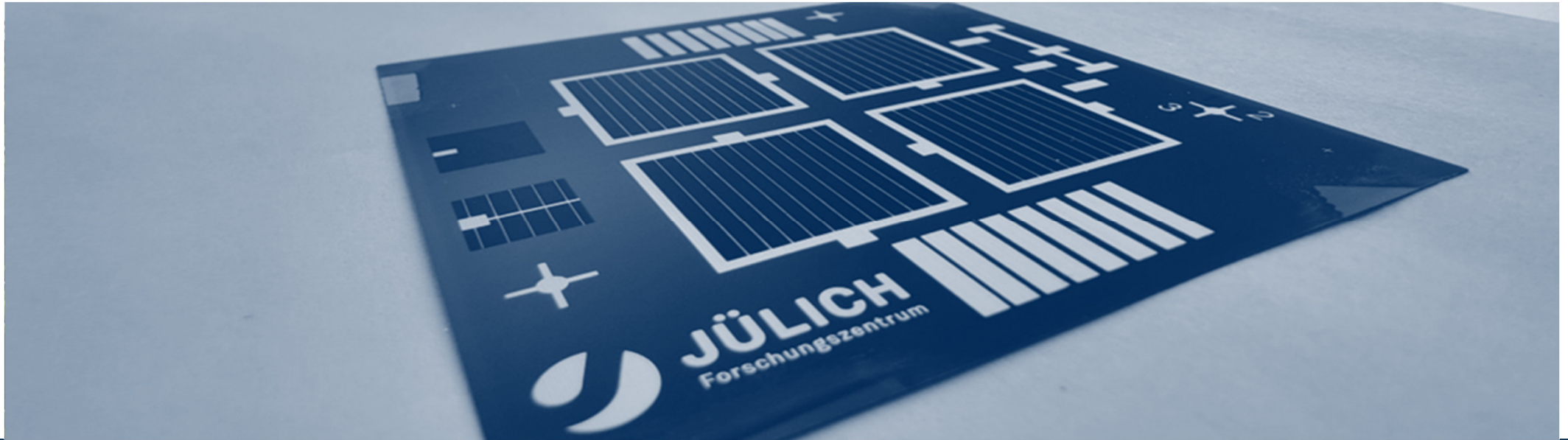




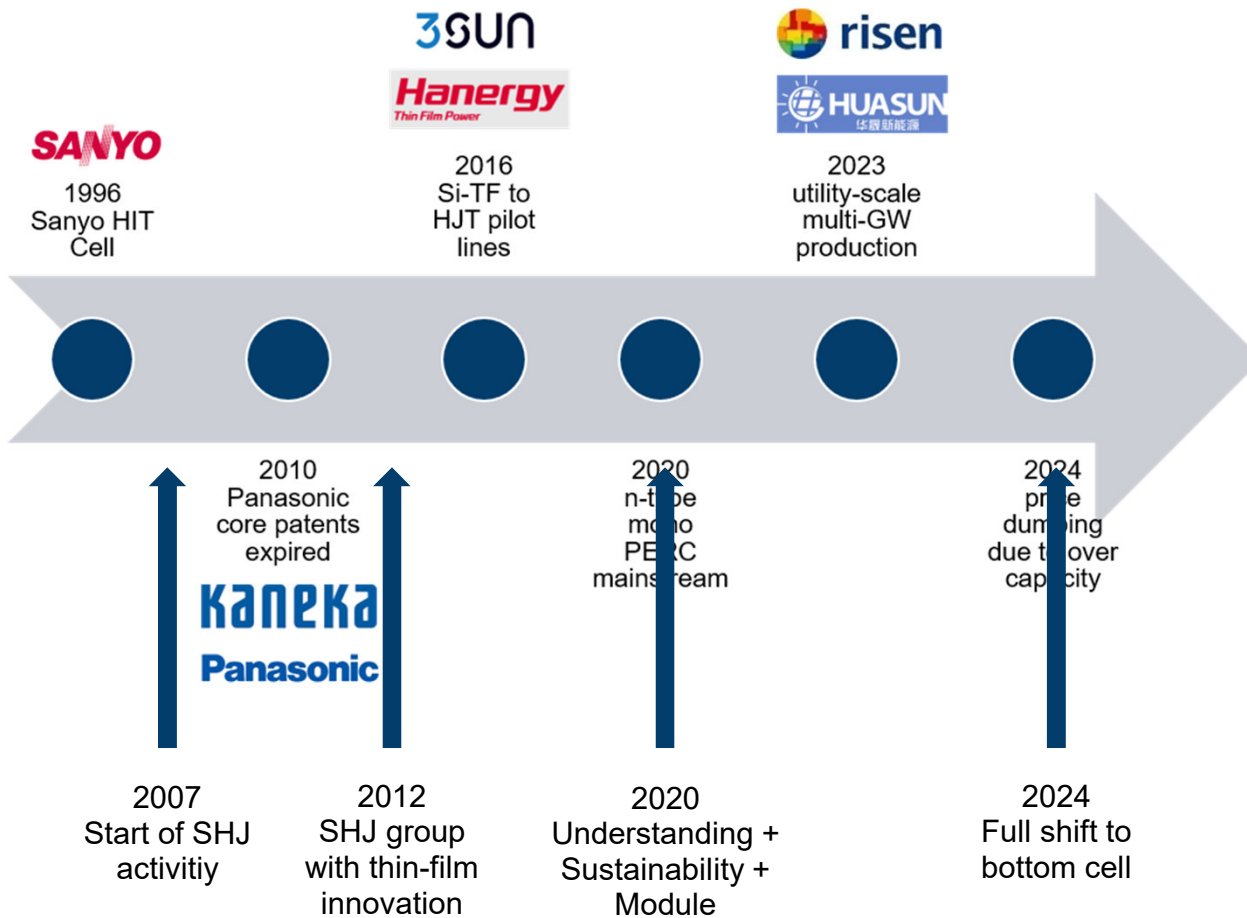
PV-Thync Lab:

From silicon heterojunction to perovskite silicon tandem solar cell

UNSW Seminar 2026, Sydney, July 2026

Kaining Ding, Head of PV-Thync Lab, IMD-3, Forschungszentrum Jülich GmbH

INTRODUCTION



2019 UNSW seminar:



Mitglied der Helmholtz-Gemeinschaft

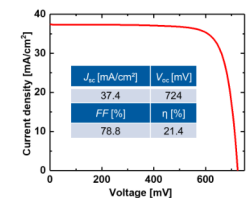


SILICON HETEROJUNCTION BASELINE

For industrial sized SHJ solar cells

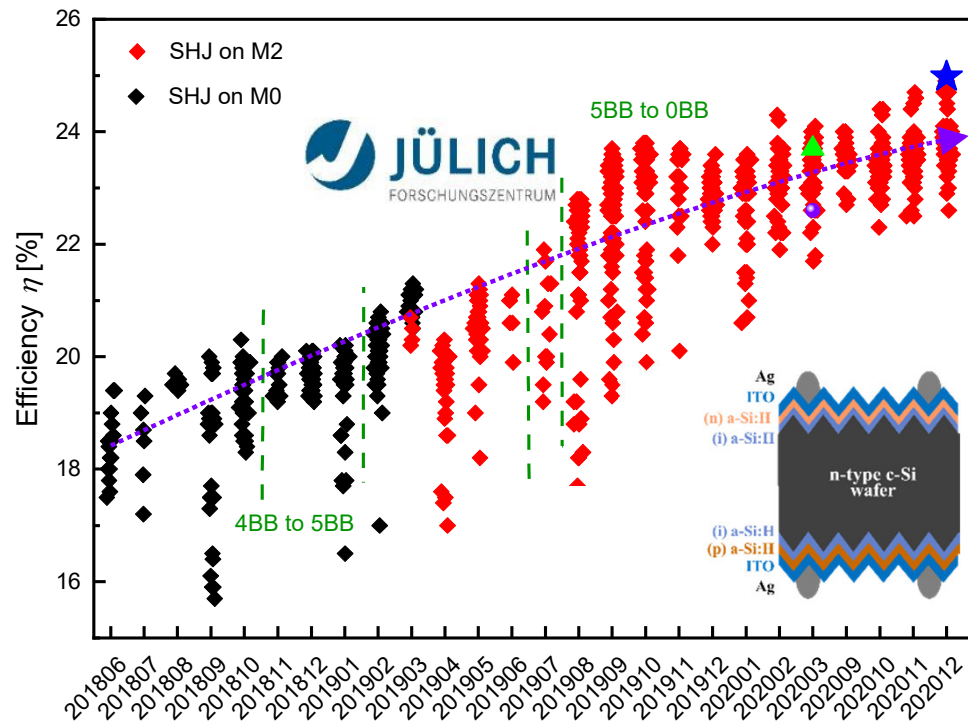
- High solar cell efficiency
- Reproducible and homogeneous process
- High throughput
- Fast feed back
- Industrial scalable tools
- Established platforms

→ Test materials and processes for $\eta > 25\%$

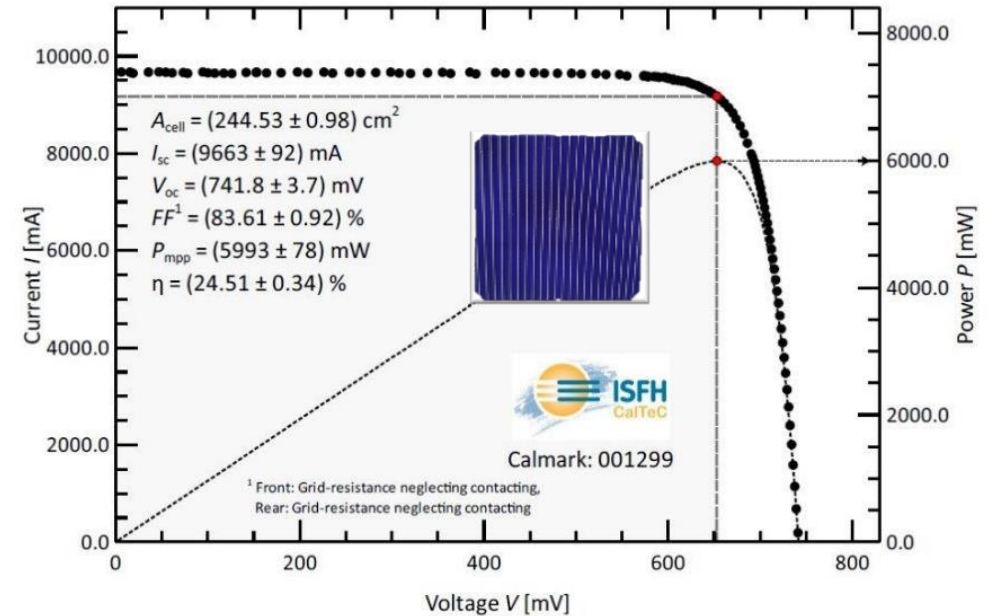


SILICON HETEROJUNCTION

Cell efficiency

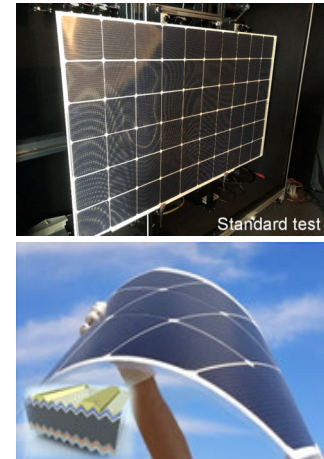
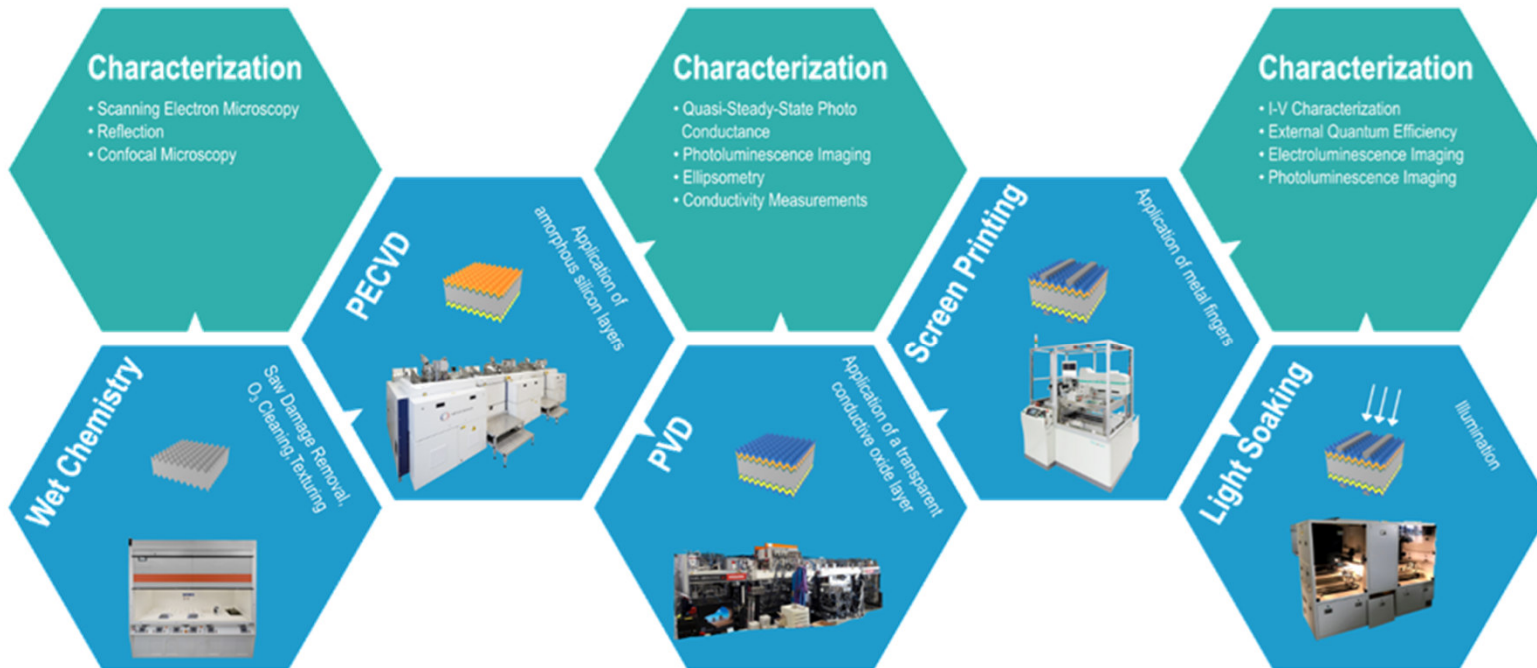


In 2020, TOP 3 industry size cell efficiency worldwide



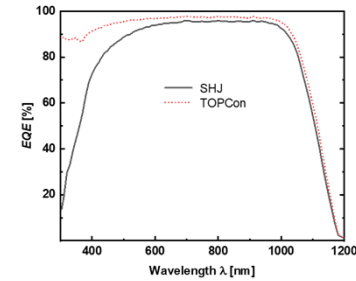
SILICON HETEROJUNCTION

Infrastructure (Industry Size up to G12 HC)

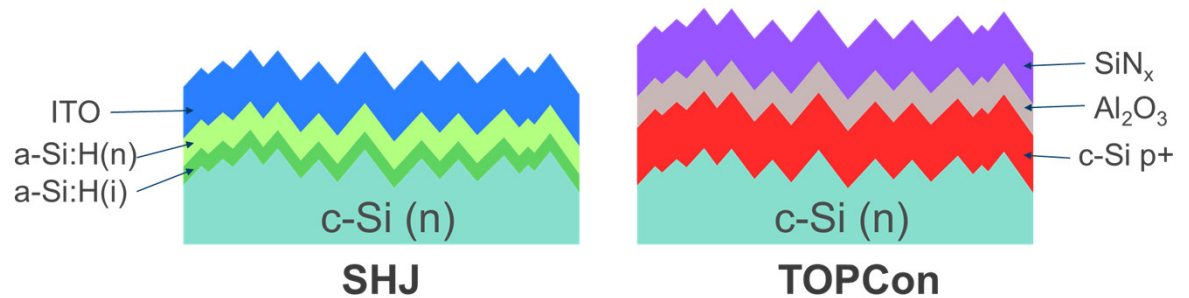
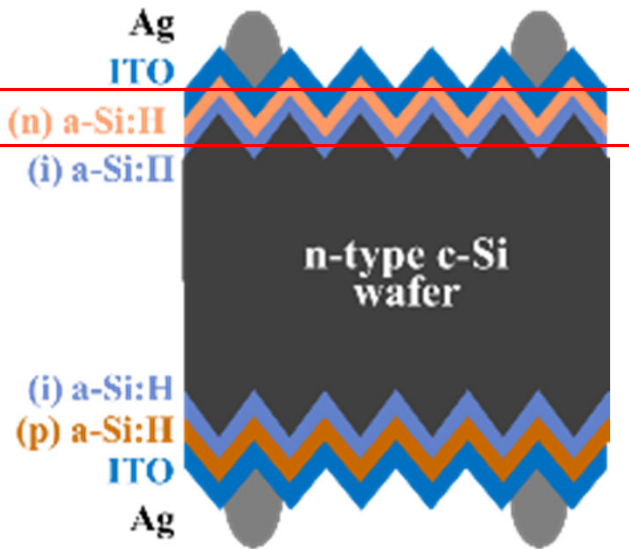


SILICON THIN-FILM DEPOSITION

Material innovation example

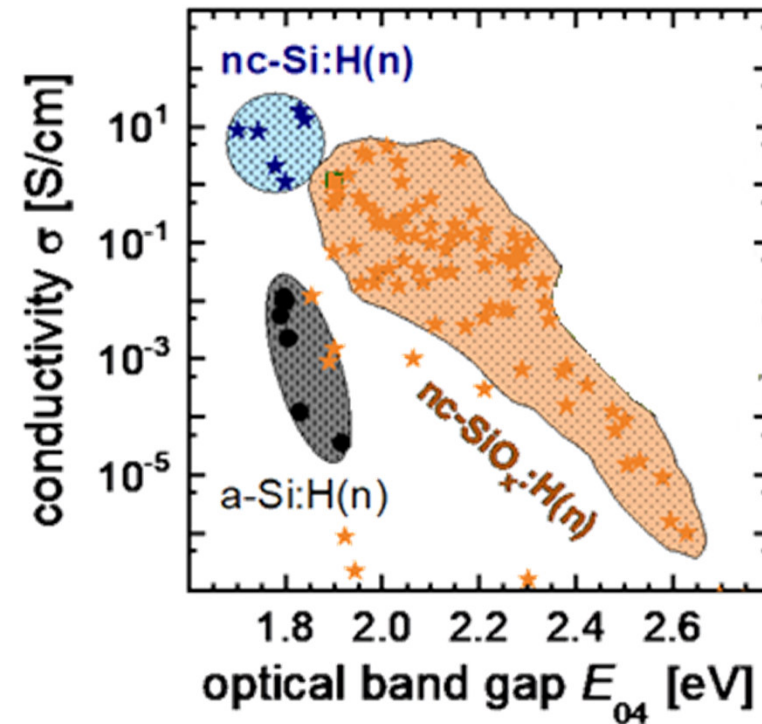
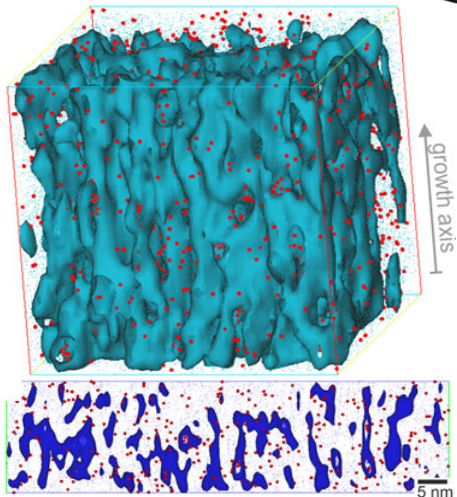
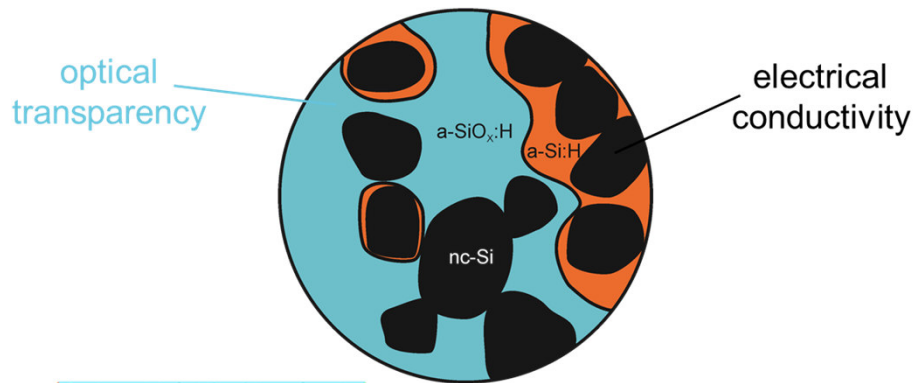


Cell type	V_{oc} [mV]	J_{sc} [mA/cm ²]	FF [%]	Eff [%]	Area [cm ²]
LONGi SHJ	748.5	39.48	85.46	25.26	244.53
LONGi TOPCon	721.6	41.64	83.90	25.21	242.97



SILICON THIN-FILM DEPOSITION

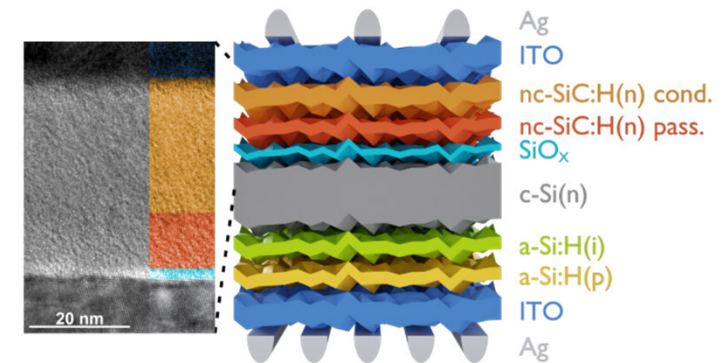
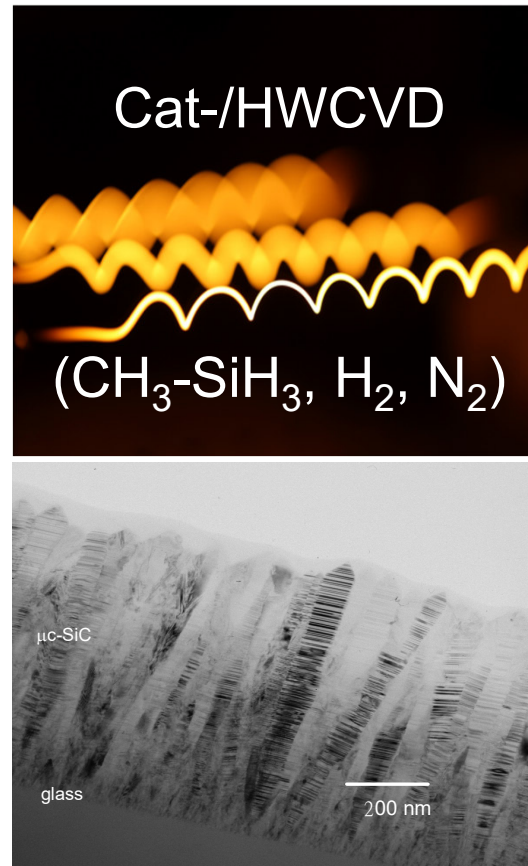
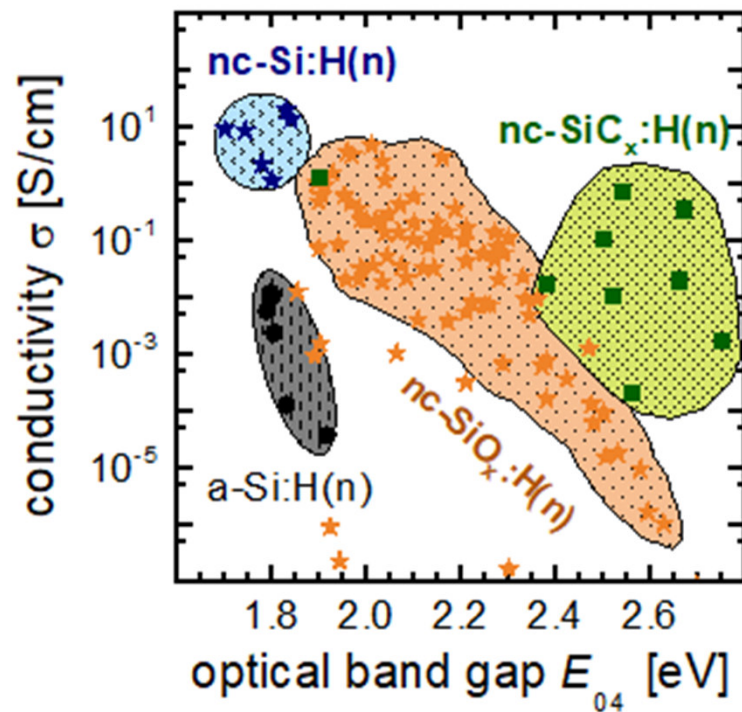
Nanocrystalline silicon oxide



- >0.4% absolute efficiency improvement
- Usually double RF frequency
- CO₂ or N₂O as oxygen source

SILICON THIN-FILM DEPOSITION

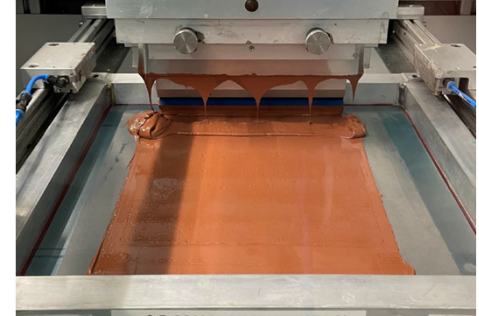
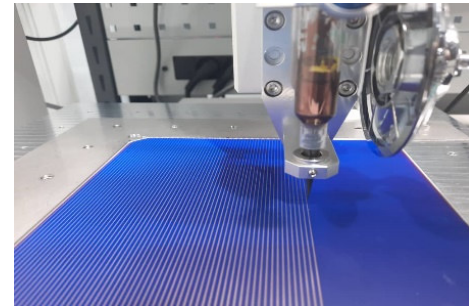
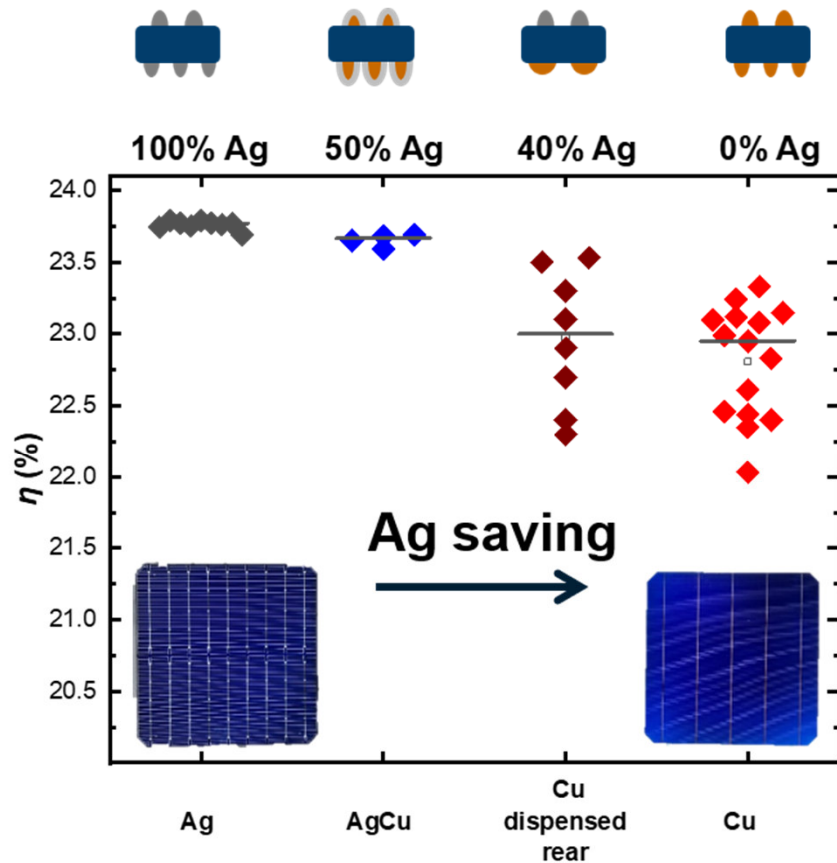
Nanocrystalline silicon carbide



- Unique selling point
- Highest Jsc at the time
- 24.2% certified

SUSTAINABILITY

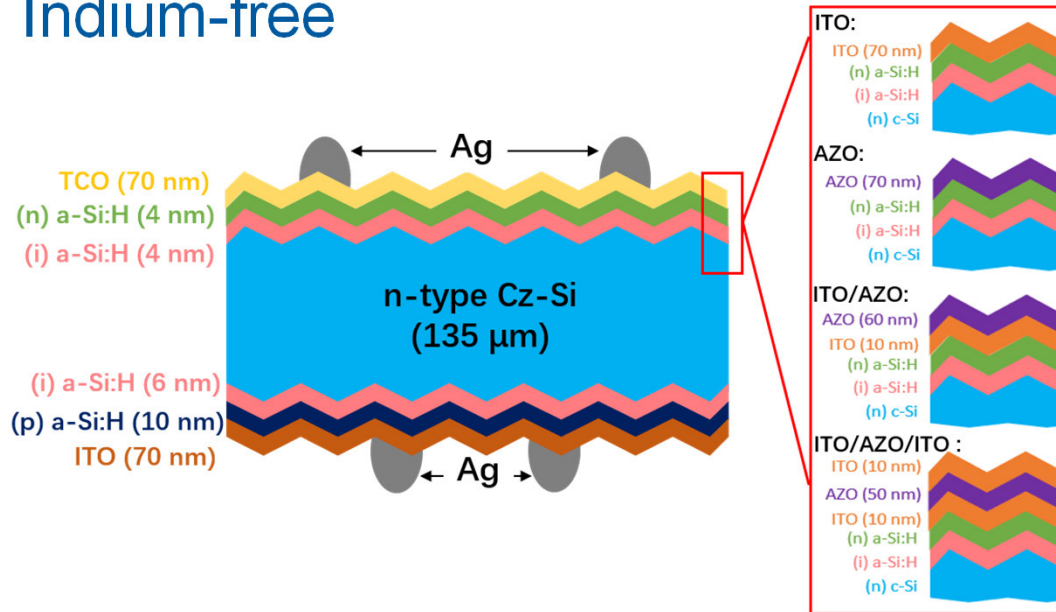
Silver-free



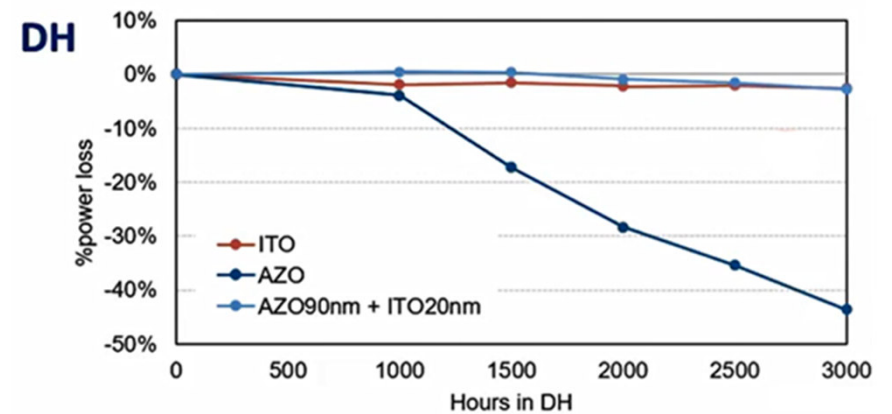
- Ag coated Cu close to reference. Industry uses 20-30%/10% front/back.
- Developed a new thermal annealing approach at 300°C for 5s
- >23% efficiency using Cu paste. Industry R&D with up to 26.5%.

SUSTAINABILITY

Indium-free



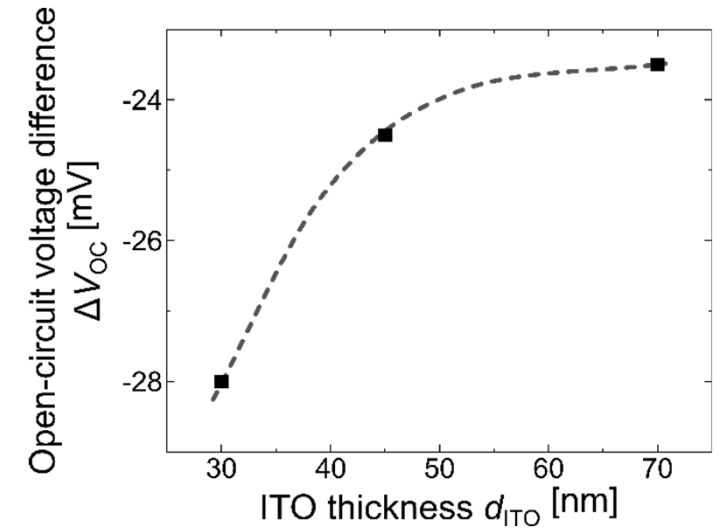
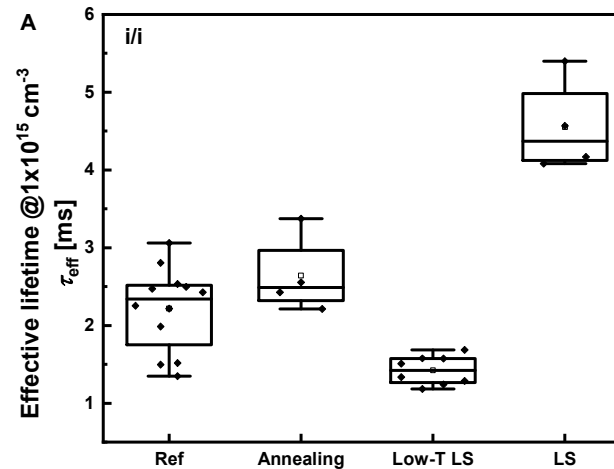
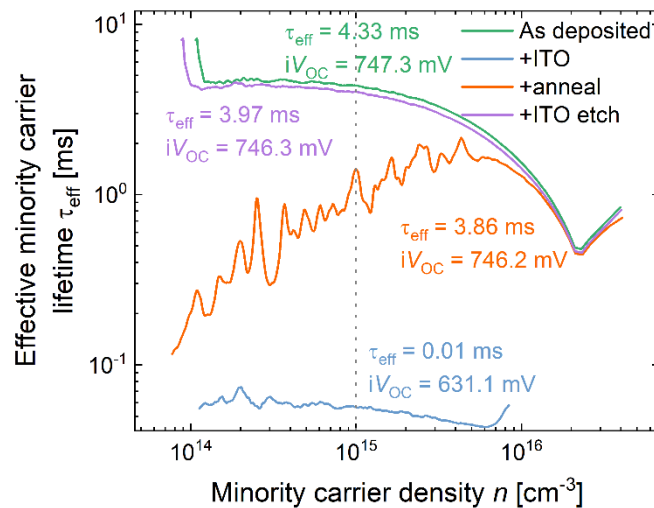
	Eff (%)	Jsc (mA/cm ²)	Voc (mV)	FF (%)	In reduction potential
ITO	24.0	39.6	737	82.1	0%
AZO	22.6	39.4	724	79.3	100%
ITO/AZO	23.6	39.4	733	81.9	93%
ITO/AZO/ITO	23.8	39.1	734	82.8	86%



- AZO alone is not sufficient
- ITO/AZO/ITO seems a compromise
- Also very similar results with SnO₂
- Later much better efficiency by company

SHJ FUNDAMENTAL RESEARCH

It is the hydrogen, stupid!



Sputter damage:

- Recoverable damage due to energy transfer to the interface

Light soaking:

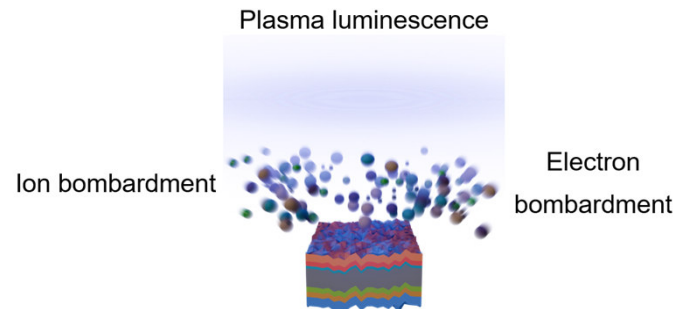
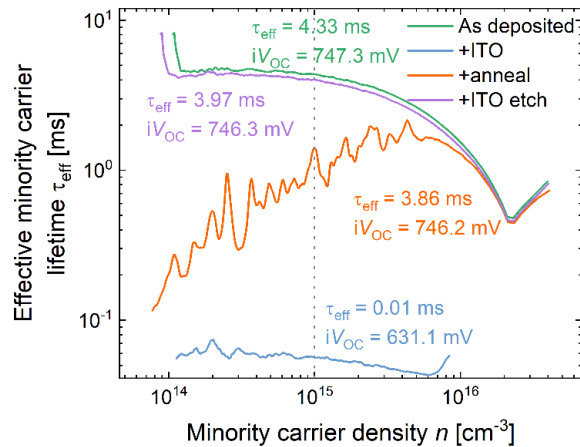
- Heat-assisted recombination-initiated defect annihilation

UV degradation:

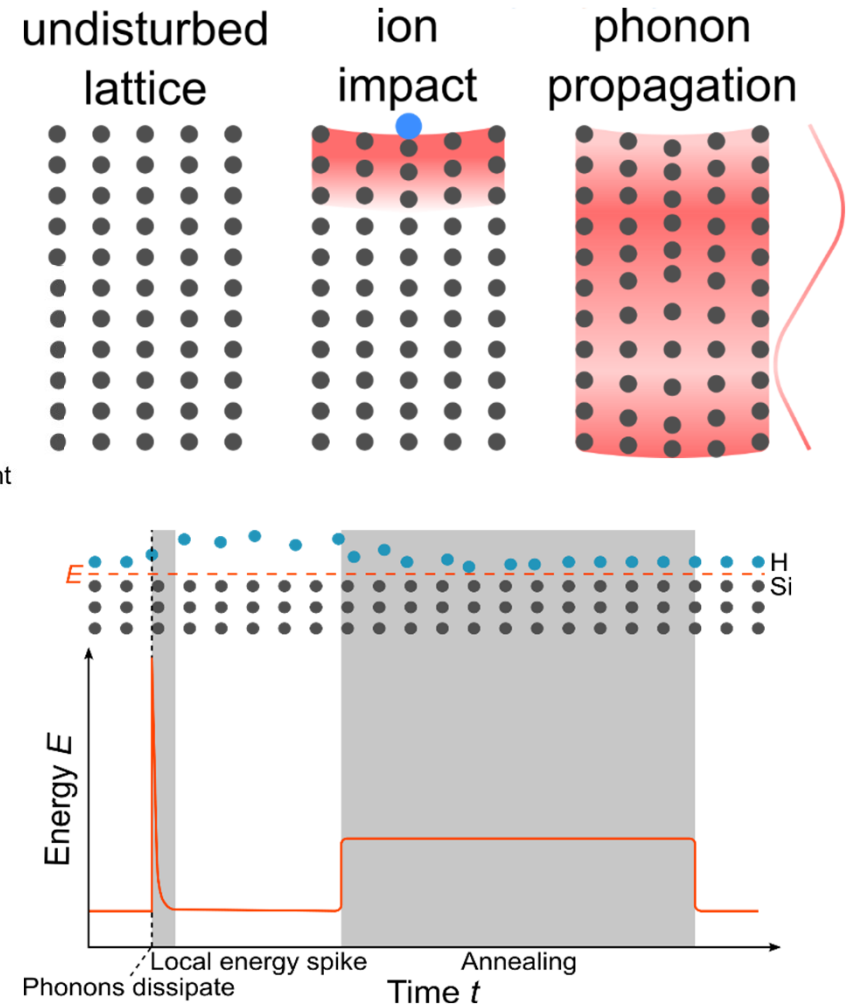
- UV light directly breaks Si-H bond at interface and migrates H

SHJ FUNDAMENTAL RESEARCH

Sputter damage during TCO deposition

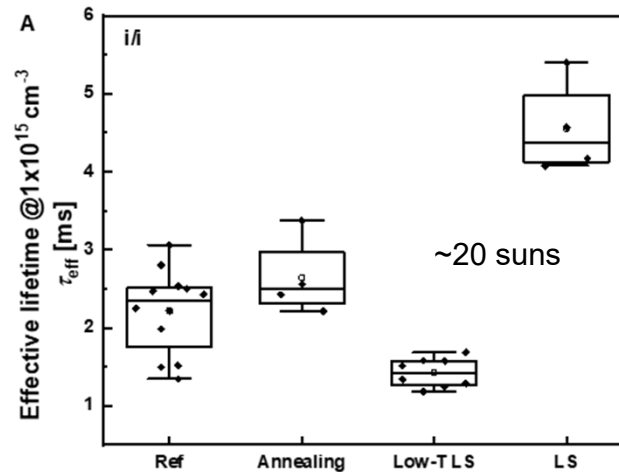
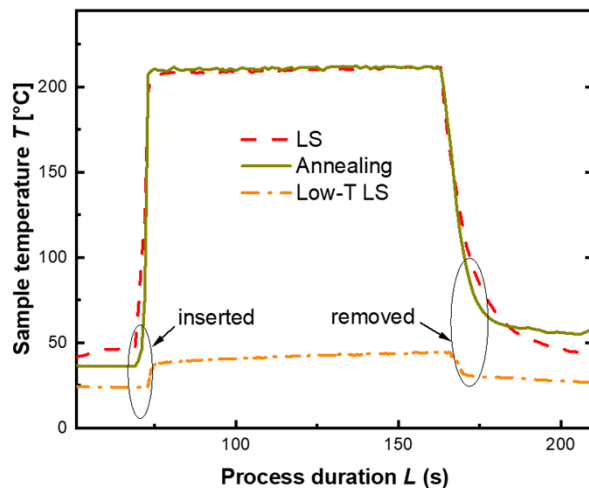


- Sputter damage can be categorized into recoverable and irrecoverable damage depending on power density and material
- In the case of recoverable damage, direct causes and some secondary effects could be excluded. Phonon propagation.

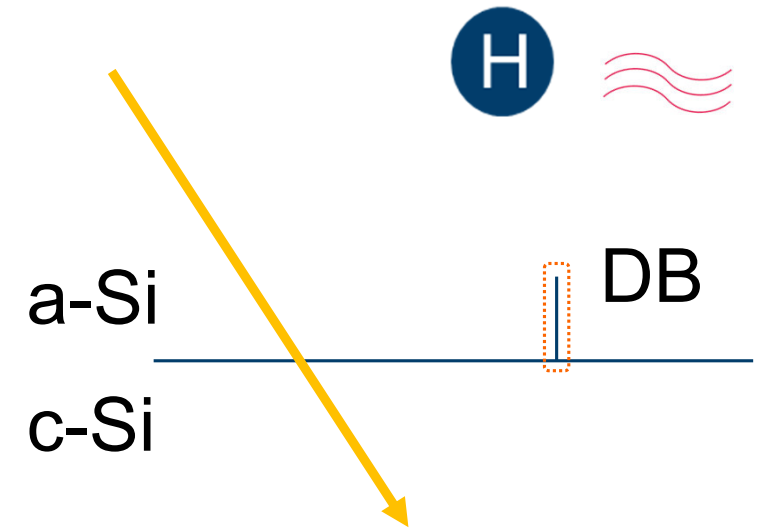


SHJ FUNDAMENTAL RESEARCH

Light soaking



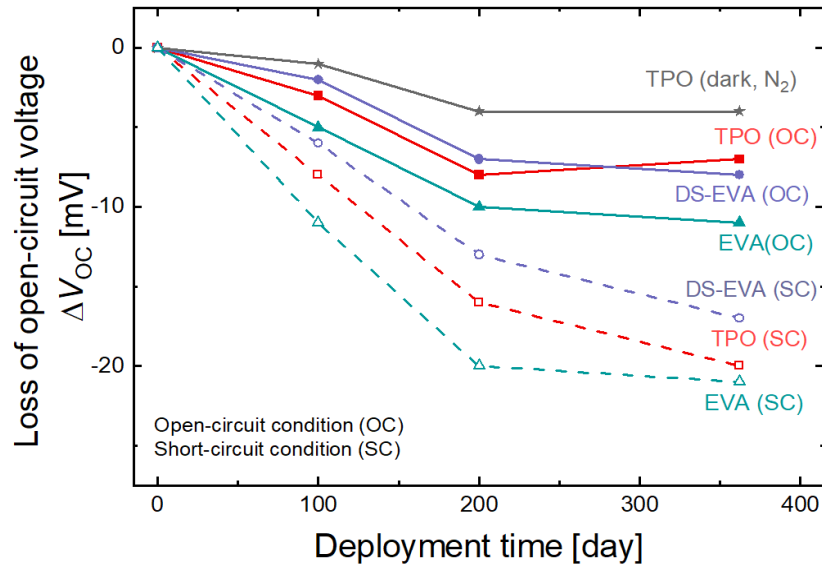
Heat-assisted recombination-initiated defect annihilation



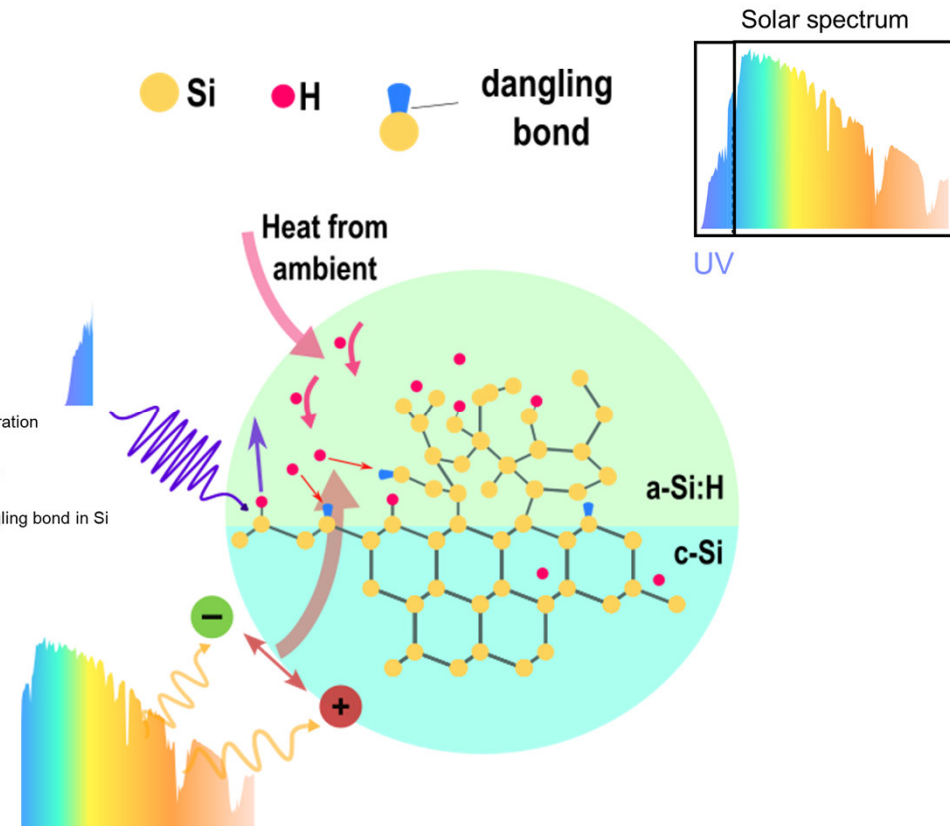
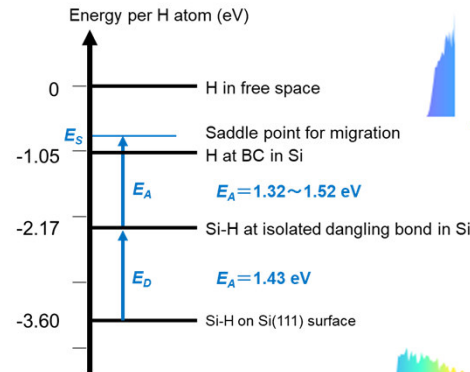
- If there is only few DB, LS will have less beneficial effect. The effect become much more effective with mobile H under annealing and in Voc condition with mandatory recombination.

SHJ FUNDAMENTAL RESEARCH

UV degradation



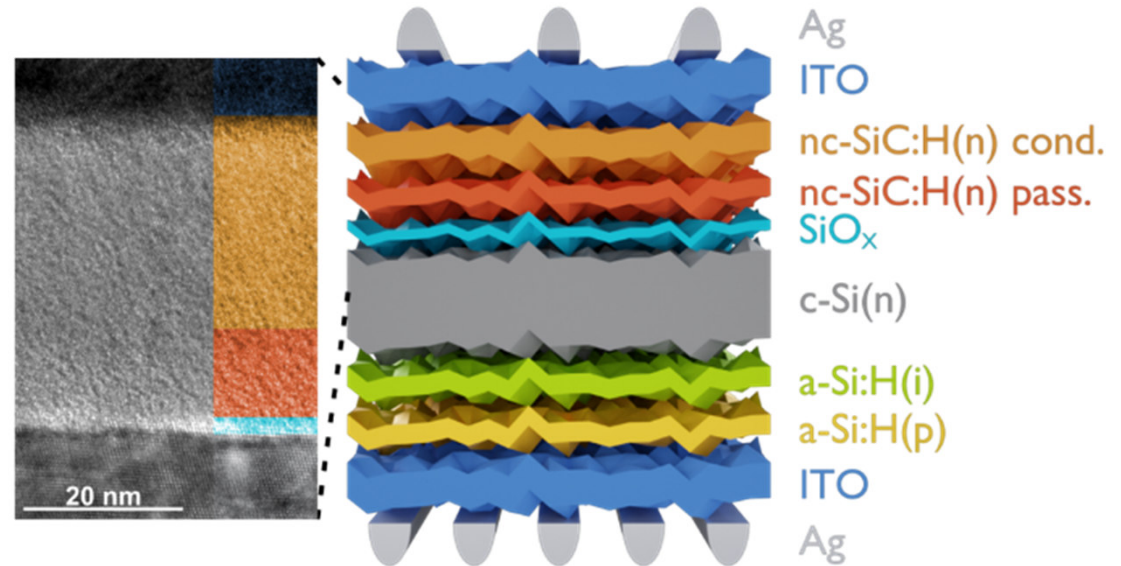
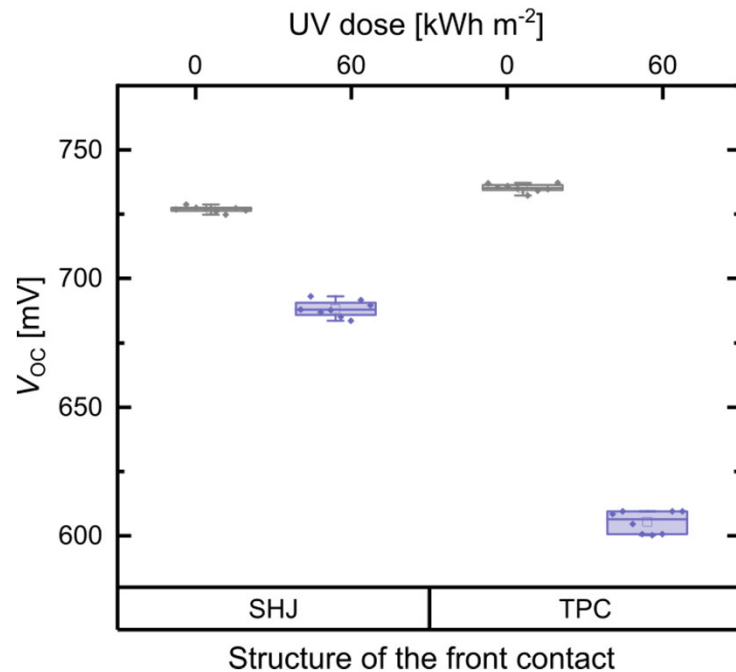
VOC loss reduced under OC condition as compared to SC condition



UV degradation and light soaking as combined effect

SHJ FUNDAMENTAL RESEARCH

UV degradation

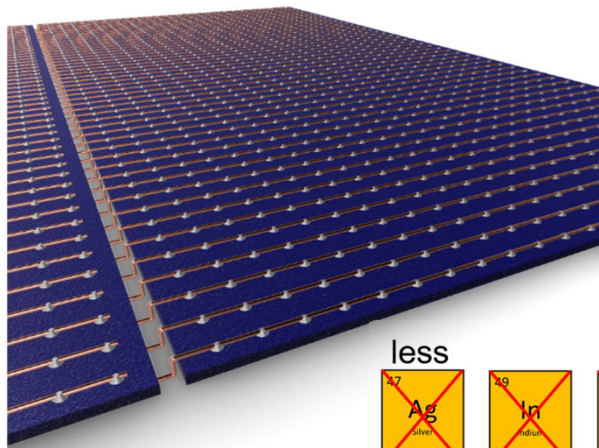


While nc-SiC:H successfully increased EQE in the short wavelength range, the UV stability decreased, as more UV light reaches the a-Si/c-Si interface

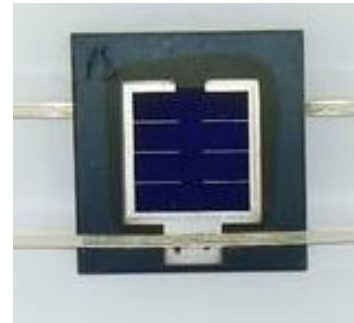
MODULE RESEARCH

Interconnection

Direct wire bonding

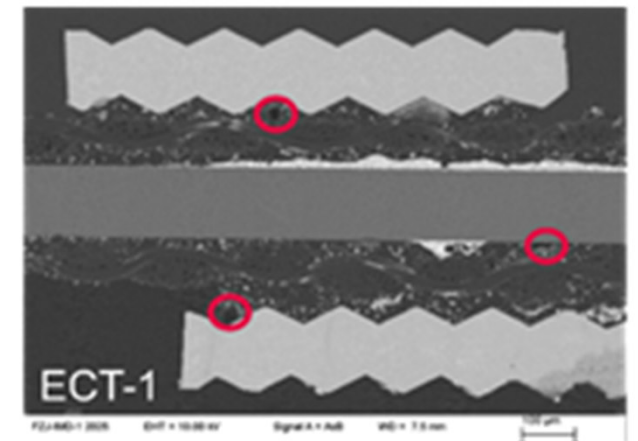


- Cu wires with diameter 30 μm are aligned onto **finger-free** SHJ solar cells
- **Ag-coated Cu paste** pads with a diameter of 300 μm with wire **interconnection**



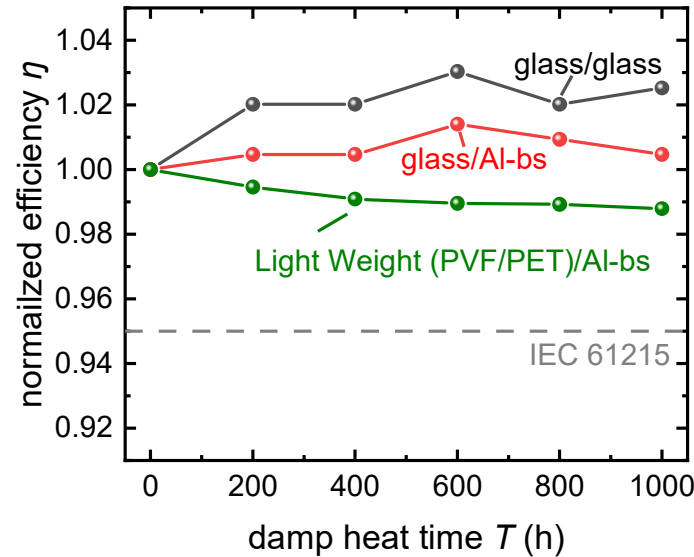
	η	V_{oc}	J_{sc}	FF
	[%]	[V]	[mA/cm ²]	%
Cell	29.9	1.883	20.7	76.7
Module	28.6	1.882	19.2	79.2

Electrically conductive tape

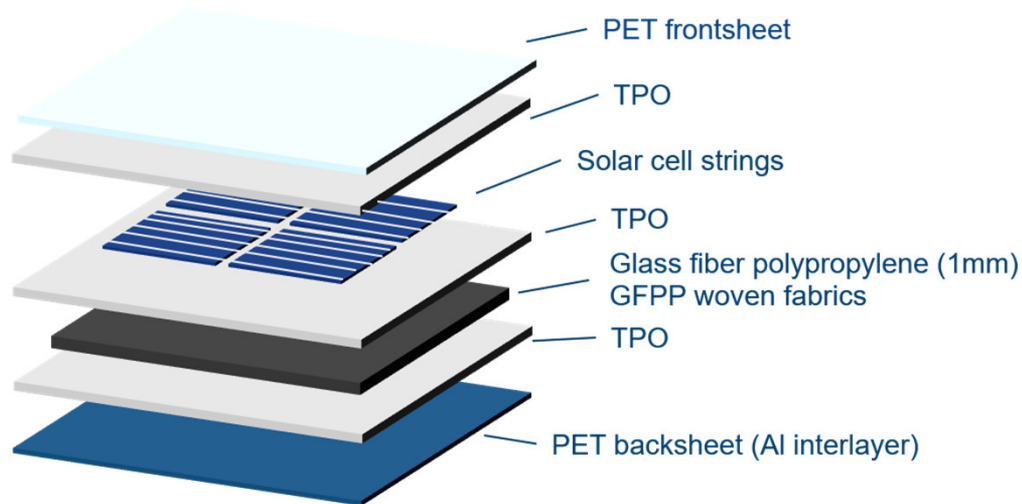


MODULE RESEARCH

Lightweight module

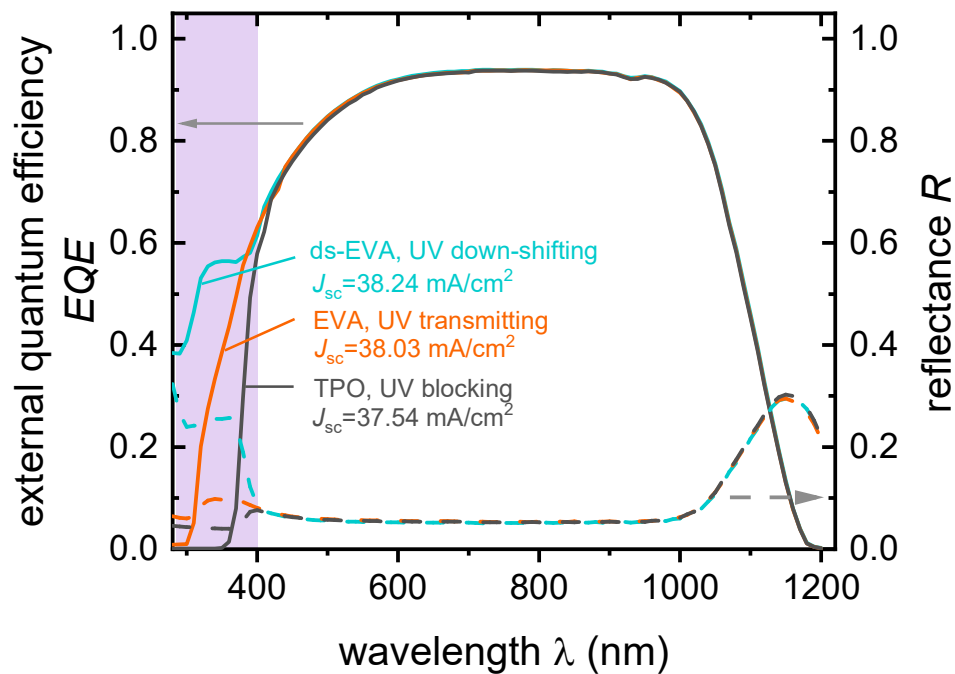


- Lightweight solar module construction with glass fiber reinforcement $< 4 \text{ kg/m}^2$
- Developed a new easy mounting system for textile roofs (no need to climb)

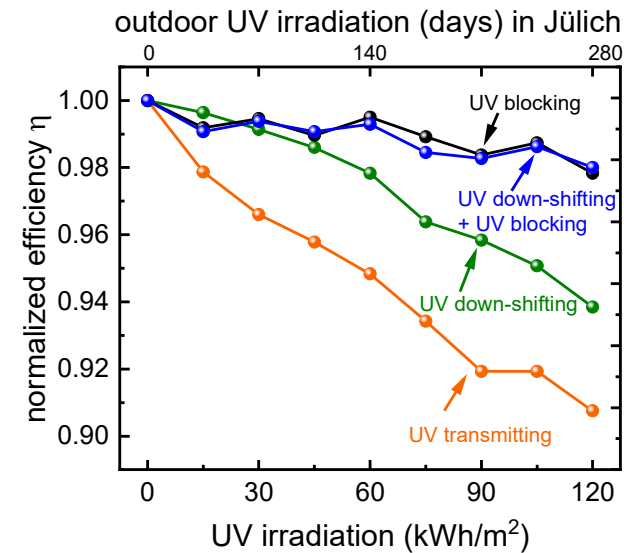
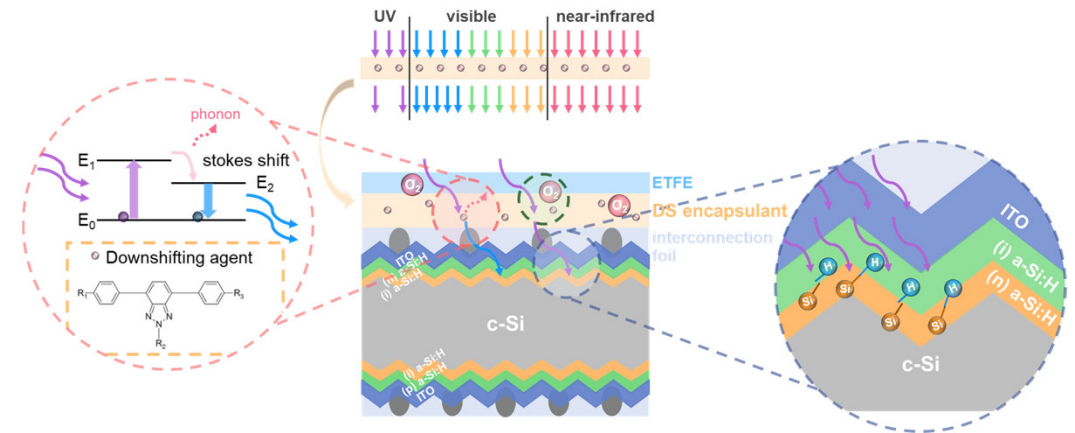


MODULE RESEARCH

UV Downshifting foil

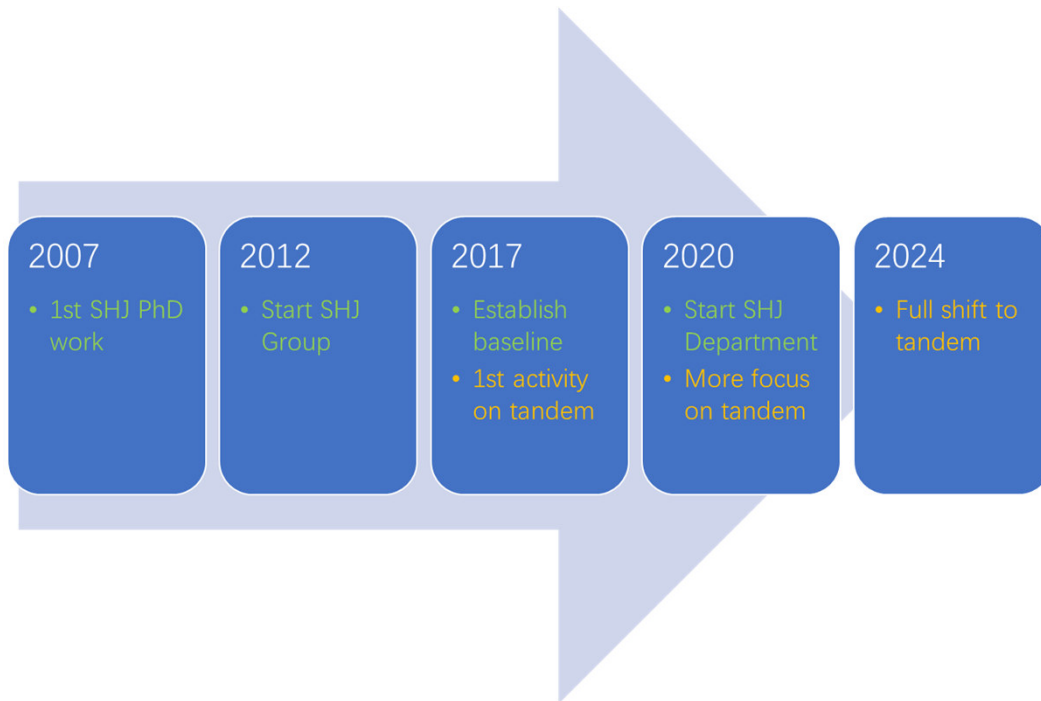


- Current gain from UV down-shifting (DS) encapsulant by 0.70 mA/cm^2 compared to that of UV blocking encapsulant.



PV-THYNC LAB

Perovskite-silicon-tandem

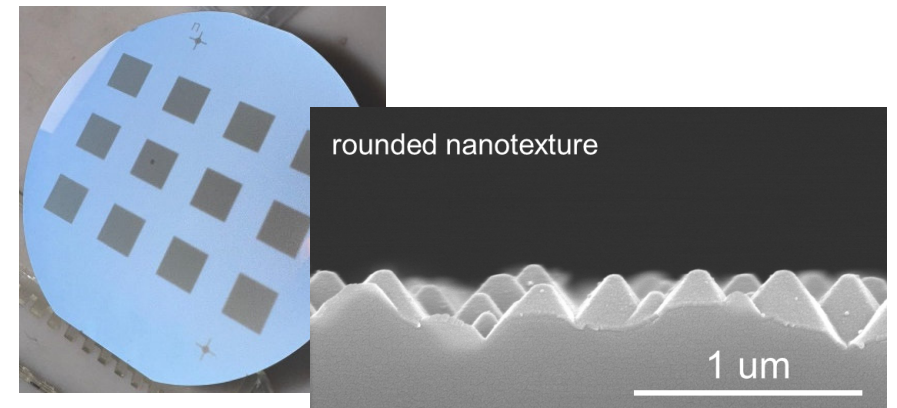
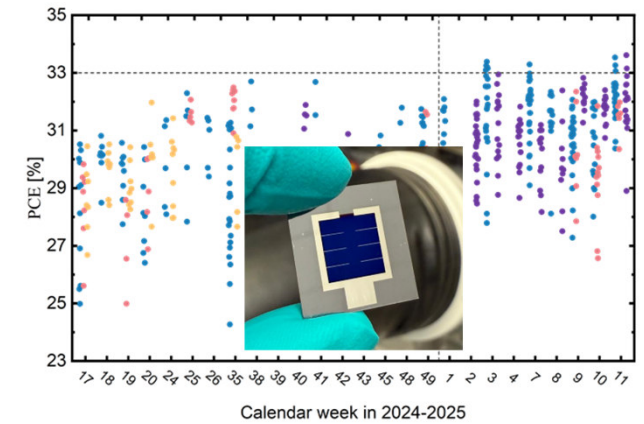
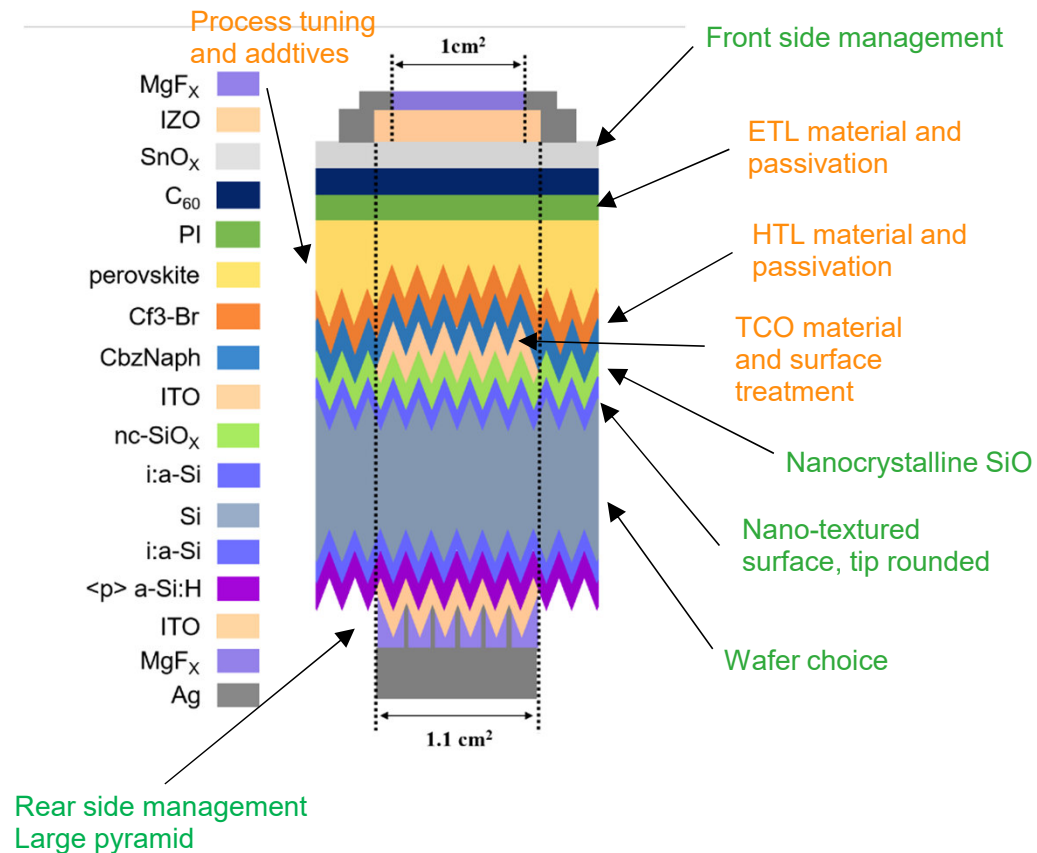


PV-Thync
Lab
PV Technology Incubation Laboratory

3 Team leaders
9 Scientific staff
13 PhD students
15 Technical staff

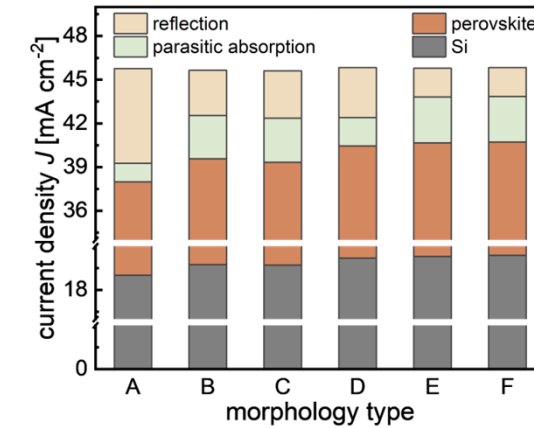
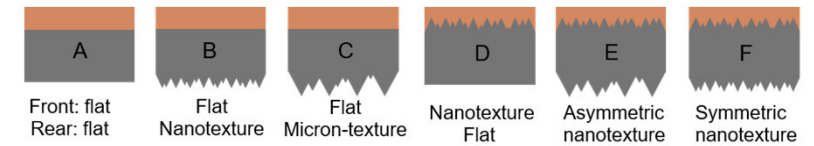
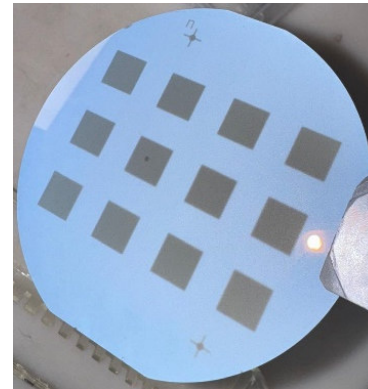
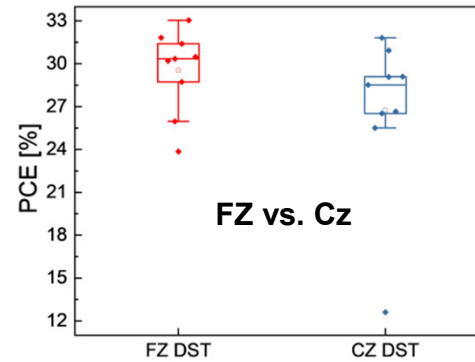
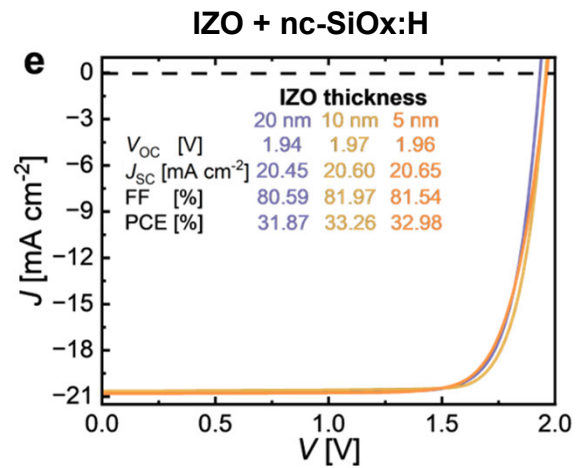
PV-THYNC LAB

Research activities



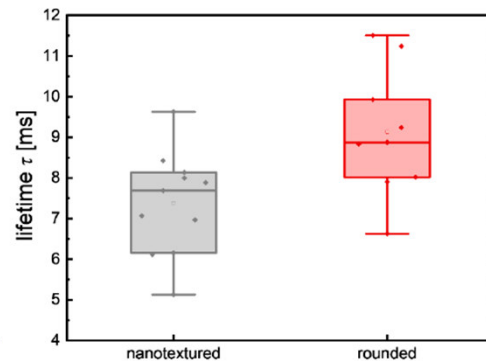
PV-THYNC LAB

Bottom cell

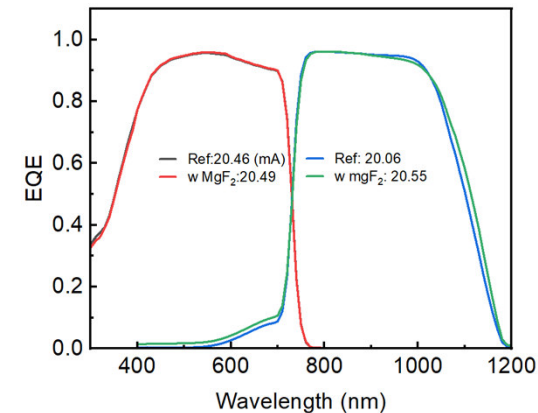


Texture design

Nanotexture rounding

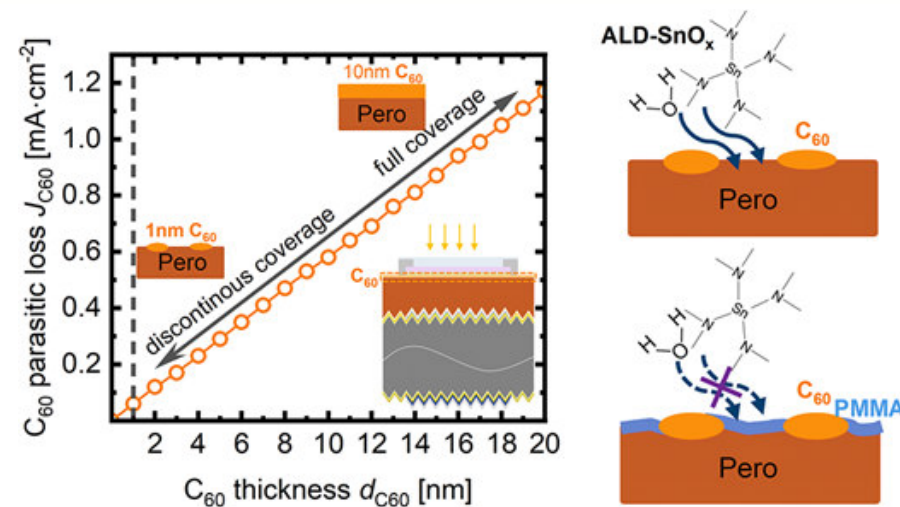
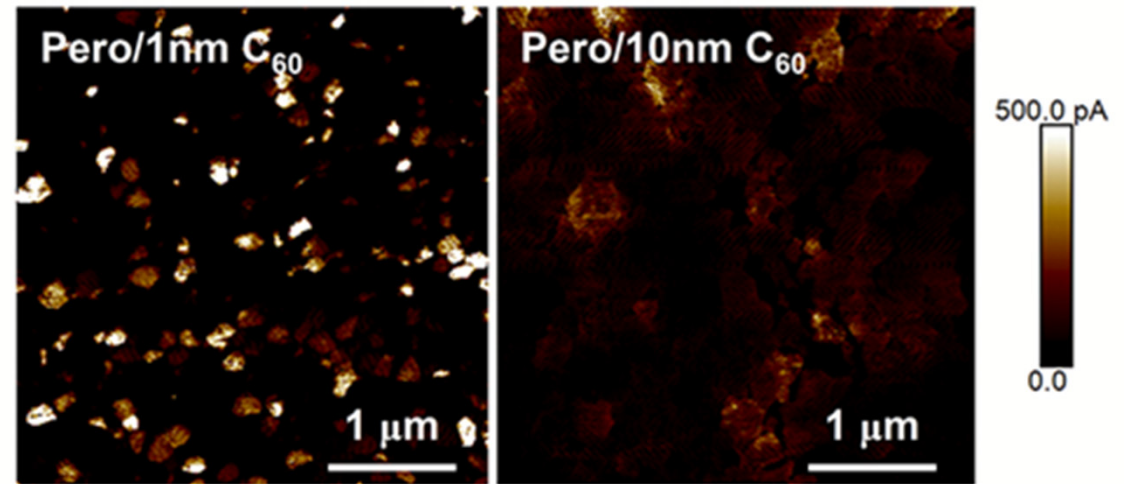
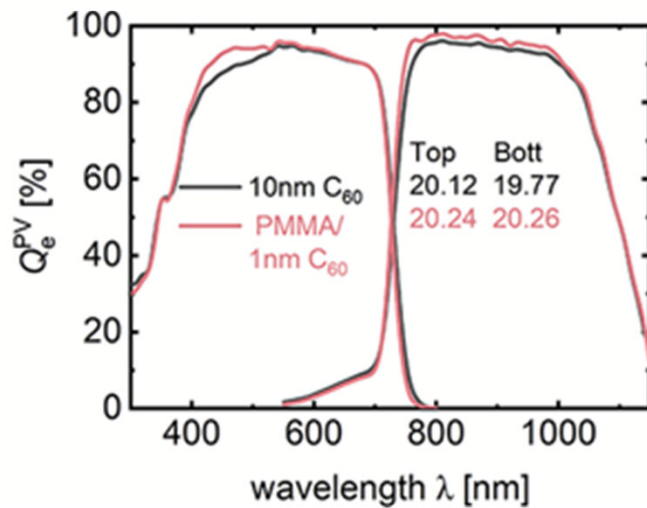
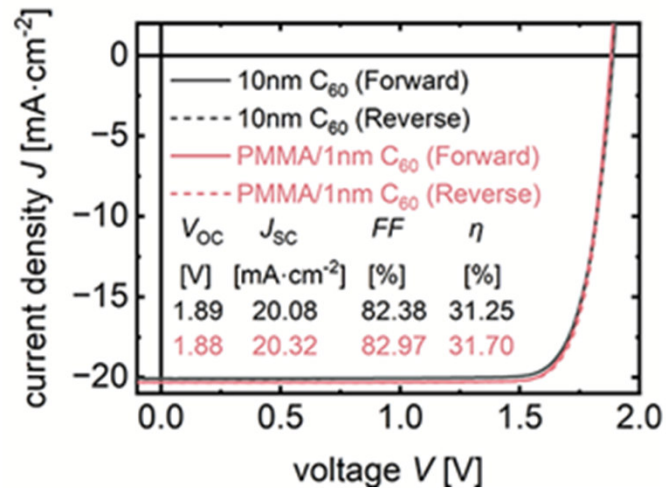


Rear MgF₂ reflector



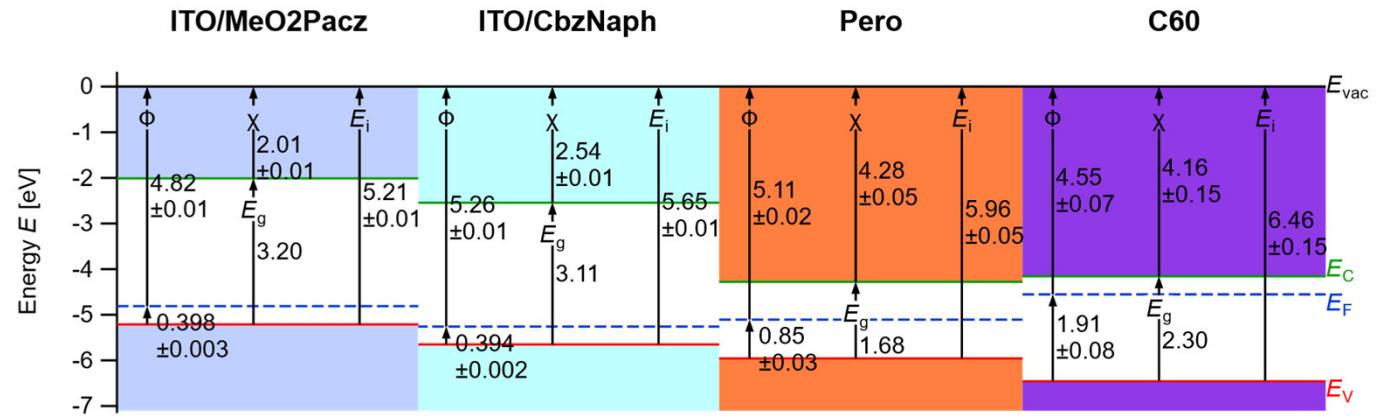
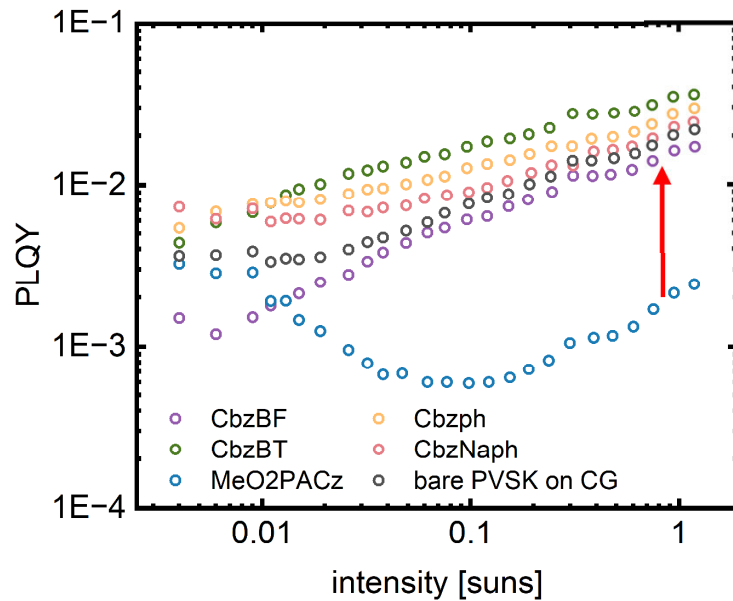
PV-THYNC LAB

ETL (1nm C60)

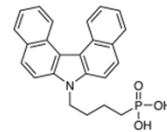


PV-THYNC LAB

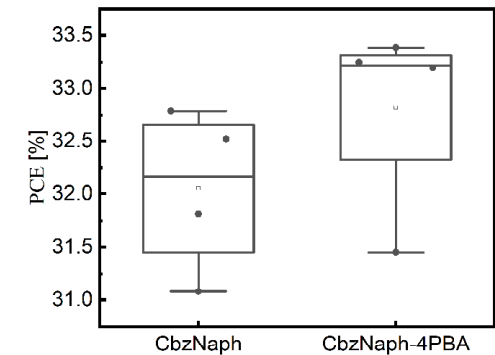
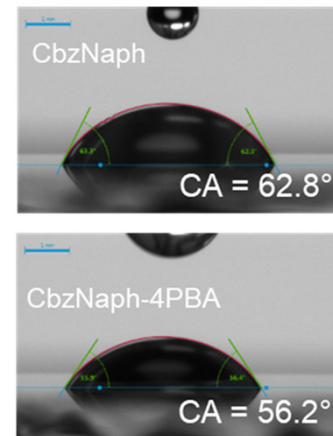
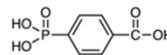
HTL (CzbNaph)



CbzNaph



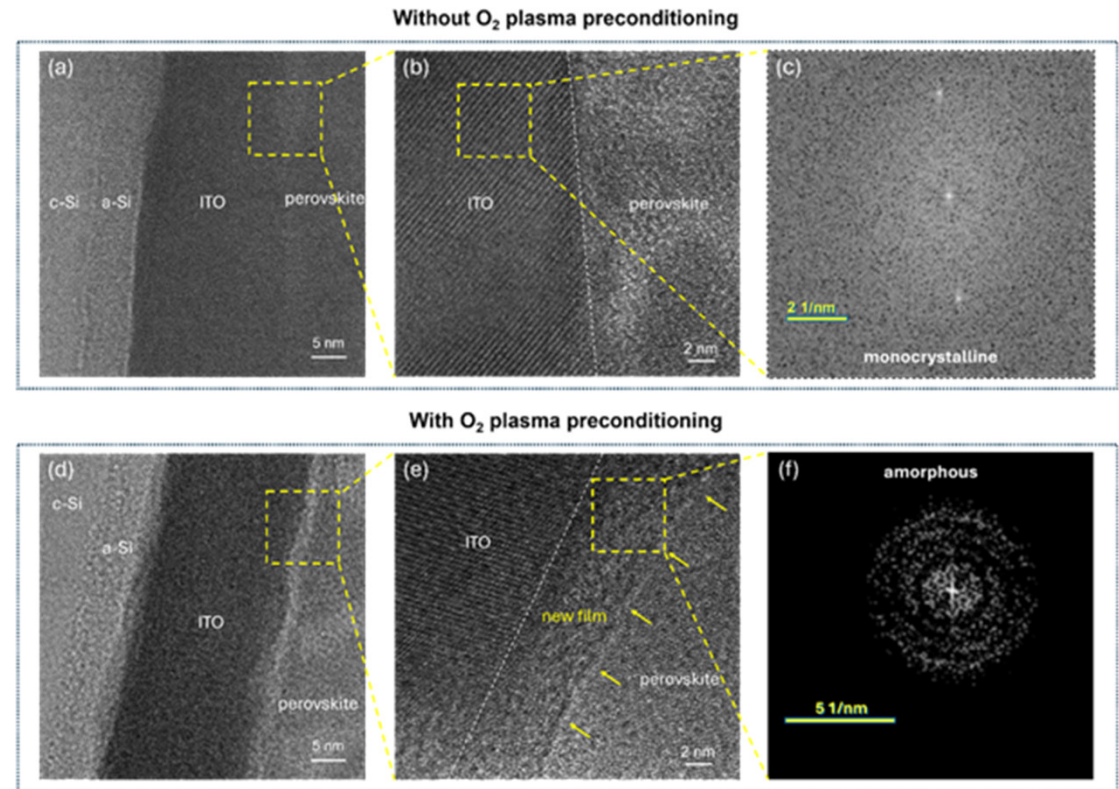
4PBA



PV-THYNC LAB

Surface treatment

- O₂ plasma treatment of the TCO before SAM layer is usually used for better wetting
- We observe that this treatment does more than just improving wettability
- It results in an oxygen rich layer in the perovskite close to the SAM
- This layer changes the surface energy and hence the crystallization kinetics



PV-THYNC LAB

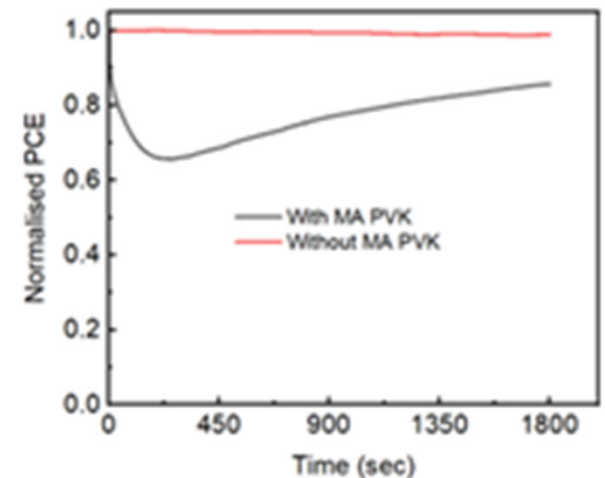
Perovskite

Initially: $\text{Cs}_{0.05}(\text{FA}_{0.77}\text{MA}_{0.23})_{0.95}\text{Pb}(\text{I}_{0.77}\text{Br}_{0.23})_3$ + 3% MAPbCl_3

- 33.5% efficiency, but not stable. Degradation during measurement.

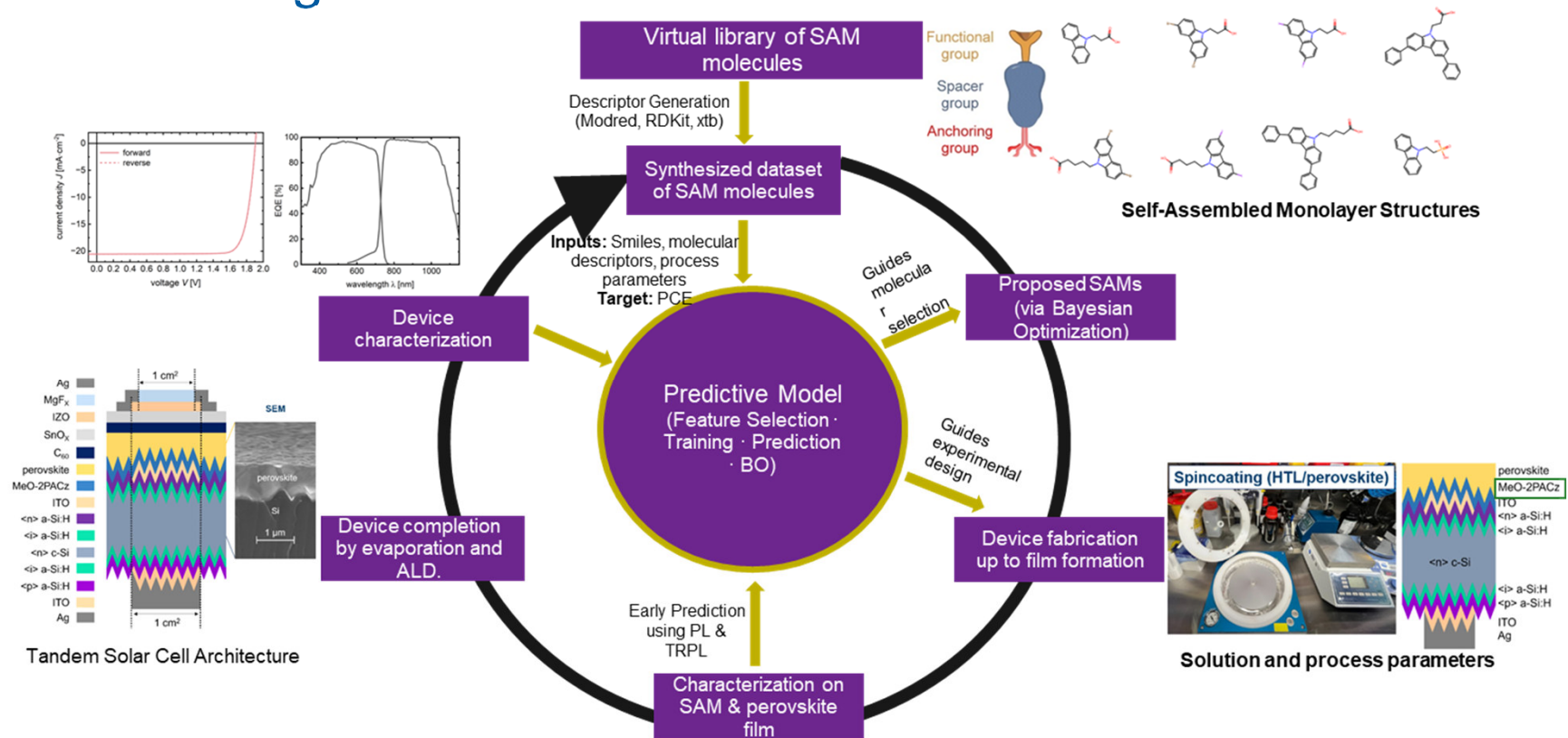
Now two new perovskites:

- V1: $\text{Cs}_{0.05}\text{FA}_{0.8}\text{MA}_{0.15}\text{Pb}(\text{I}_{0.75}\text{Br}_{0.25})_3$ + 7.5% PbX_2
- V2: $(\text{Cs}_{0.07}\text{FA}_{0.93})\text{Pb}(\text{I}_{0.75}\text{Br}_{0.25})_3$
- Much more stable, but efficiency still at ~32%
- Each layer must be optimized again



PV-THYNC LAB

Machine learning



PV-THYNC LAB

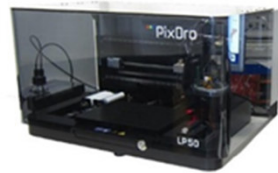
Upscaling to G12 HC

Sputtering



- Nickeloxid

Inkjet



- SAM
- Passivation

Slot-die & Dip-coating



- Perovskite
- Gas-Quenching

Evaporation

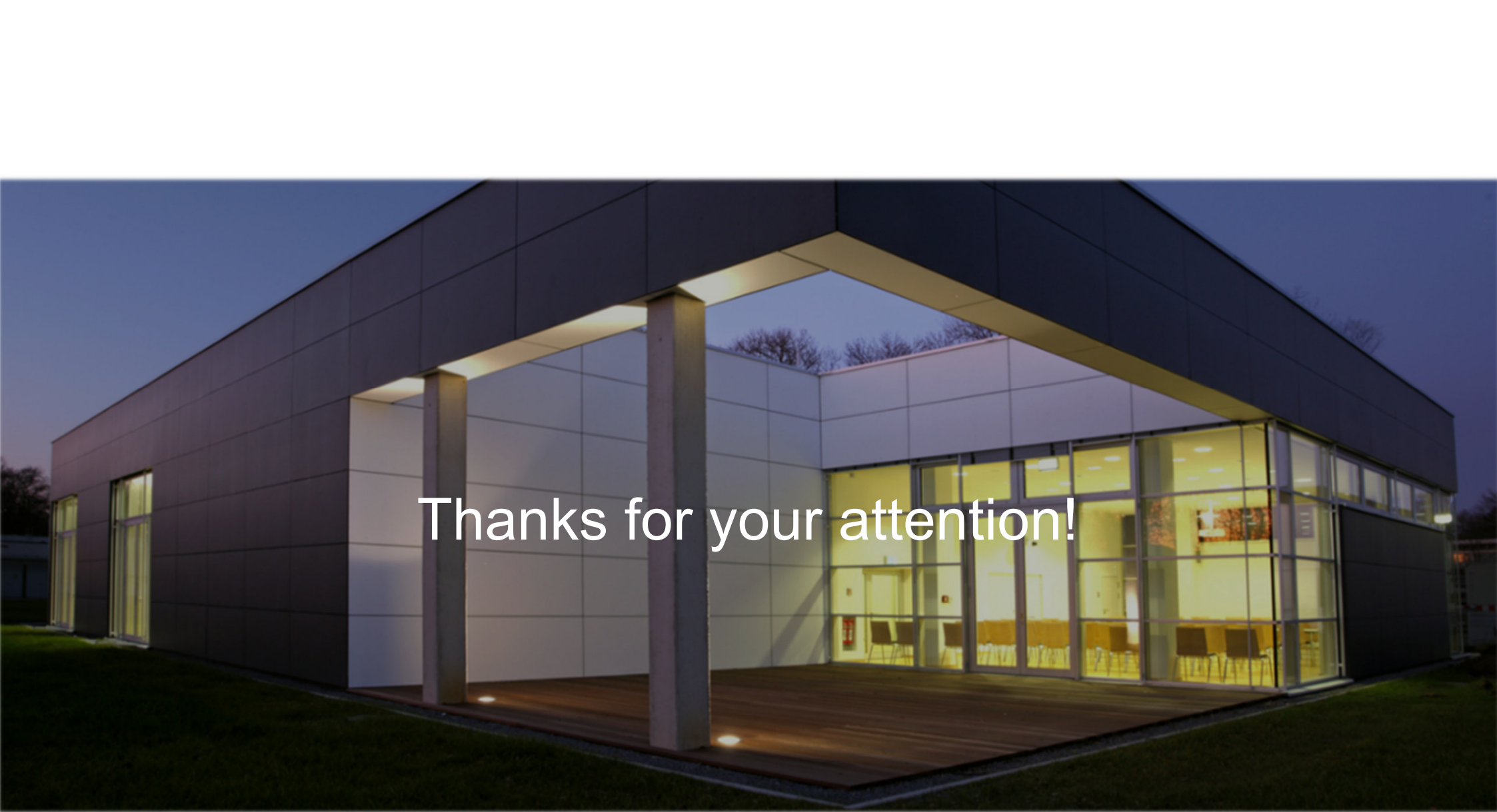


- C60

ALD



- SnOx



Thanks for your attention!

Member of the Helmholtz Association

