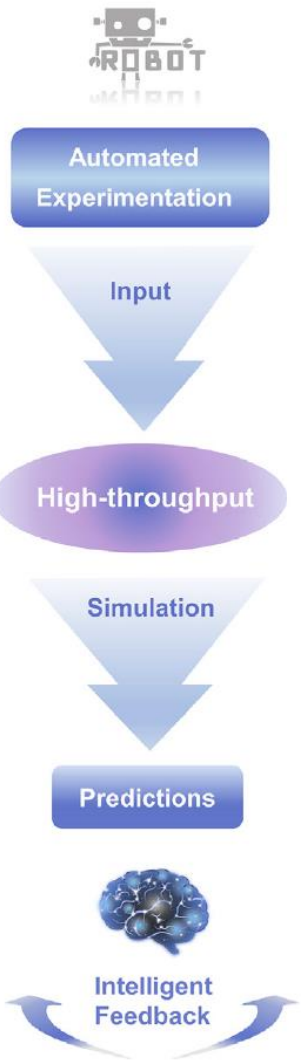
Pristine	Doping content (at.%)	0	10	20	30	40	50	60	70	80	90	100
$MAPbI_3$	$MAPbBr_3$	770	764	730	714	690	659	632	609	589	569	545
		1.00	0.93	1.78	0.53	0.49	0.49	1.66	3.89	2.95	0.88	5.62
		1.49	1.51	1.59	1.68	1.76	1.77	1.85	1.93	1.99	2.02	2.18
	$FAPbBr_3$	772	766	714	711	679	660	625	609	594	574	550
		1.00	0.84	4.37	0.02	4.72	19.59	2.26	3.64	1.32	1.59	7.98
		1.50	1.51	1.58	1.68	1.76	1.80	1.91	1.96	2.01	2.07	2.16
	$FAPbI_3$	762	763	775	776	777	778	781	795	798	793	787
		1.00	1.24	1.24	2.06	1.68	2.59	3.15	12.50	11.85	18.05	6.45
		1.50	1.50	1.50	1.48	1.47	1.47	1.46	1.46	1.46	-	-
	$CsPbI_3$	763	757	762	756	754	750	746	745	-	-	-
		1.00	1.68	1.65	1.85	1.30	1.72	0.65	0.31	-	-	-
		1.50	1.52	1.53	1.53	1.54	1.54	1.55	1.56	-	-	-
$FAPbI_3$	$MAPbBr_3$	785	779	770	745	709	687	660	641	624	608	544
		1.00	2.01	2.31	3.79	0.97	0.89	0.29	0.42	0.20	0.14	1.53
		-	1.52	1.53	1.60	1.73	1.77	1.79	1.82	1.91	1.97	2.16
	$FAPbBr_3$	786	784	764	743	704	680	656	639	612	580	549
		1.00	2.21	4.98	2.28	1.81	0.66	0.58	0.65	0.38	0.06	1.11
		-	1.53	1.55	1.65	1.74	1.81	1.85	1.89	1.95	2.05	2.17
	$CsPbI_3$	787	781	777	783	790	801	-	-	-	-	-
		1.00	2.33	4.06	1.95	0.75	0.84	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-
$CsPbI_{3áá}$	$MAPbBr_3$	-	-	-	661	660	659	650	615	590	555	543
		-	-	-	0.72	0.73	0.93	0.67	0.32	0.37	0.09	1.00
		-	-	-	1.74	1.75	1.76	1.80	1.80	1.85	2.06	2.17
	$FAPbBr_3$	-	-	-	753	720	715	685	651	621	571	546
		-	-	-	7.10	7.92	4.85	1.37	0.21	0.25	0.34	1.00
		-	-	-	1.65	1.74	1.76	1.80	1.90	1.93	2.08	2.16
$MAPbBr_3$	$FAPbBr_3$	540.1	540.3	540.5	540.5	540.6	540.7	540.7	540.7	541.1	549.2	550.3
		1.00	1.06	3.59	7.42	2.60	3.18	2.14	1.25	1.53	2.49	1.97
		2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.20	2.19	2.19	2.19

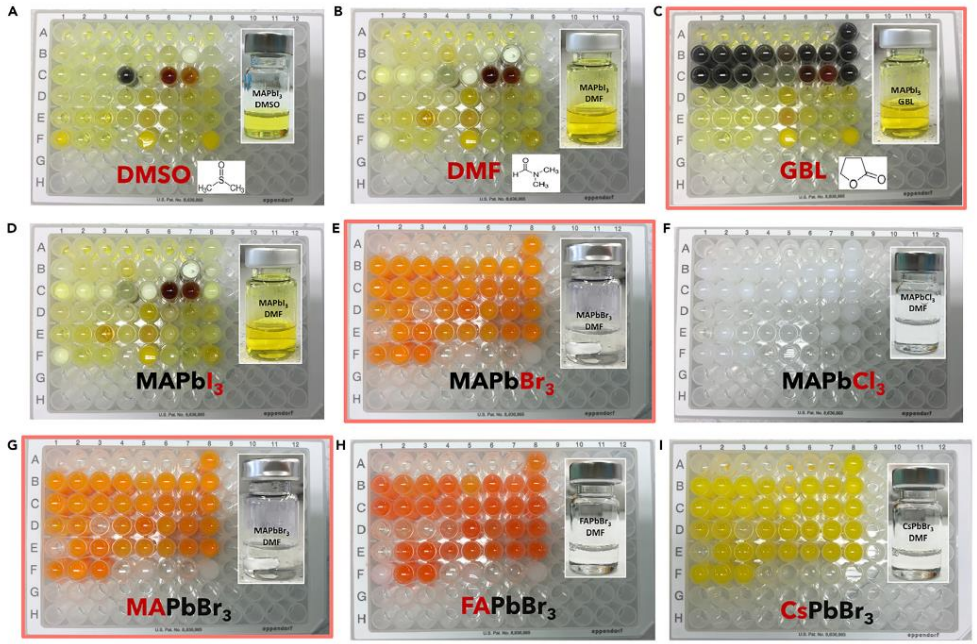


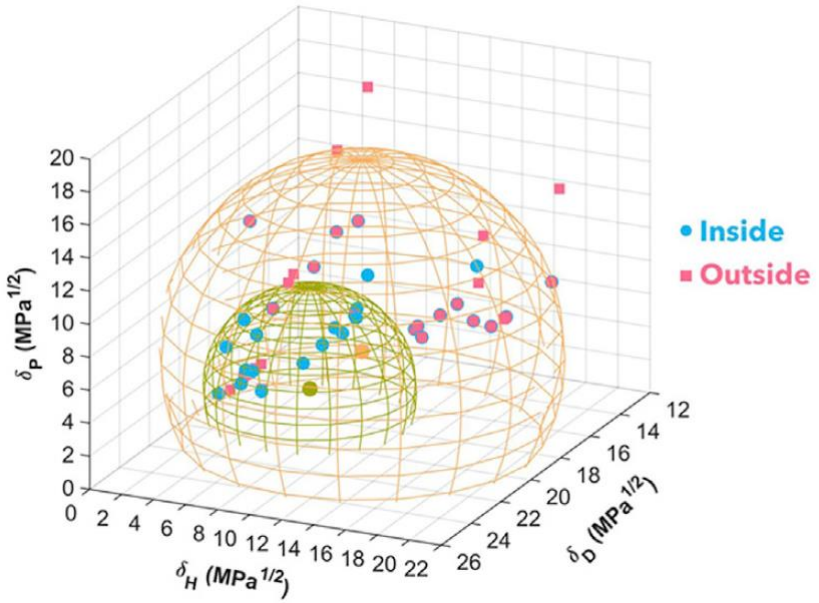
- Synthesis in 96-Well-Plates
- Charakterization in solution

Chen, S. et al. Exploring the Stability of Novel Wide Bandgap Perovskites by a Robot Based High Throughput Approach. **Adv. Energy Mater**. 8, 1701543 (2018). https://doi.org/10.1002/aenm.201701543

Automated Screening of Antisolvents for P Joule



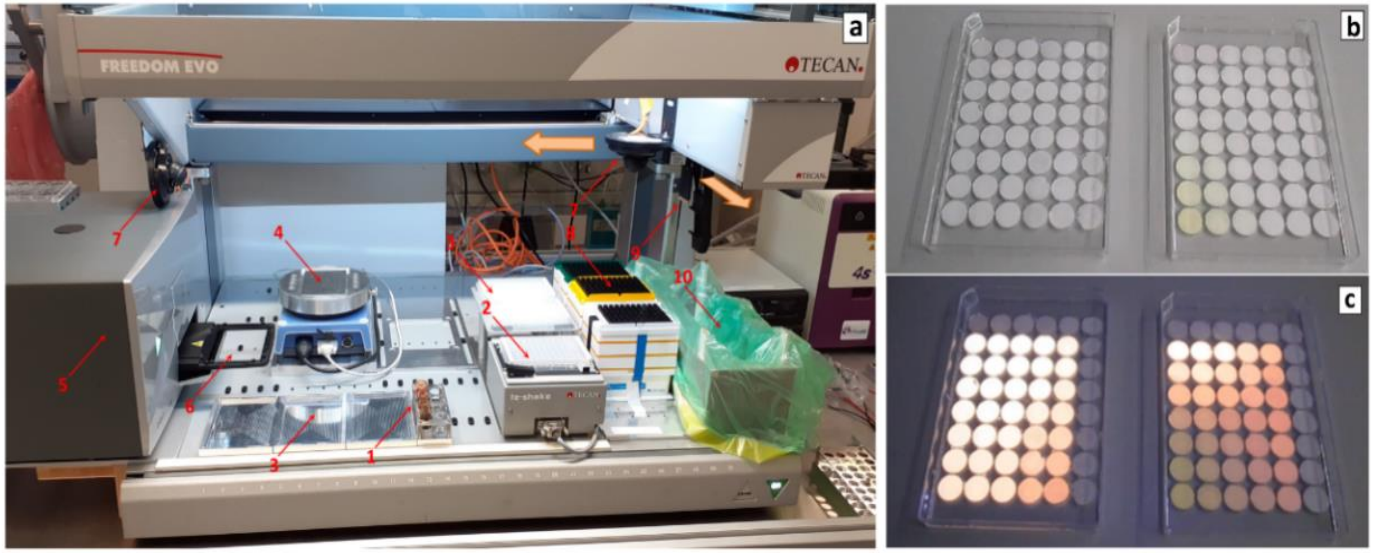




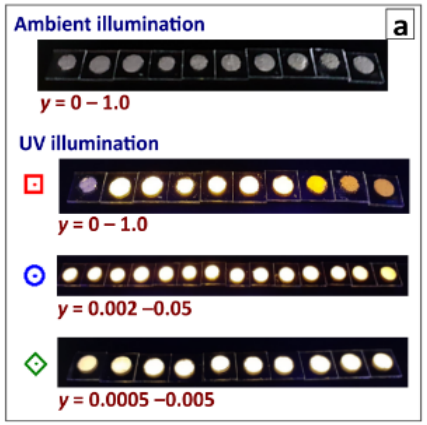
- Utilization of an automated platform for solvent engineering
- Combination of measurements and simulation
- Determination of Hansen Parameters to determine solvent space
- Creation of antisolvent database

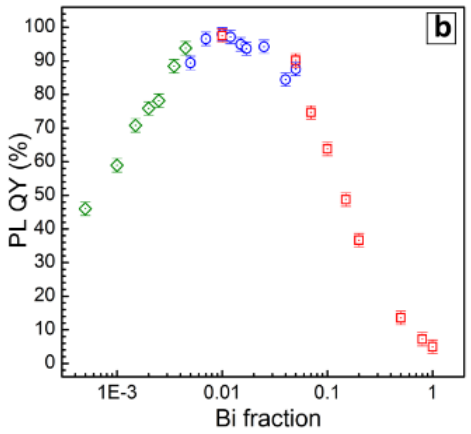
- Gu et al., Robot-Based High-Throughput Screening of Antisolvents for Lead Halide Perovskites, **Joule** (2020), https://doi.org/10.1016/j.joule.2020.06.013

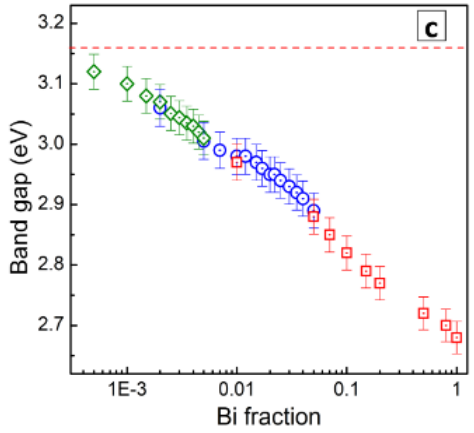
Synthesis of CANBIC lead-free perovskites

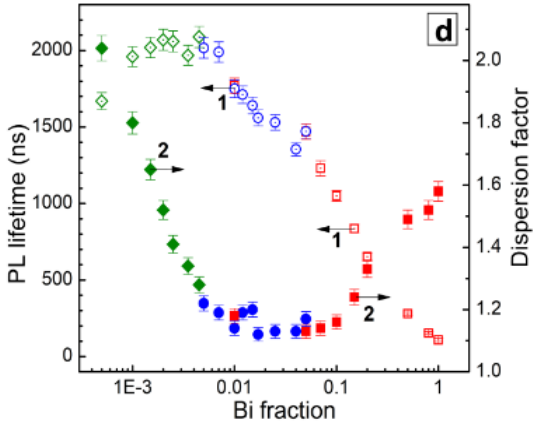


- Low temperature automated synthesis $Cs_2Ag_xNa_{1-x}Bi_yIn_{1-y}Cl_6$ (CANBIC) lead-free PSKs
- Variation of Bi content by 4 orders of magnitude
- Discovery of ~100% PLQY
- Charge carrier lifetimes of up 2µs

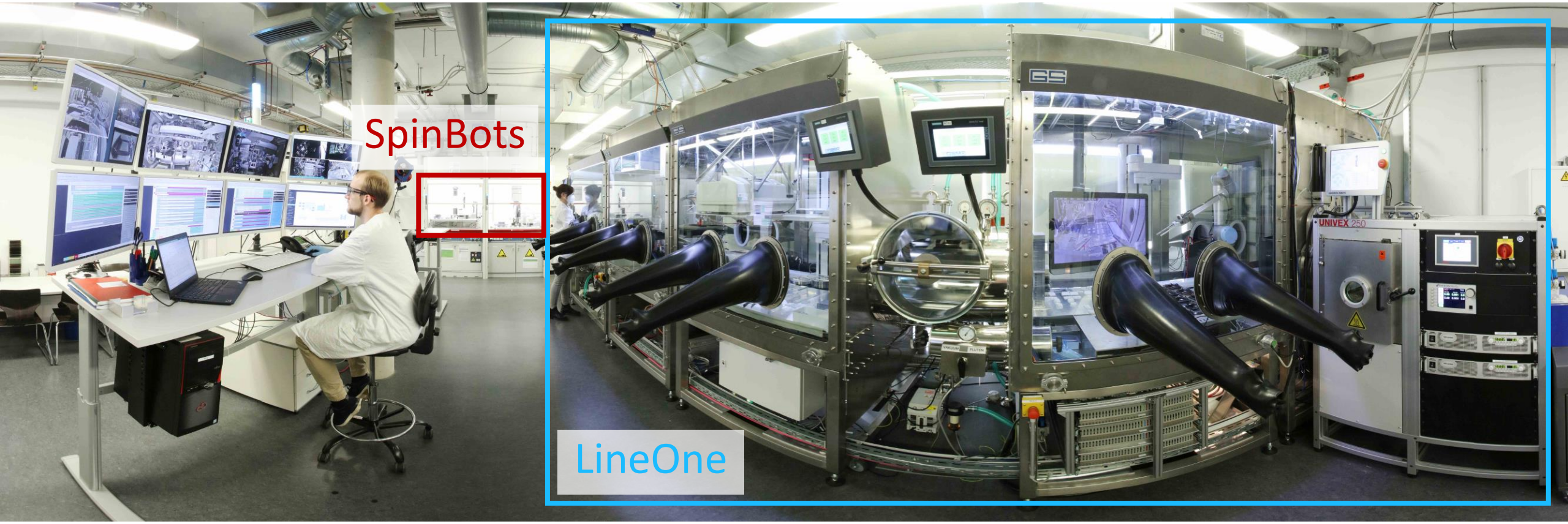






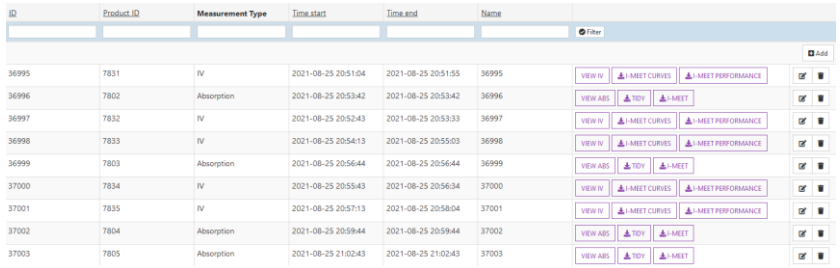


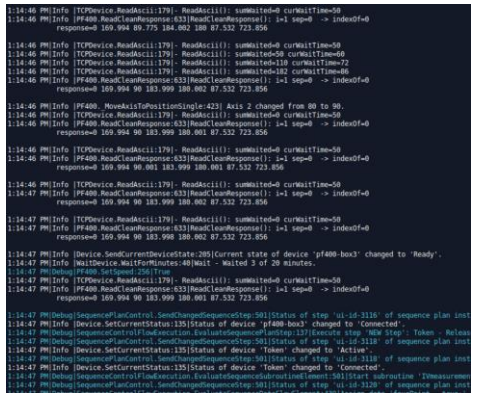
The AMANDA Lab



The AMANDA Platform – a System for Controlling Multiple Material Acceleration Platforms (MAPs)

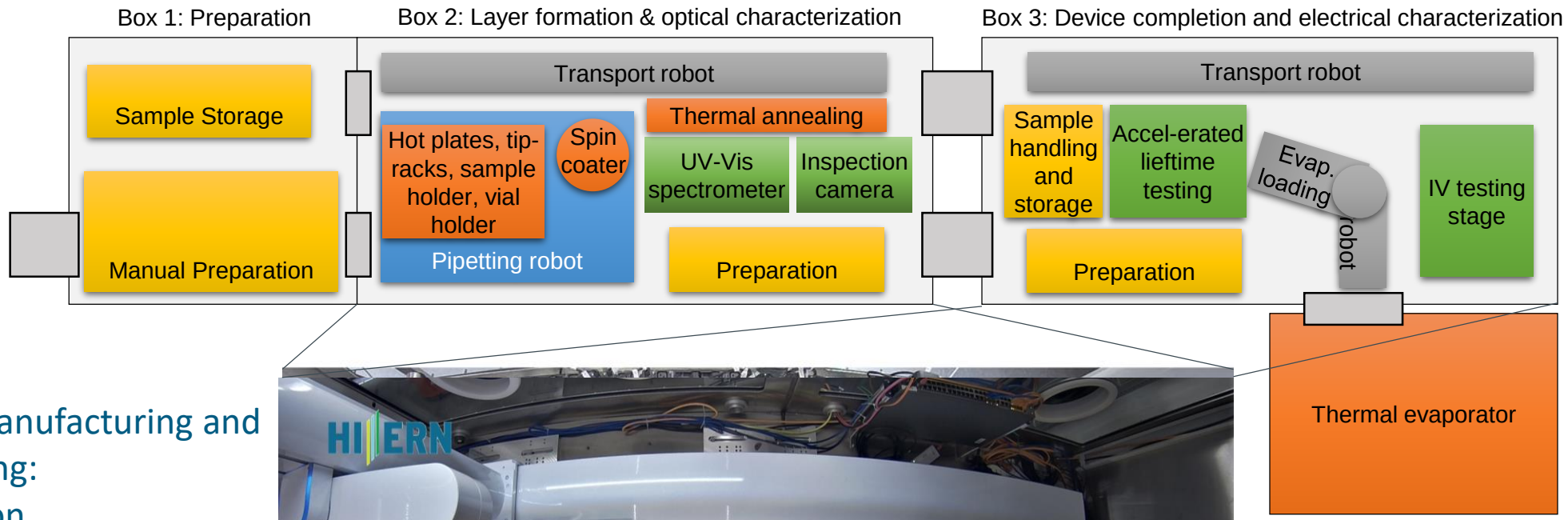
AMANDA - Platform





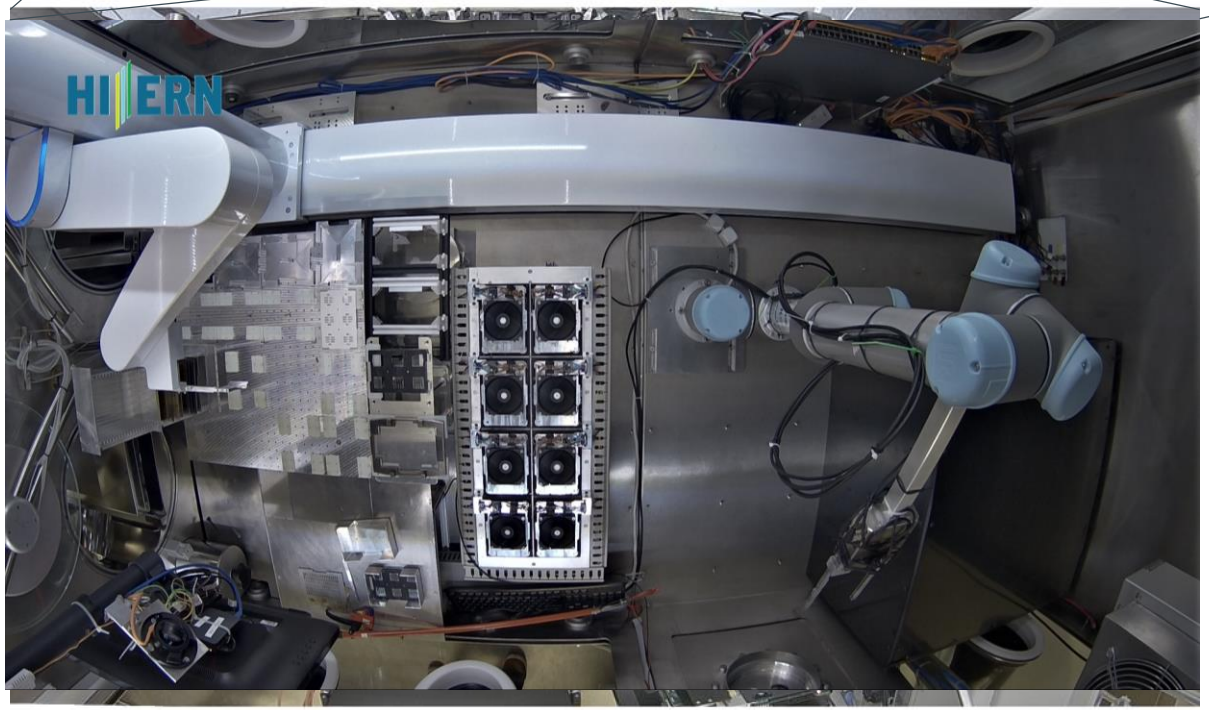
Wagner et al., The evolution of Materials Acceleration Platforms: toward the laboratory of the future with AMANDA, Journal of Materials Science (2021), https://doi.org/10.1007/s10853-021-06281-7

LineOne – An autonomous fabrication line for solution based solar cells

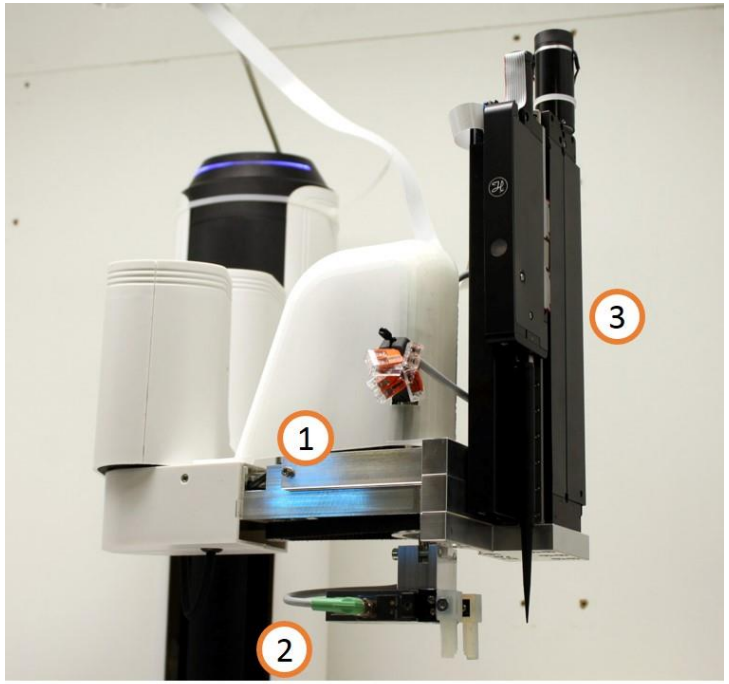


Features

- Fully automated OPV manufacturing and characterization including:
  - Solution preparation
  - Spin coating
  - Thermal annealing
  - Thermal evaporation
  - Optical absortion measurement
  - Electrical characterization
  - Accelerated lifetime testing
- Operating in inert atmosphere
- High flexibility in process design
- In-line ML integration



Spinbot – A Fully Automated Spin Coating Setup

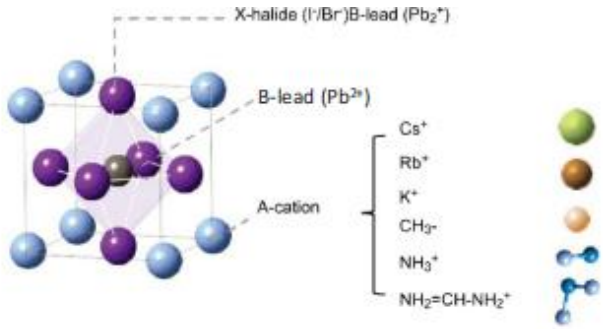


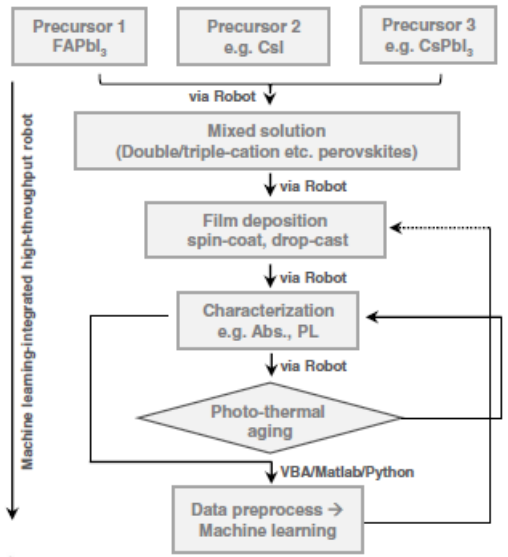
Scara-Robot (1), Gripper (2), pipetting channel (3)

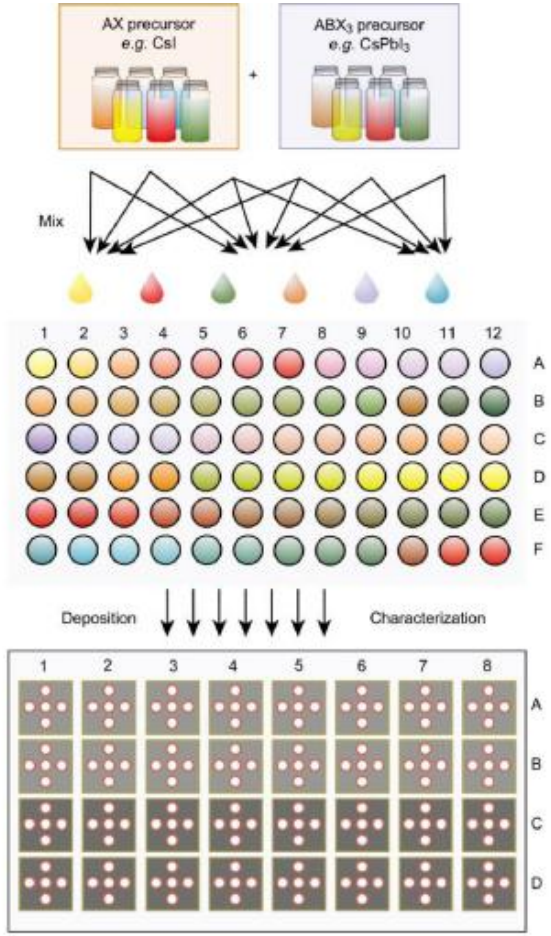
Features

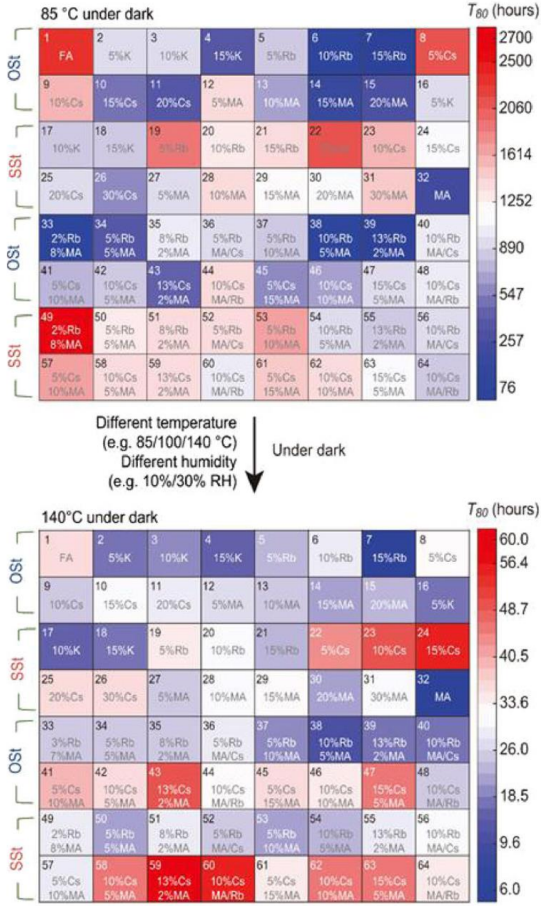
- Sample transport
- Pipetting
- Spincoating
- Thermal annealing

HT Investigation of PSK-Stability





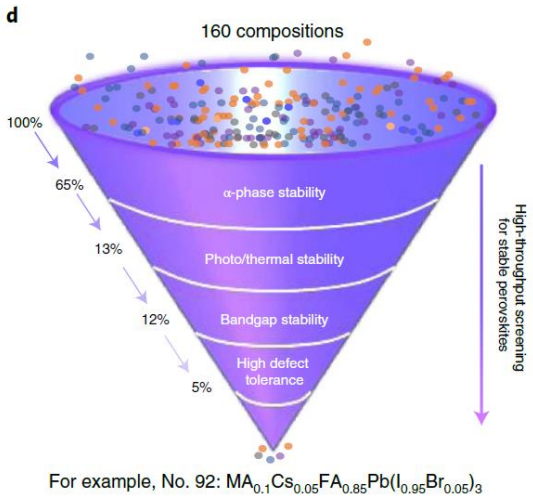


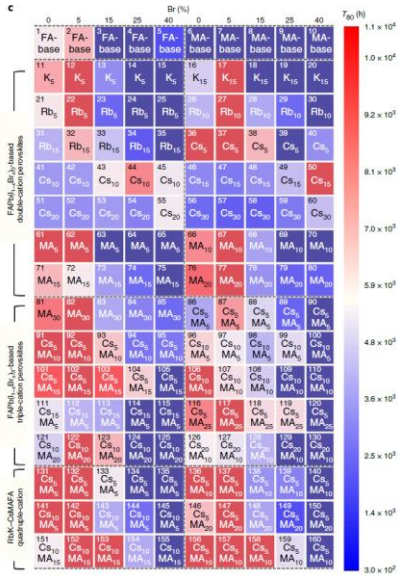


- **Testing the effect of various cations of device stability at various temperatures**
- **Discovery of „stability reversal“ for several compositions**

Y. Zhao et al.: Discovery of temperature-induced stability reversal in perovskites using high-throughput robotic learning, https://doi.org/10.1038/s41467-021-22472-x , **Nature Communications** (2021)

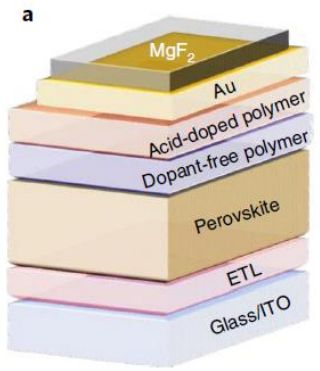
Ultrastable Perovskite Solar Cells with 1400hrs stability

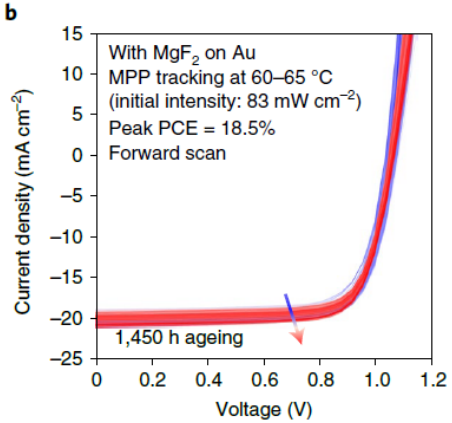




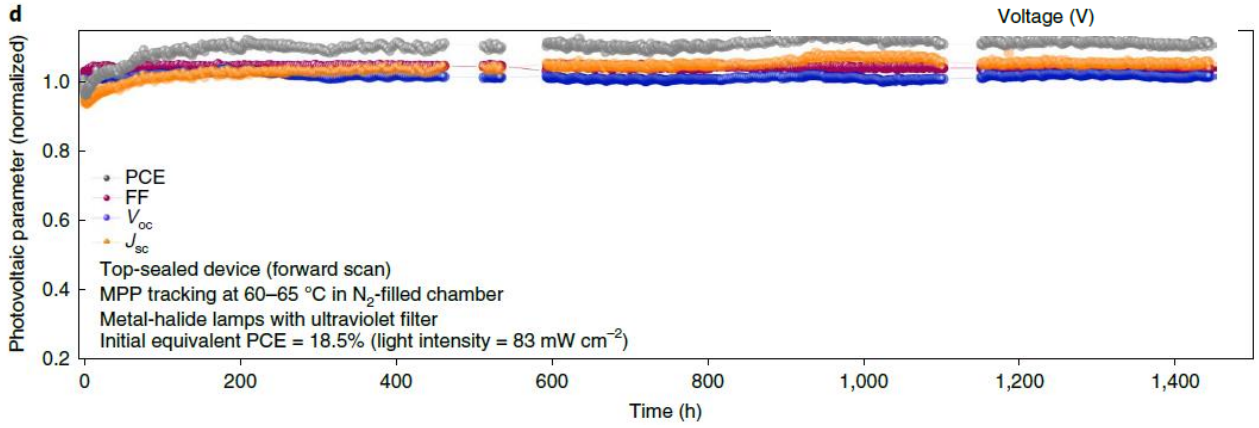
- Stability screening of 160 mixed cation, mixed halide perovskites
- Novel bilayer polymer hole transport layer
- Stabilized top electrode

nature energy



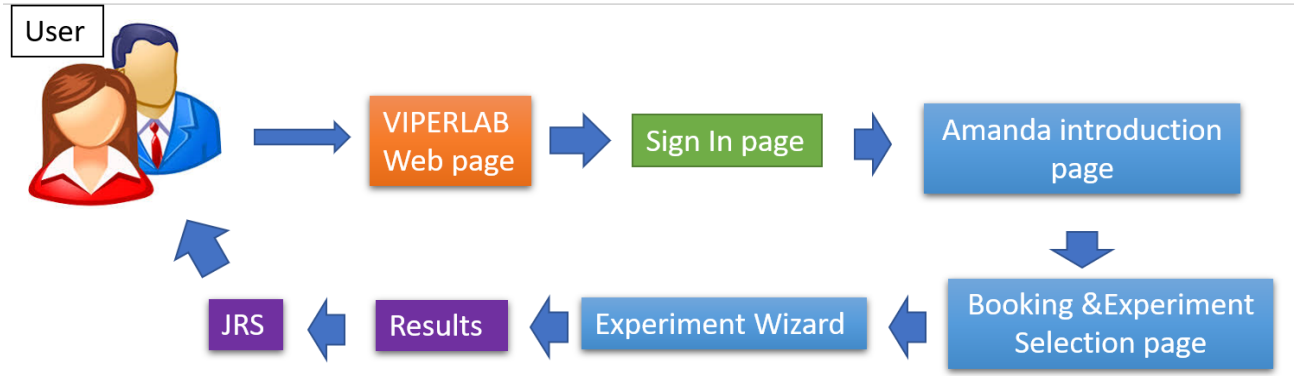


- More than 1400hrs operational stability @65°C/0.8suns
- No hysteresis



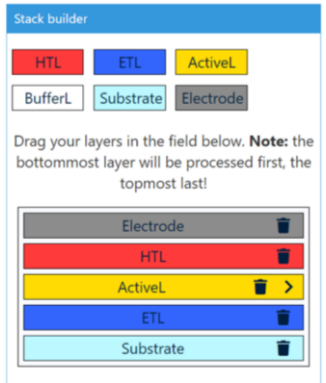
(1) Y. Zhao, T. Heumueller, J. Zhang, J. Luo, C. Berger, S. Langner, B. Liu, J. Elia, A. Osvet, J. Wu, C. Liu, N. Li, J. Hauch, C. J. Brabec: A bilayer-conducting-polymer structure for planar perovskite solar cells with over 1400 hrs operational stability at elevated temperatures; Nature energy (2021); DOI: 10.1038/s41560-021-00953-z

Virtual Access to AMANDA

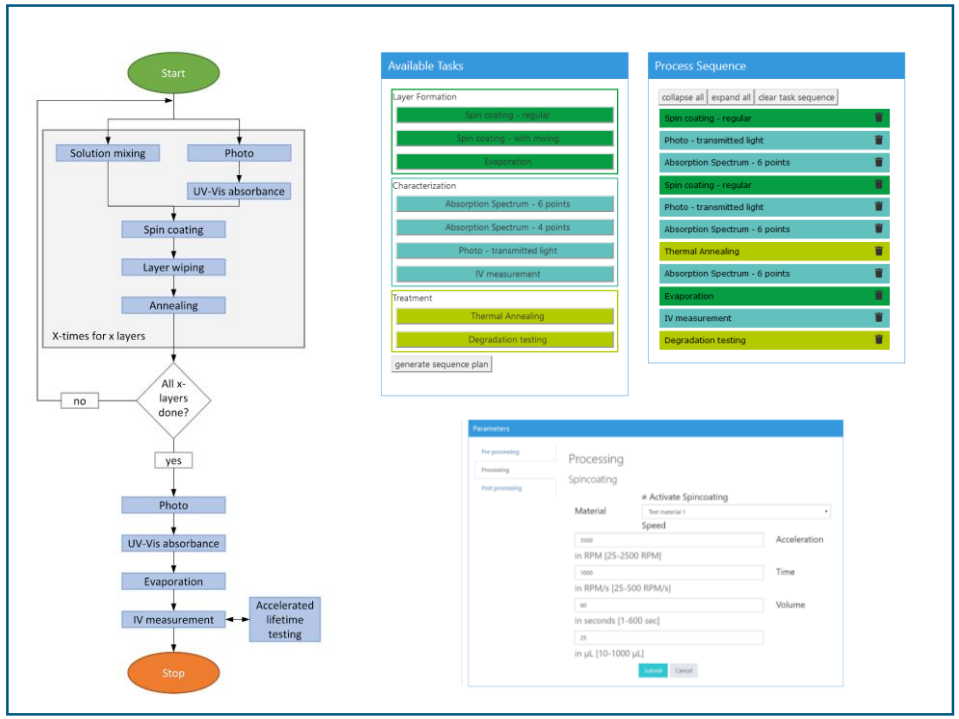


VIPERLAB
FULLY CONNECTED VIRTUAL AND PHYSICAL PEROVSKITE PHOTOVOLTAICS LAB

Stack Builder



Process Builder



Sequence Plan Generator

Experiment as a Service

HI ERN
Helmholtz Institute
Erlangen-Nürnberg

Thank you for your attention!

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METADATA COLLABORATION

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