Solar cells based on perovskites:

An overview of recent results and insights

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SunDay 8/11/2017

Bussum, The Netherlands

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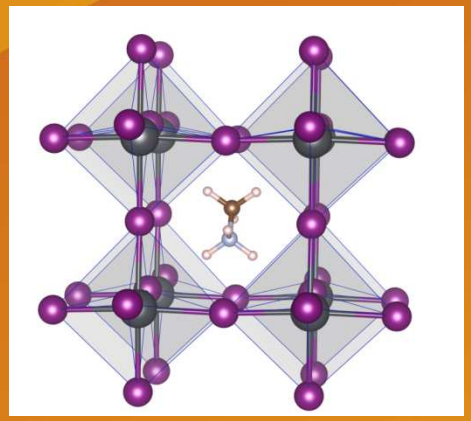
Perovskite Solar Cells



Interesting material properties:

- **direct semi-conductor**
- **sharp band edge**
- **low conc. of defects**
- **good charge carrier mobility & lifetime → carrier diffusion length**
- **abundantly available elements & inexpensive (precursor) materials**
- **solution processable**

Courtesy: Aron Walsh, Bath Uni. (E-MRS 2015)

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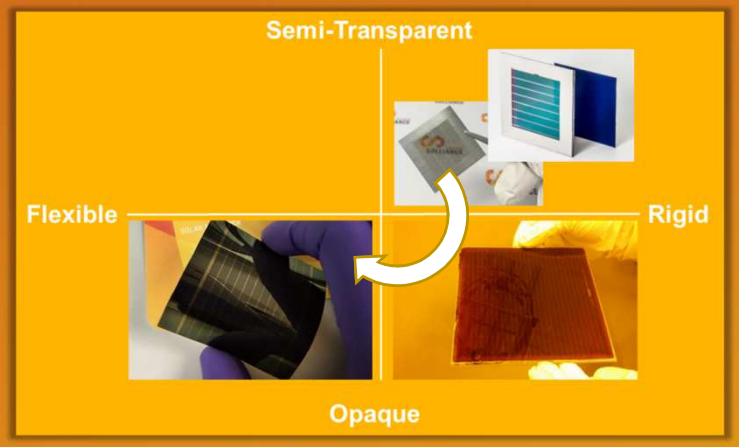
Menu

- Perovskite based PV (PSC) Program
- Latest news



- Insights and future work
- Conclusions

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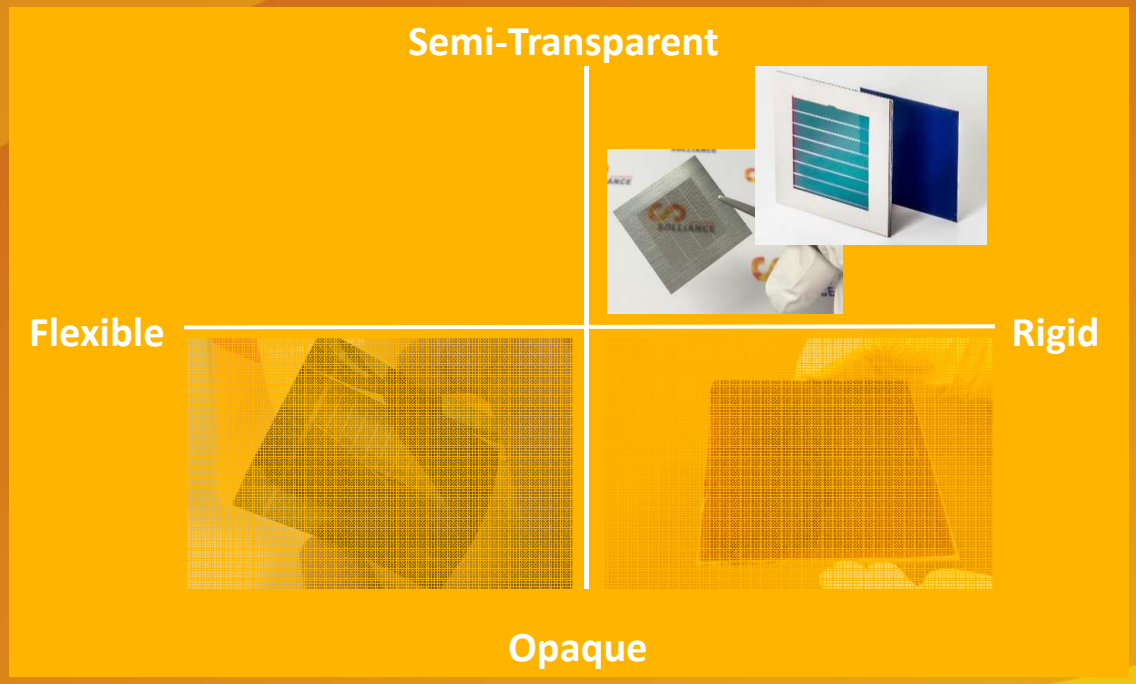
Latest news



Translucent perovskite modules

- Microscopic
- 10% - 50% transparency
- Efficiency scales with active area

→ Windows, etc.

ST perovskite cells & modules

- Two TCO electrodes
- Transmits IR light
- Tunable band gap
- Low sub band gap absorption

→ Tandems - high efficiency

→ Bifacial applications

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Status four-terminal perovskite/c-Si solar devices
ST perovskite (p-i-n) & c-Si cell technologies of ECN

Cell type	Description	J_{sc} (mA/cm^2)	V_{oc} (V)	FF	eta (%)	
Semi-transparent perovskite cell with MgF_2 on both sides	Backward scan	19.8	1.061	0.81	17.0	
	Forward scan	19.7	1.054	0.79	16.4	
	MPPT	-	-	-	16.4	
MWT-SHJ c-Si cell	single junction	39.8	0.731	0.781	22.7	
	bottom cell	14.2	0.696	0.794	7.85	
Tandem cell	-	-	-	-	24.3	**+ 1.6%**
MWT-homo c-Si cell	single junction	38.7	0.653	0.736	18.6	
	bottom cell	13.7	0.616	0.76	6.4	
Tandem cell	-	-	-	-	22.8	**+ 4.2%**

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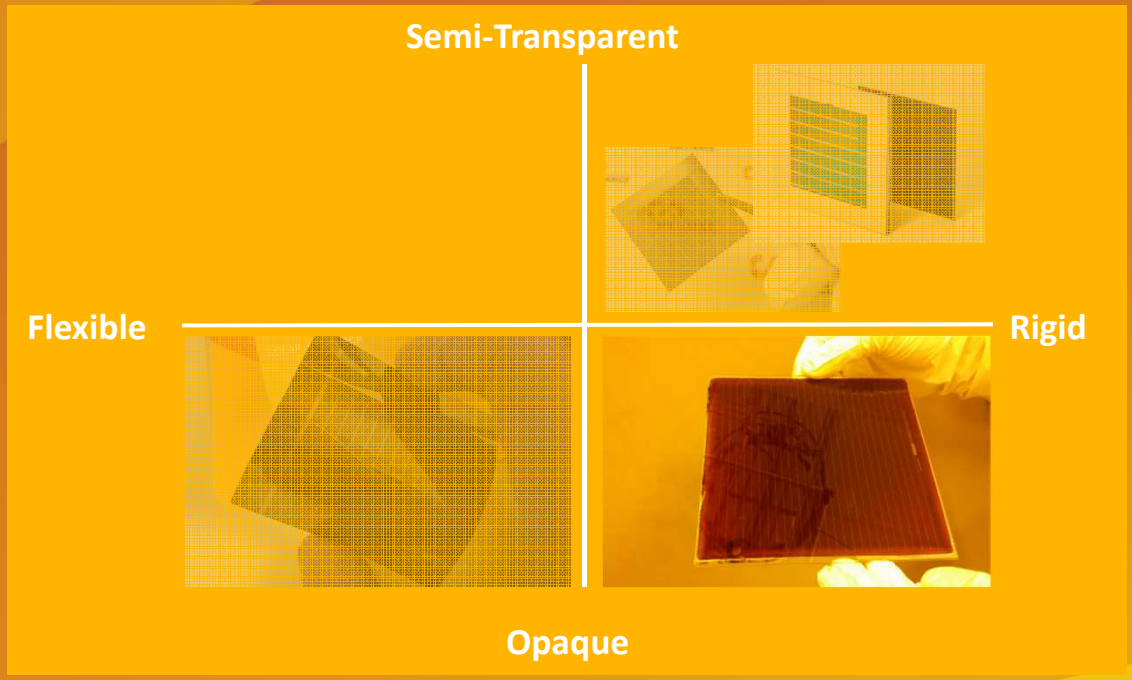
Latest news

NT perovskite cells & modules

- 6 inch modules
- High efficiency
- Tailor-made
- Semi-fabricate for translucent modules

→ BAPV, BIPV



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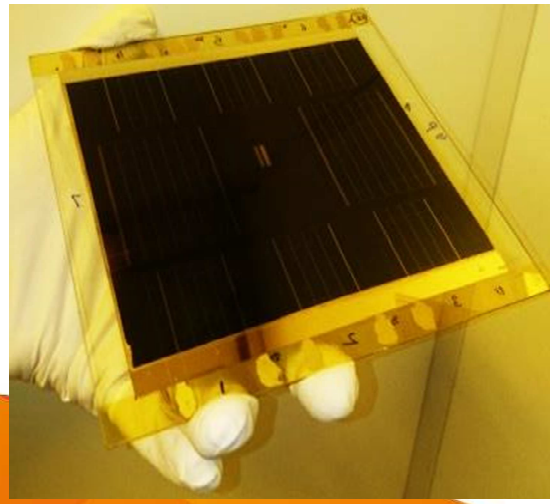
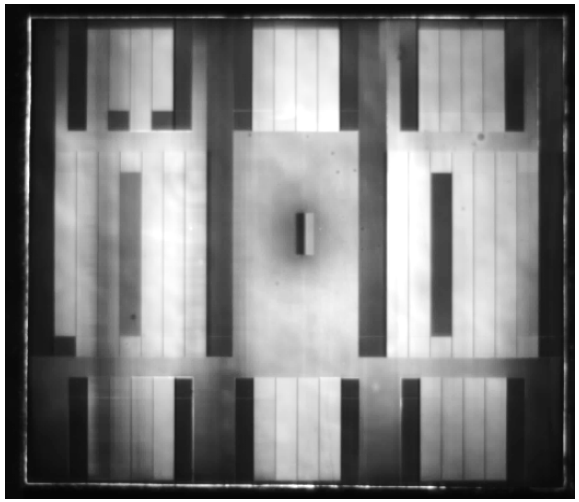
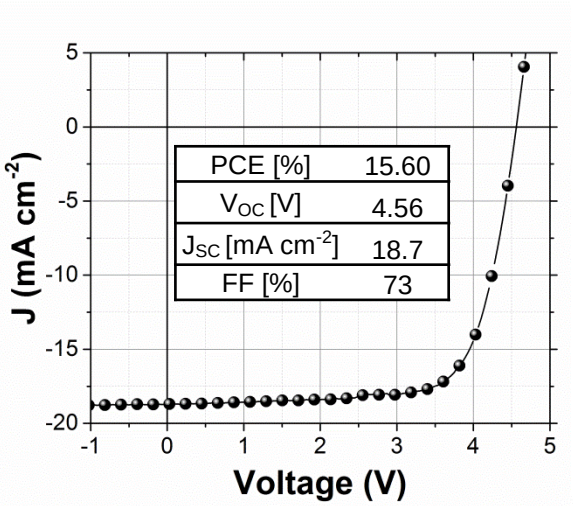
Opaque and rigid mini-modules

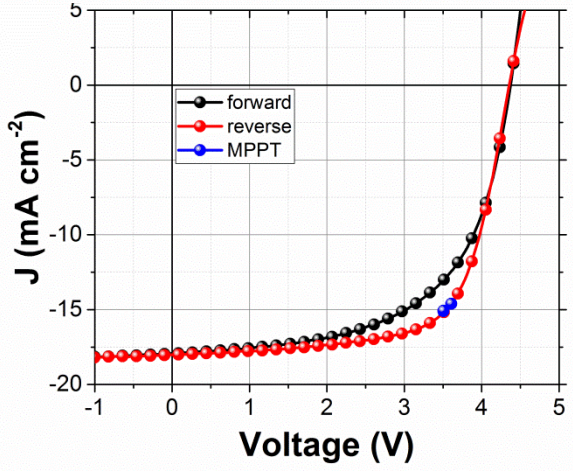
- **Highest PCE with 3x SD layers on 6 inch**
  - 15.6% on aperture area (50mV/s/cell - 4 cm^2)
  - 16.4% on active area (50mV/s)



6 inch PL map







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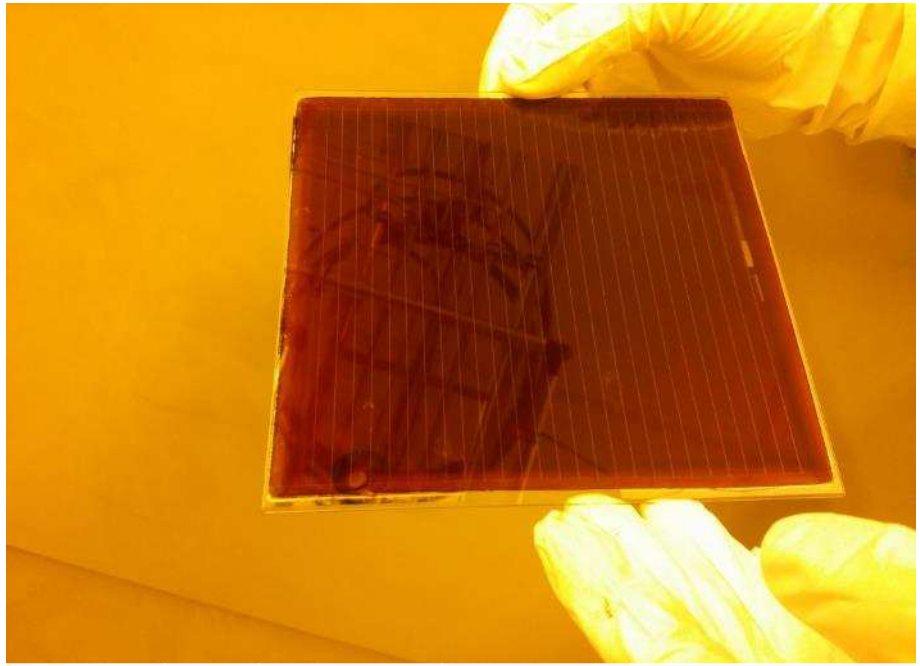
Up-scaled 6x6 inch^2 opaque PSC module on glass

- **Combining up-scaled processes**
  - S2S Slot Die coated layers
  - S2S Laser scribed interconnections
  - S2S Packaged with laminated flexible barrier

- Fully up-scaled, modules with PCE >11% on 6 inch substrates (baseline 1)
- Fully up-scaled, modules with PCE 15-16% on mini-modules (4 cm^2 – 16 cm^2) processed on 6 inch substrates (baseline 2)



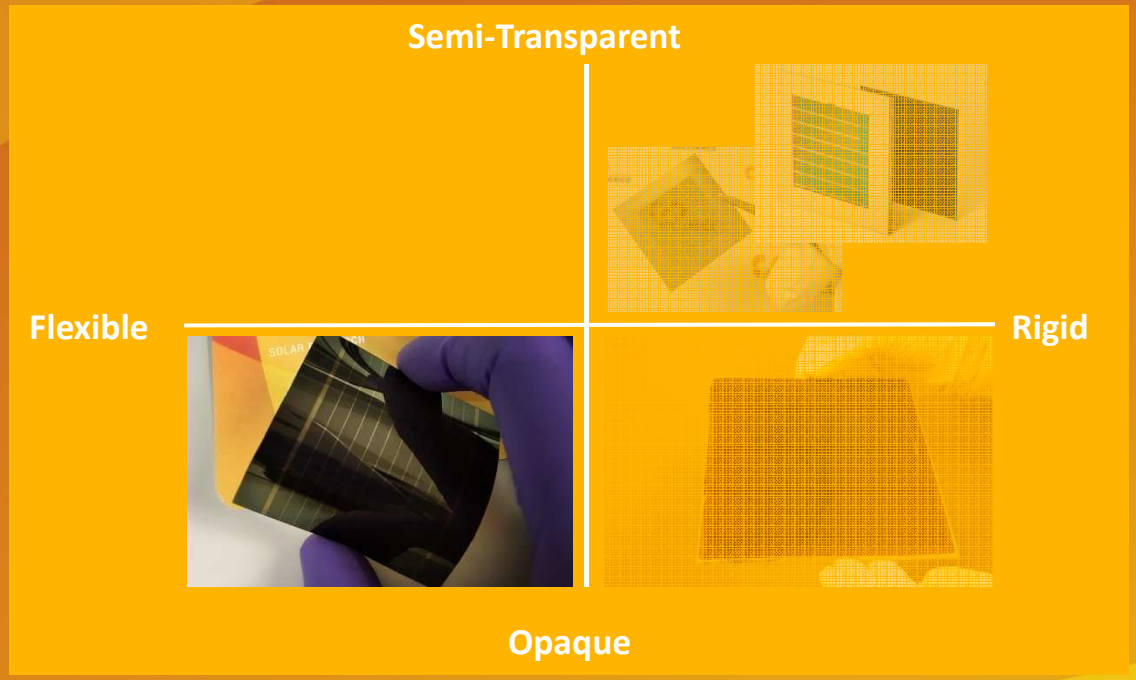
Aperture Area	Sub cells	V_{oc}	I_{sc}	FF	Aperture Efficiency
150 cm^2 GFF ≥ 95%	23	20.8 V	114 mA	70.6%	**11.2 %**

Latest news

NT flex perovskite cells & modules

- R2R/S2S on PET
- Low T, high throughput processing
- Flex modules

→ Customizable PV, outdoor, BAPV, BIPV



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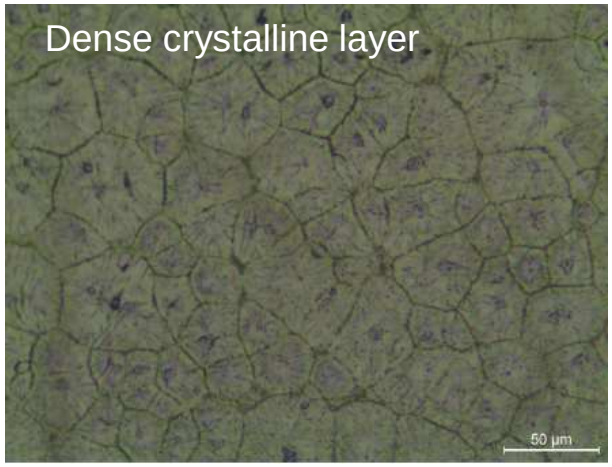
Flexible opaque PSC modules: R2R processing

Substrate PET/ITO

- Slot Die ETL S2S → R2R
- Slot Die PER S2S → R2R
- S2S Slot Die HTL & Au



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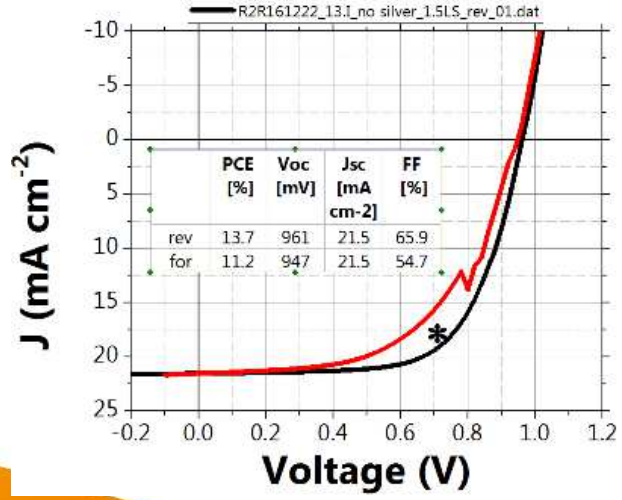
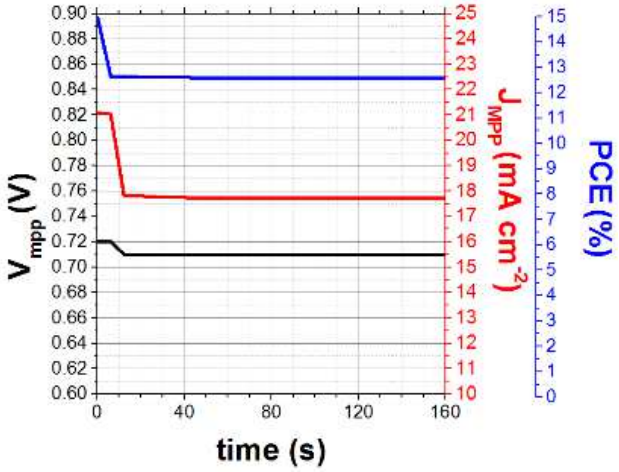
Flexible opaque PSC: (R2R) device results

- **Device performance:**
  - Max PCE:
    - **13,5%** MPPT, 13,7% JV scan
    - Reproduced!





- Withstands 100x bending with r=10 mm

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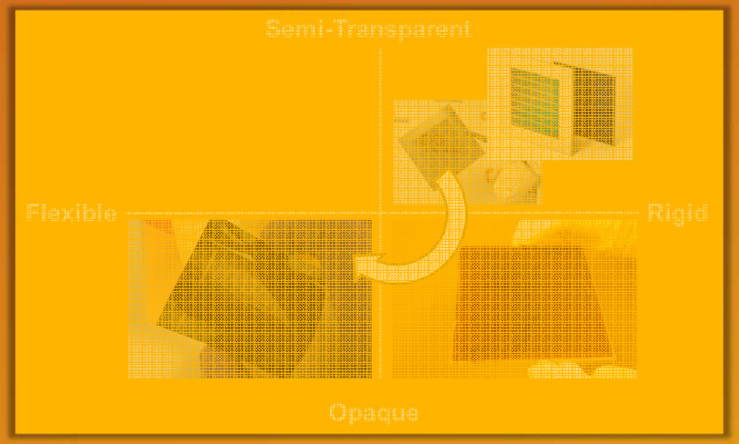

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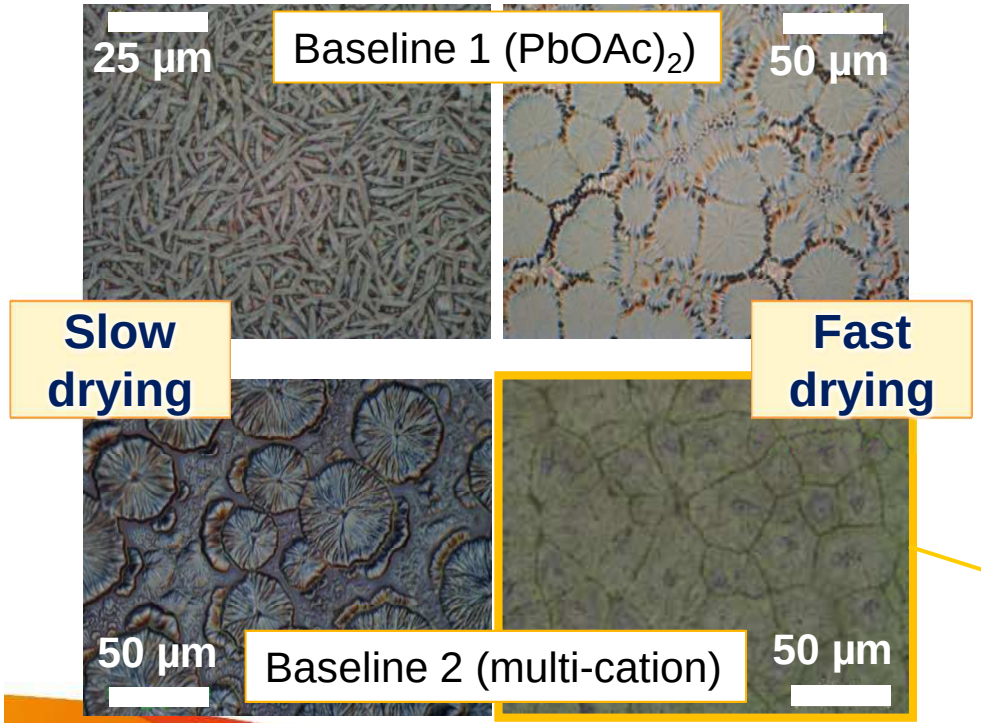
Tuning & controlling the morphology

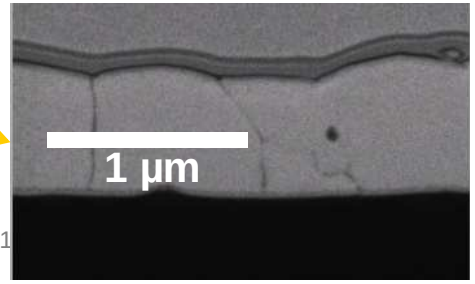


Composition/temperature

- Change the shape and size of perovskite colloidal dispersion
- Large domains are the footprint of the intermediate complex phase

With multi-cation perovskite (higher eff.&stab.):

- High coverage and large domains
- Requires well-controlled quenching step during drying
- Grains spanning the full film thickness



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Solliance research partners

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Solliance industrial partners

DSM, VDL, DYESOL, solartek, nano-c, Heliatek, HyET Solar, MEYER BURGER, SPARK, vito, heijmans, nTact, Rexroth Bosch Group, TULiPPS Solar System Solutions, eternal sun, TOE TROLLER, MAAN GROUP, Meco, SEAC, Scheuten, ccm centre for concepts in mechatronics, SoLayTec

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Thank you for your attention!

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