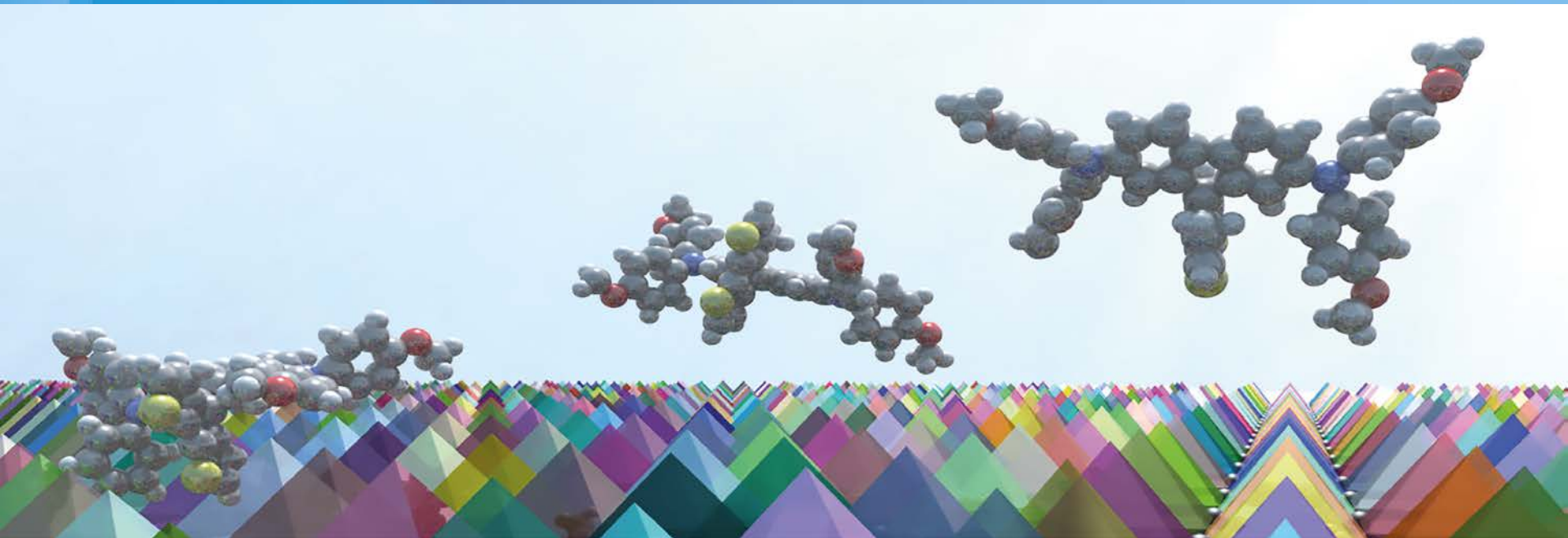
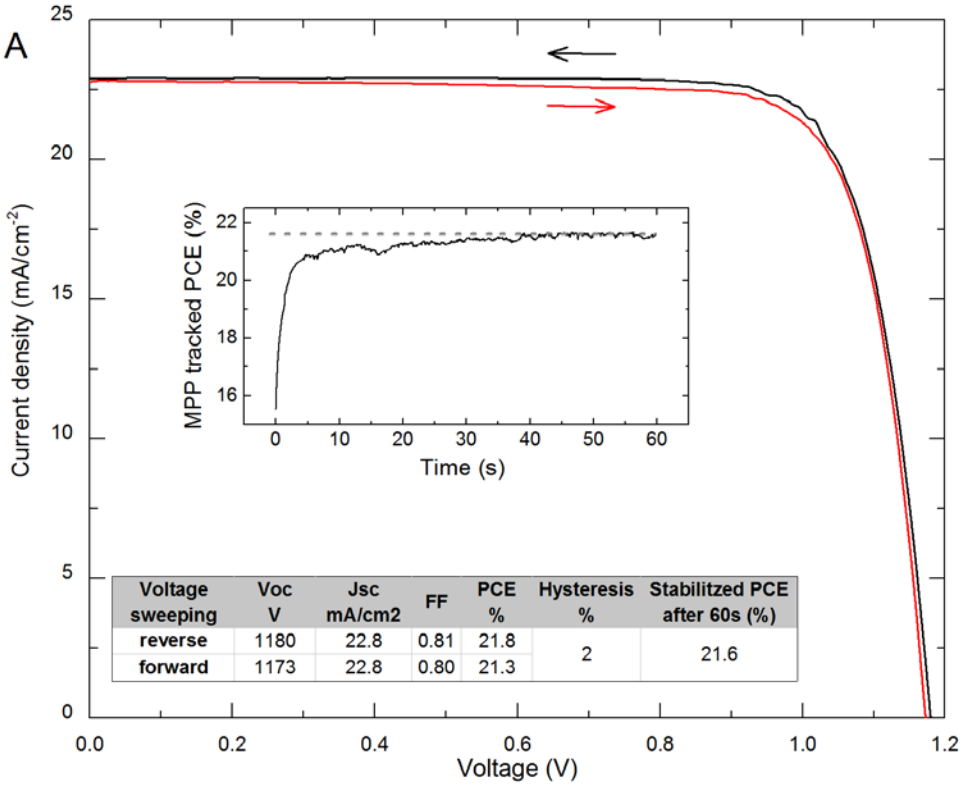
HZB Helmholtz Zentrum Berlin

Antonio Abate

INTER-ACTIVE: Active materials and interfaces for stable perovskite solar cells

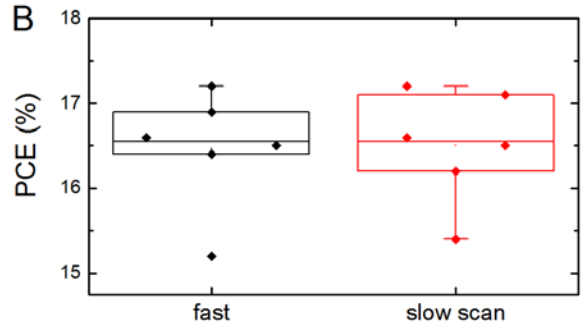


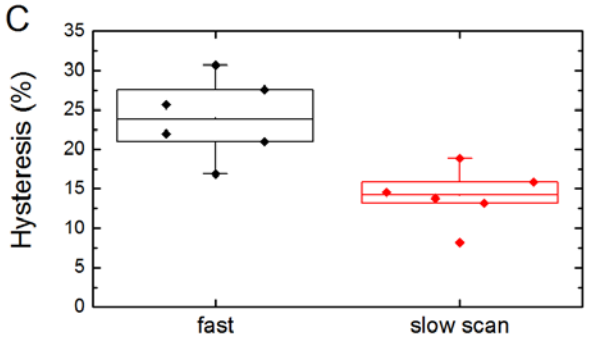
The well-known “hysteresis” of the JV curves

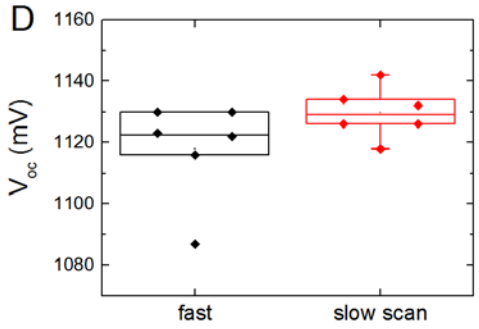


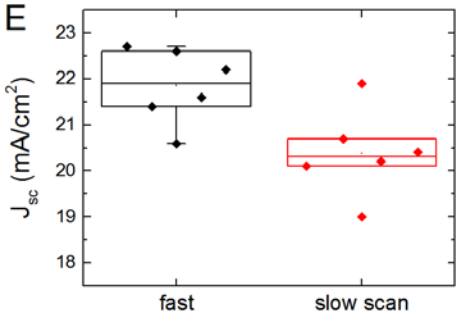
Voltage sweeping	Voc V	Jsc mA/cm2	FF	PCE %	Hysteresis %	Stabilitzed PCE after 60s (%)
reverse	1180	22.8	0.81	21.8	2	21.6
forward	1173	22.8	0.80	21.3		

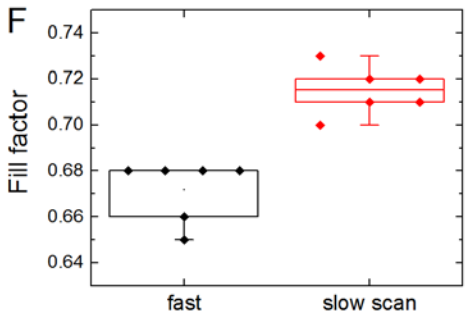
$$\text{Hysteresis} = \frac{\text{PCE (reverse)} - \text{PCE (forward)}}{\text{PCE (reverse)}}$$











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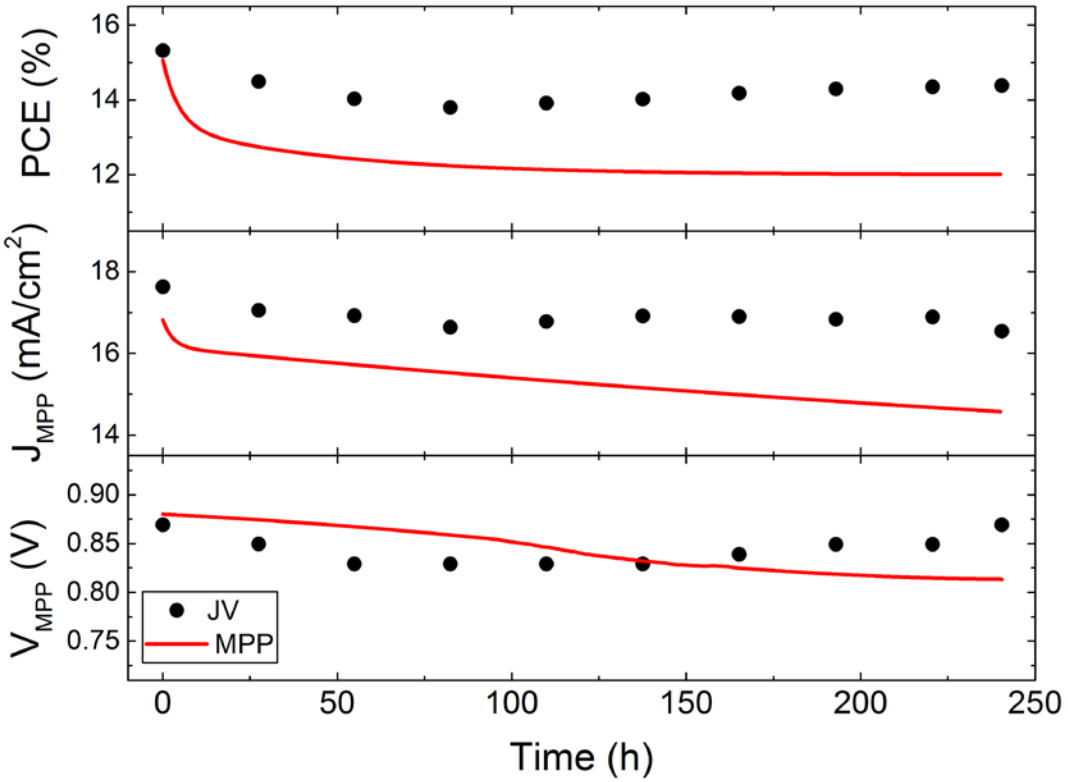
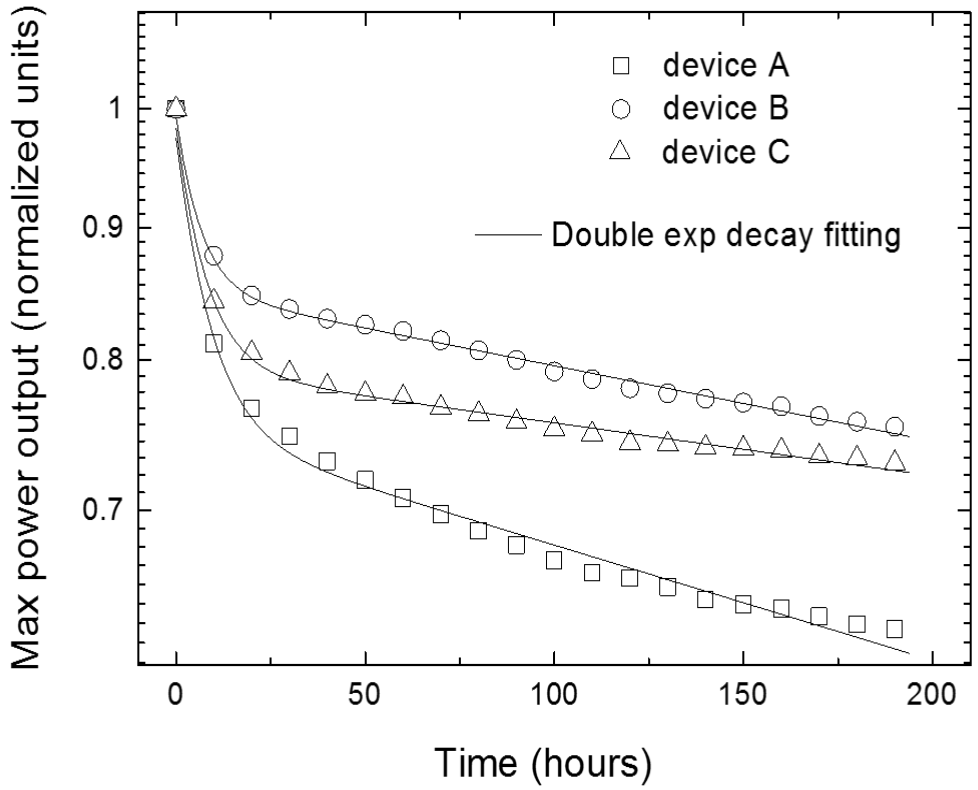
JV curves **overestimate** efficiency of ageing devices



Tracking the Maximum Power Output versus time we found a double exponential decay, in Argon and UV filtered sunlight



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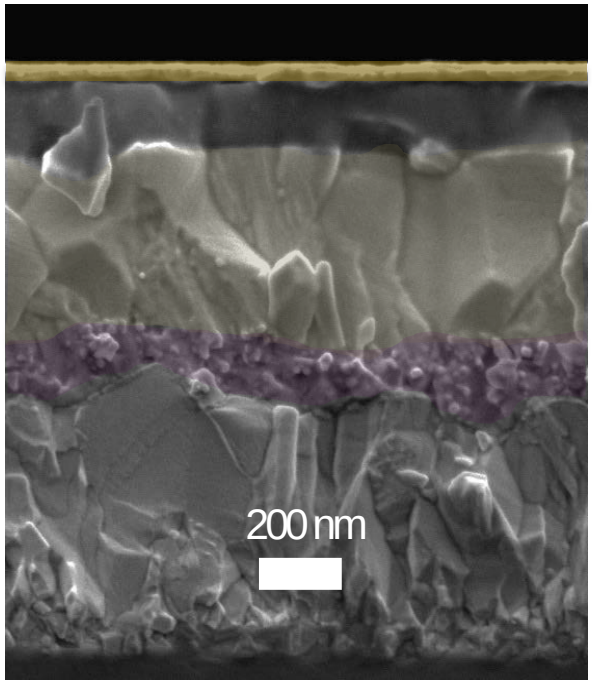
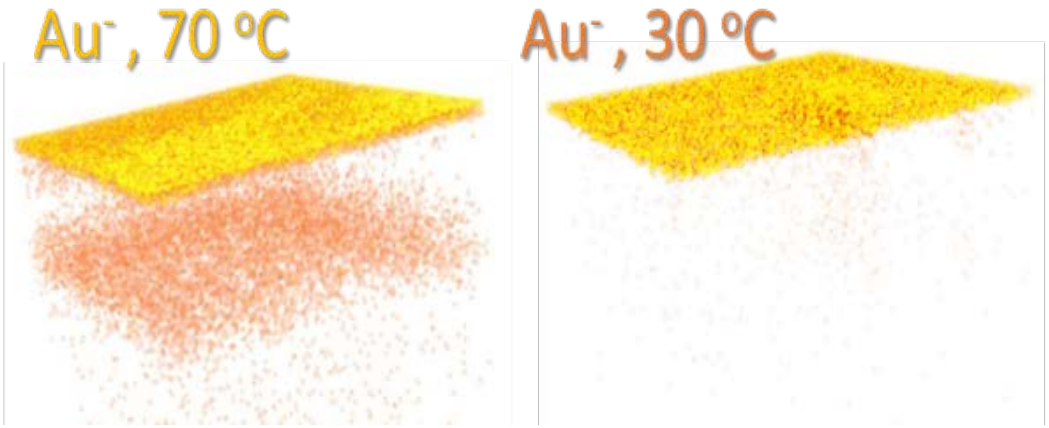
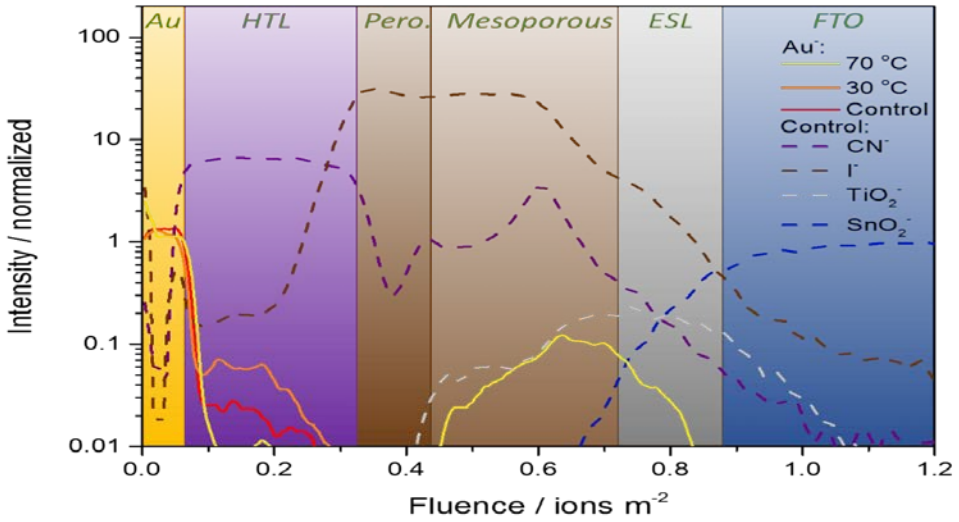
EES
2015, 8, 2946

Time of flight secondary ion mass spectroscopy show evidence of gold migration







Domaski
ACSnano
2016, 10 (6) 6306–6314

Guarnera
JPCL
2015, 6 (3), 432

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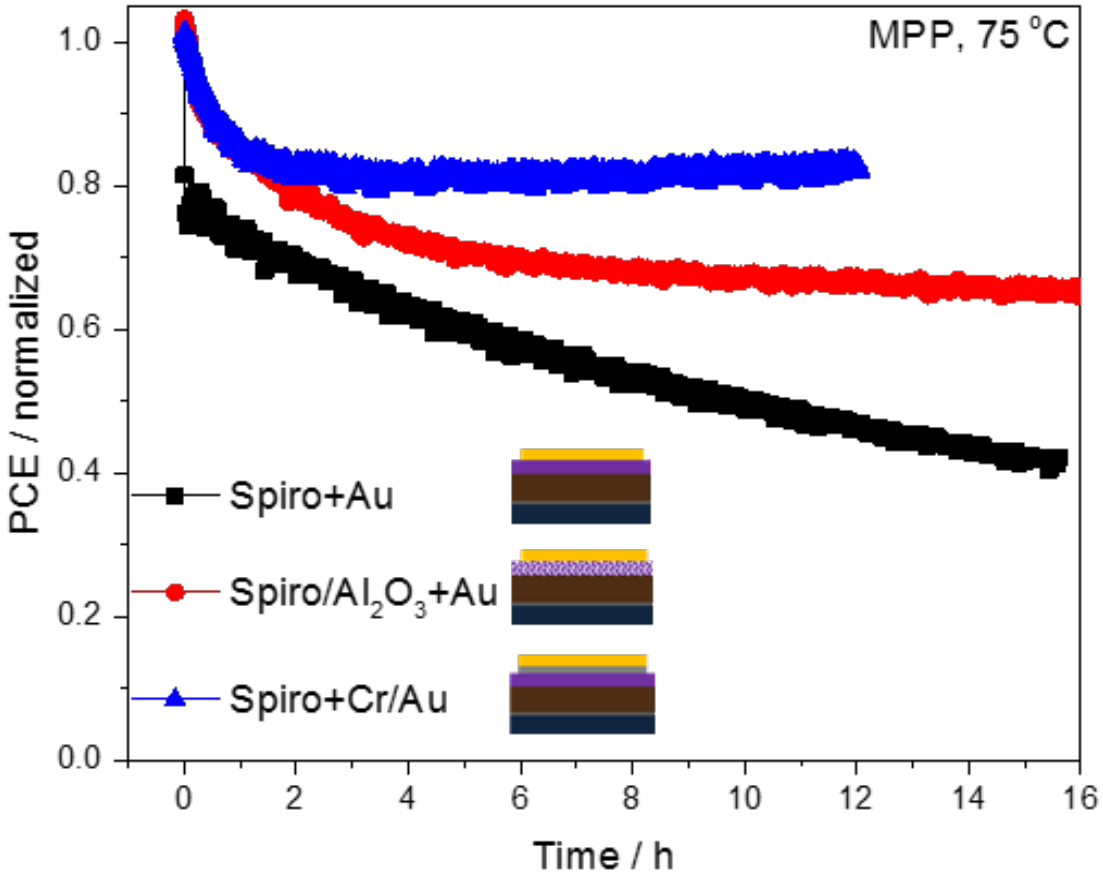
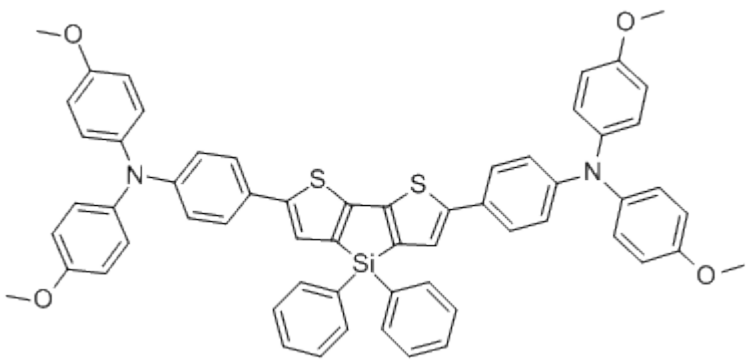
Blocking the gold migration significantly improved the long term stability

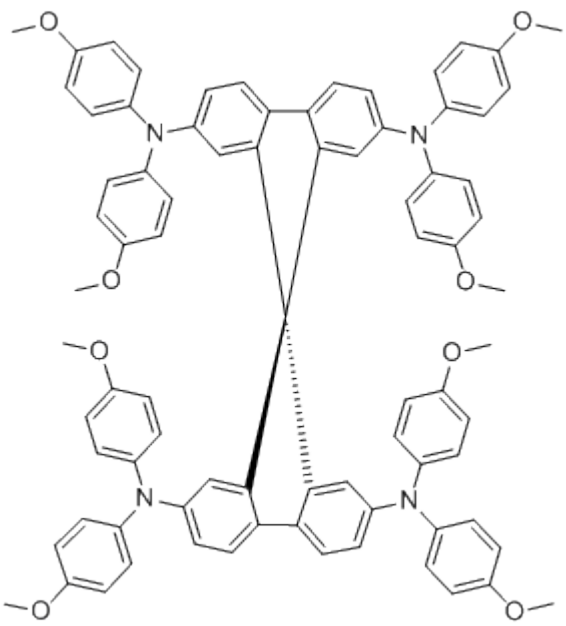


Domaski
ACSnano
2016, 10 (6) 6306–6314

Silolothiophene-Linked Triphenylamines HTMs



PEH-2



Spiro-OMeTAD

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2015, 8, 2946

Sanghyun Paek, PhD @EPFL

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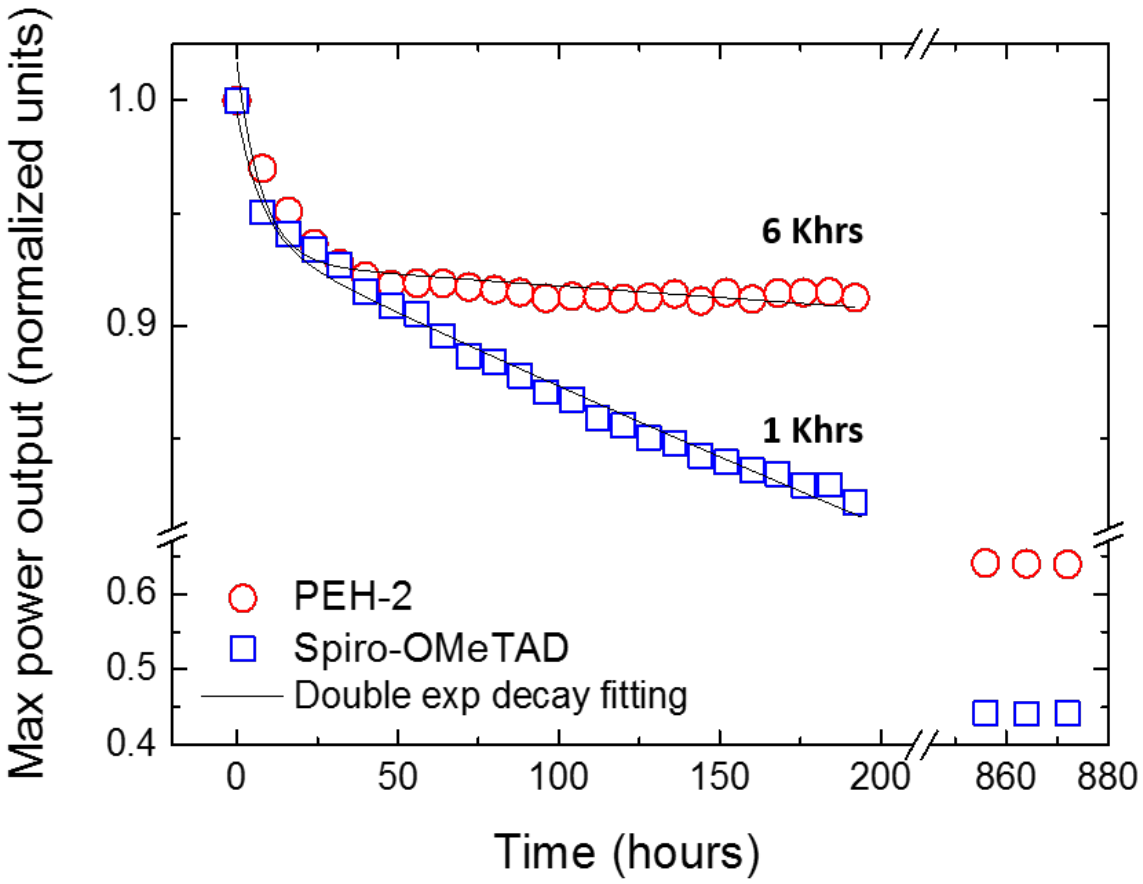
Silolothiophene-Linked Triphenylamines enable more stable perovskite solar cells



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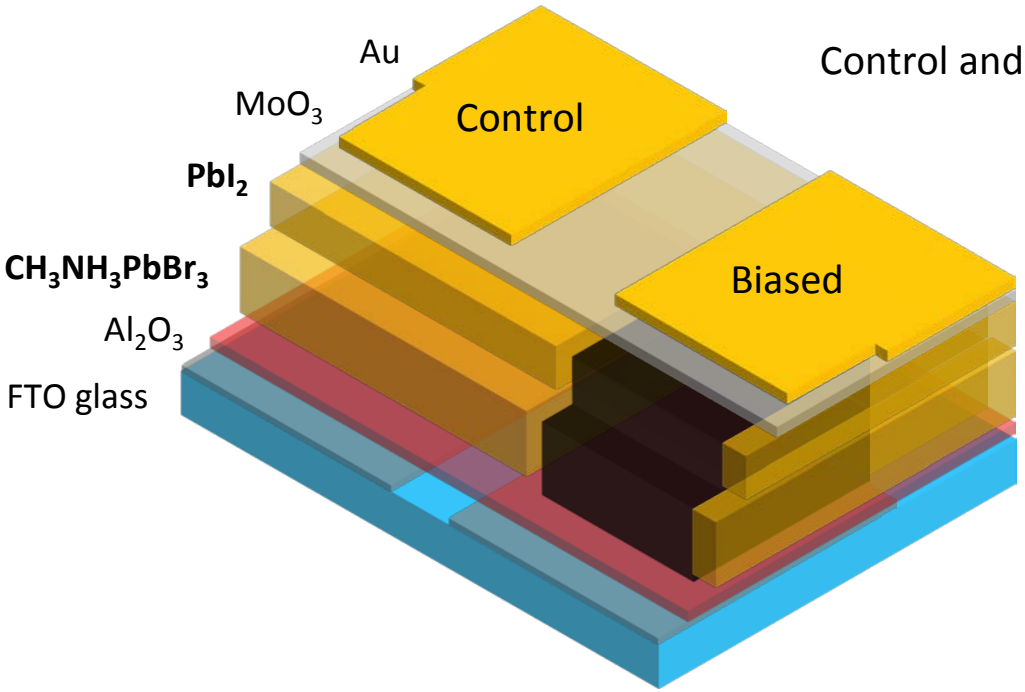
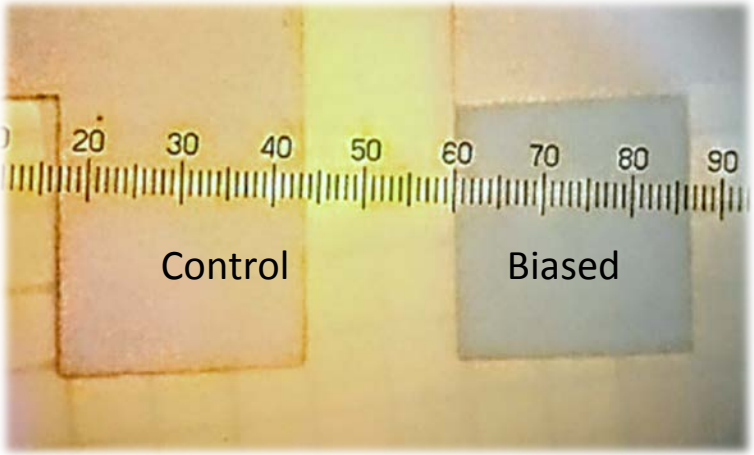
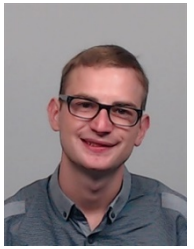
Direct evidence of electric field induced ion migration



Control and biased pixel both heated at 70 °C



Unpublished data



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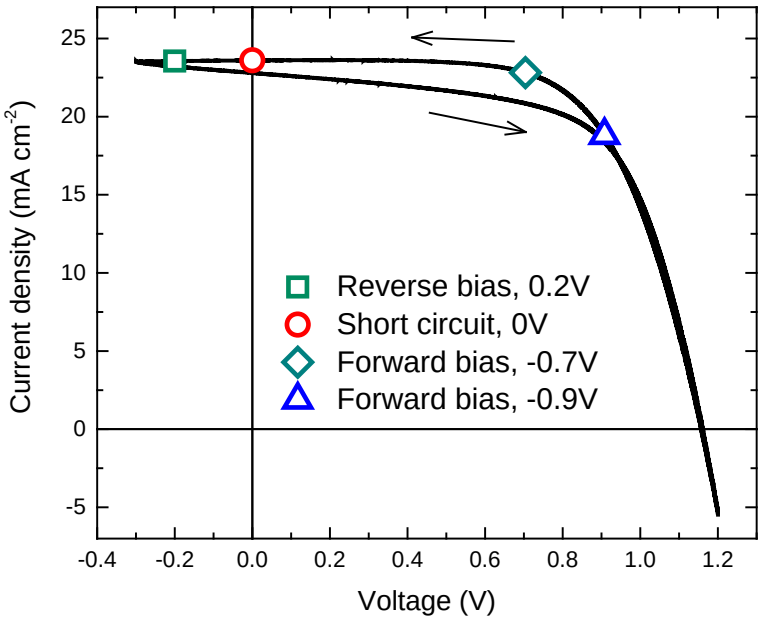
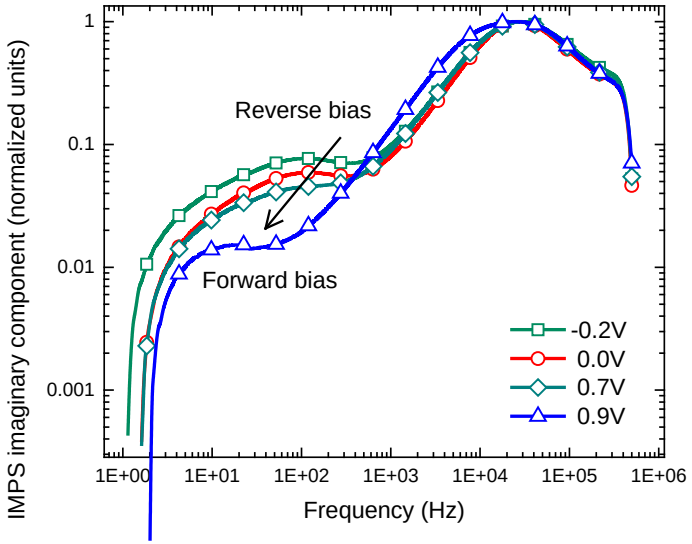
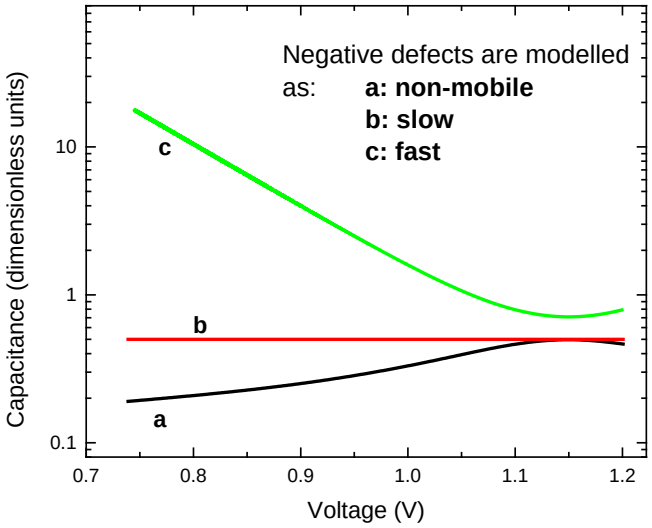
konrad.domanski@epfl.ch

Intensity modulated photocurrent spectroscopy suggest migration of cation vacancies







Abate
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2017, 10, 604

Antonio Abate, PhD G.Richardson@soton.ac.uk

Impact of the steady-state ion distribution on the charge extraction (over 20min stabilization time)

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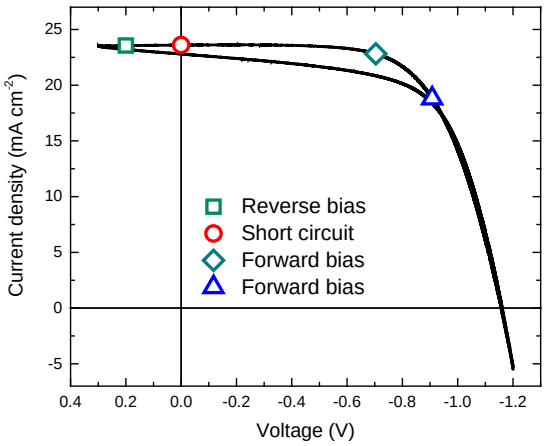
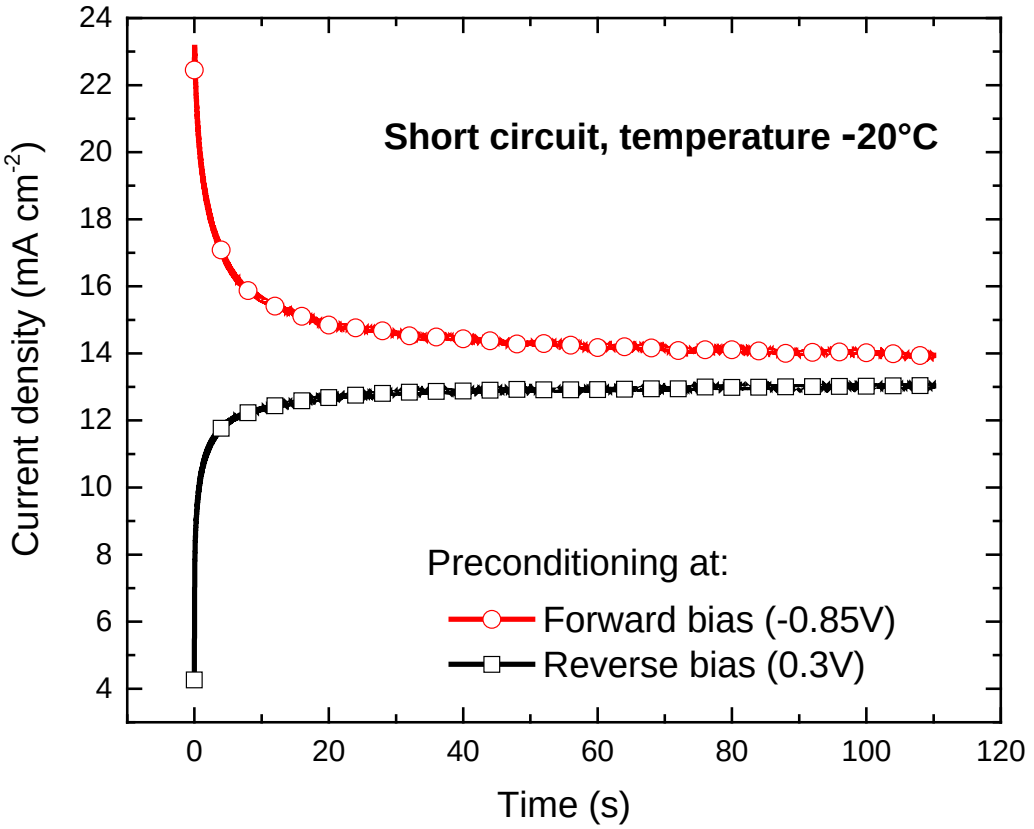
2017, 10, 604





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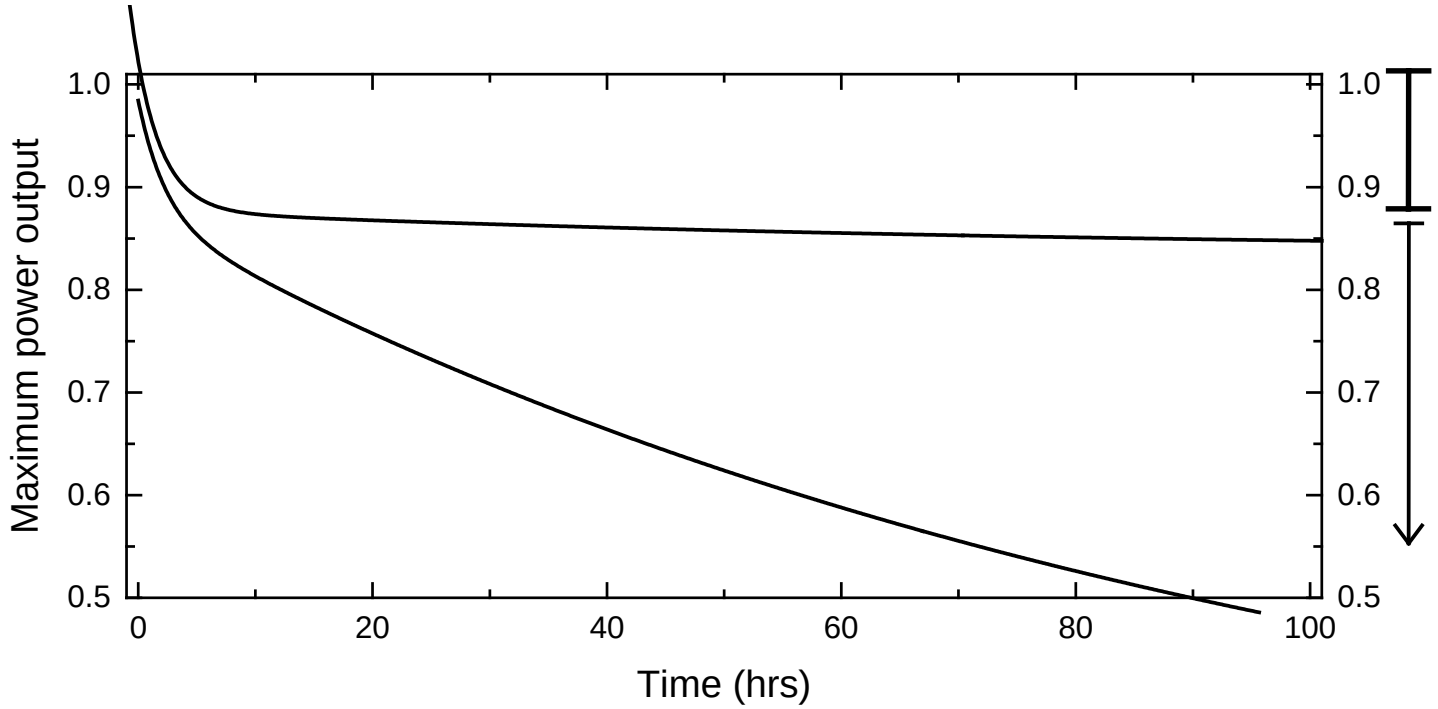
The early rapid decay in the MPP is always the same regardless the device long-term stability



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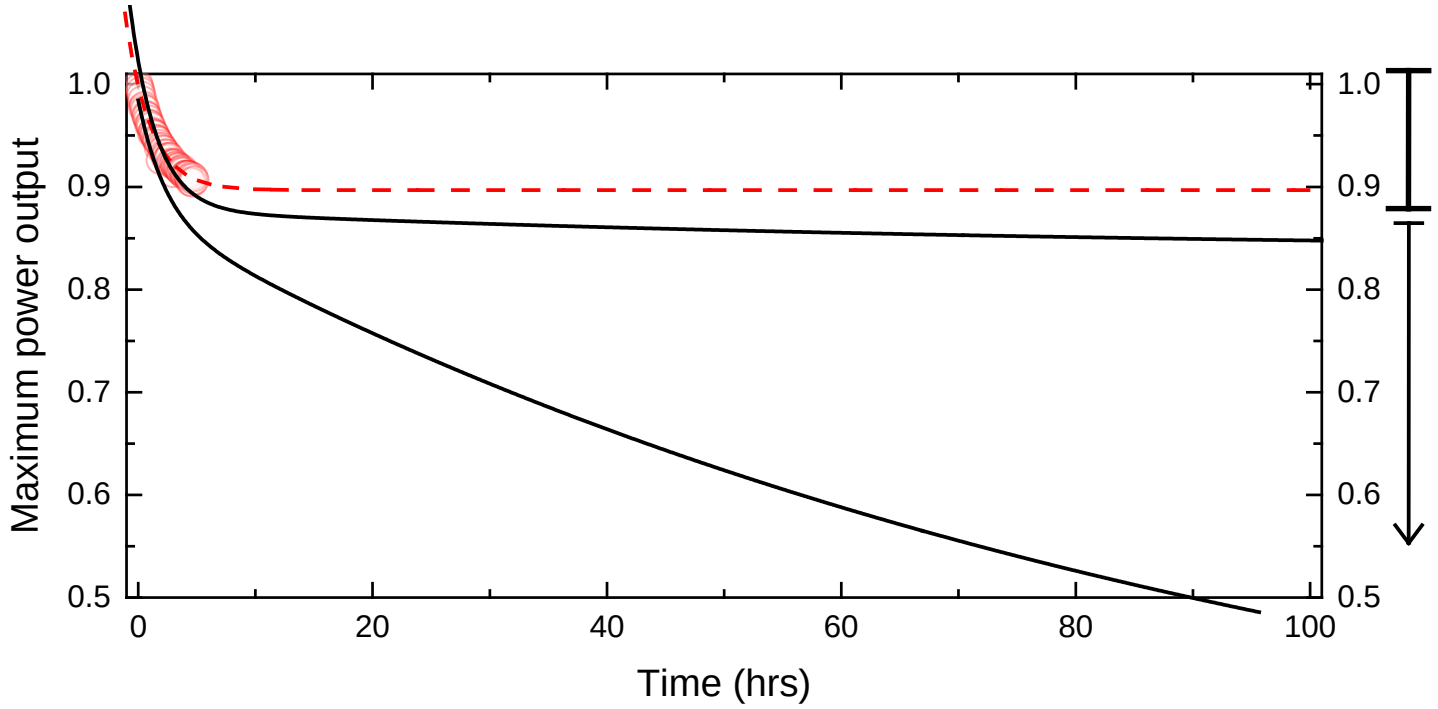

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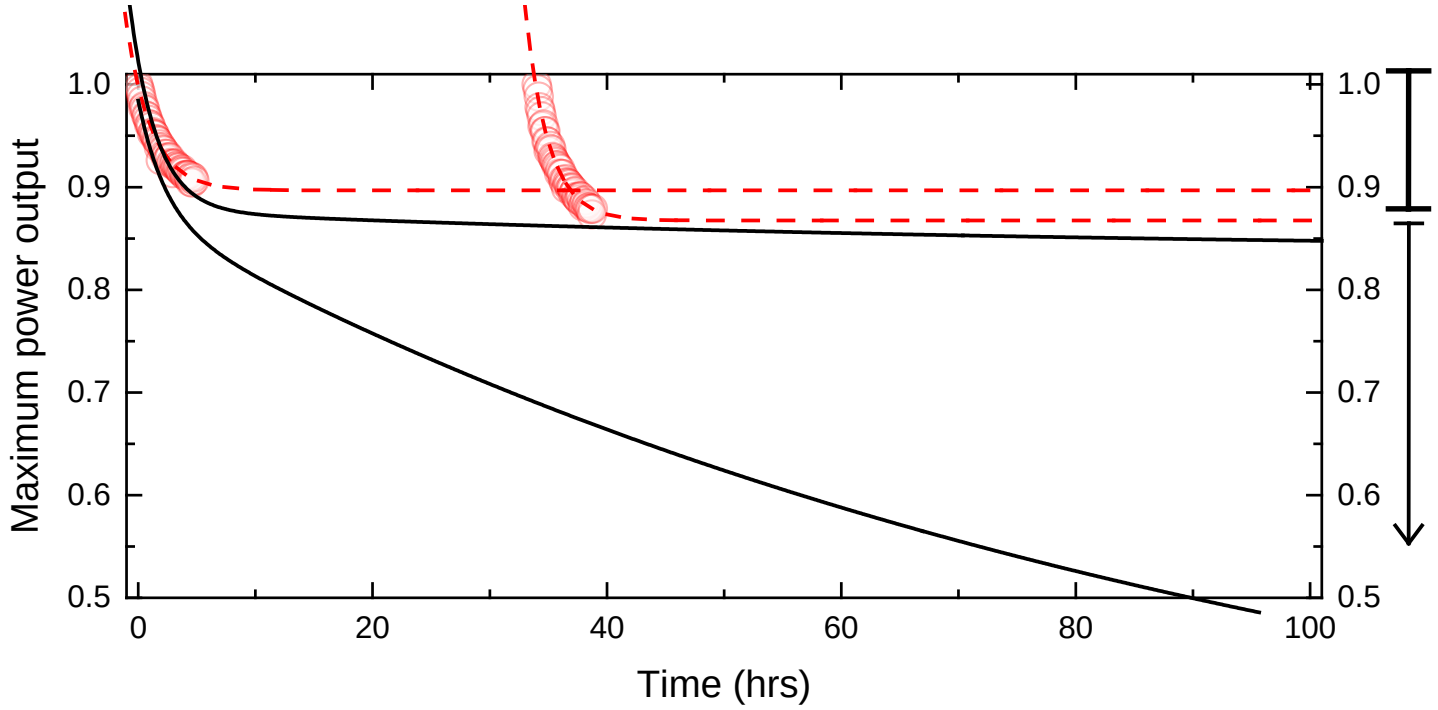
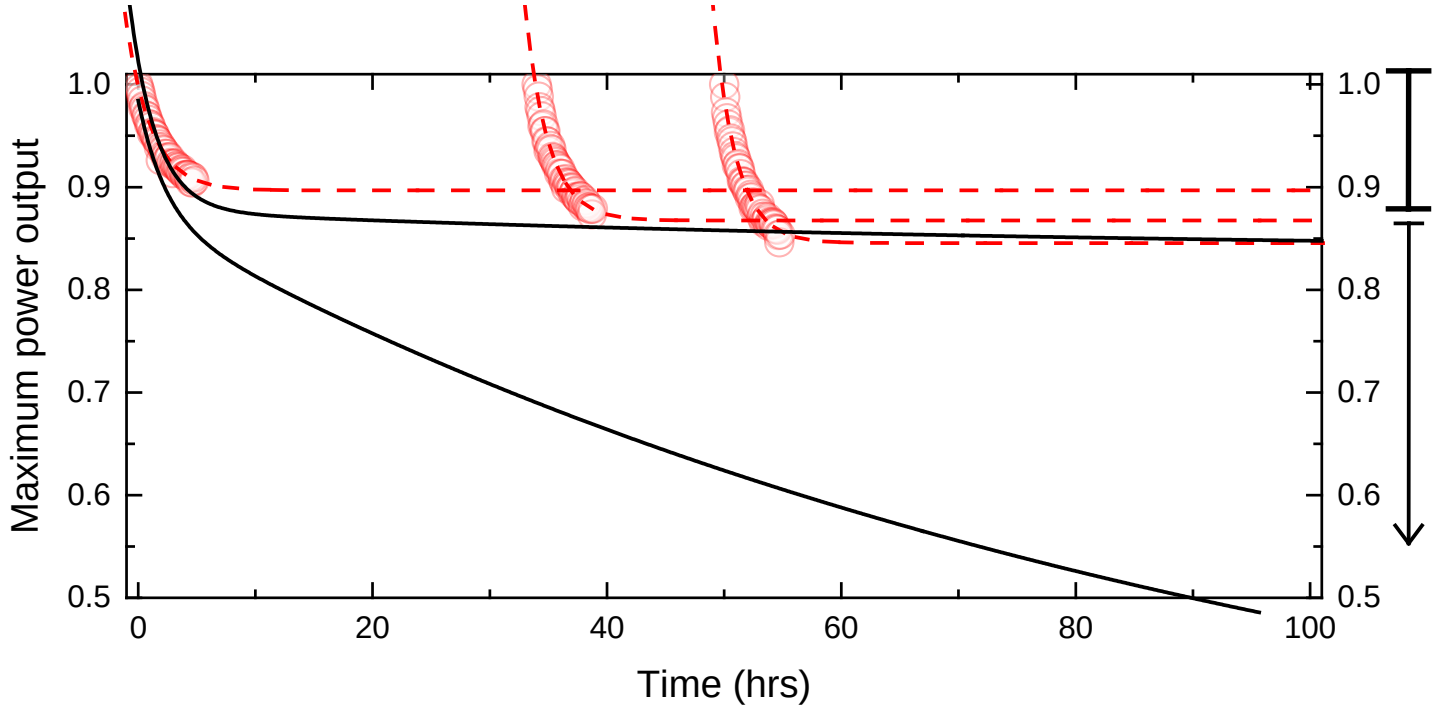
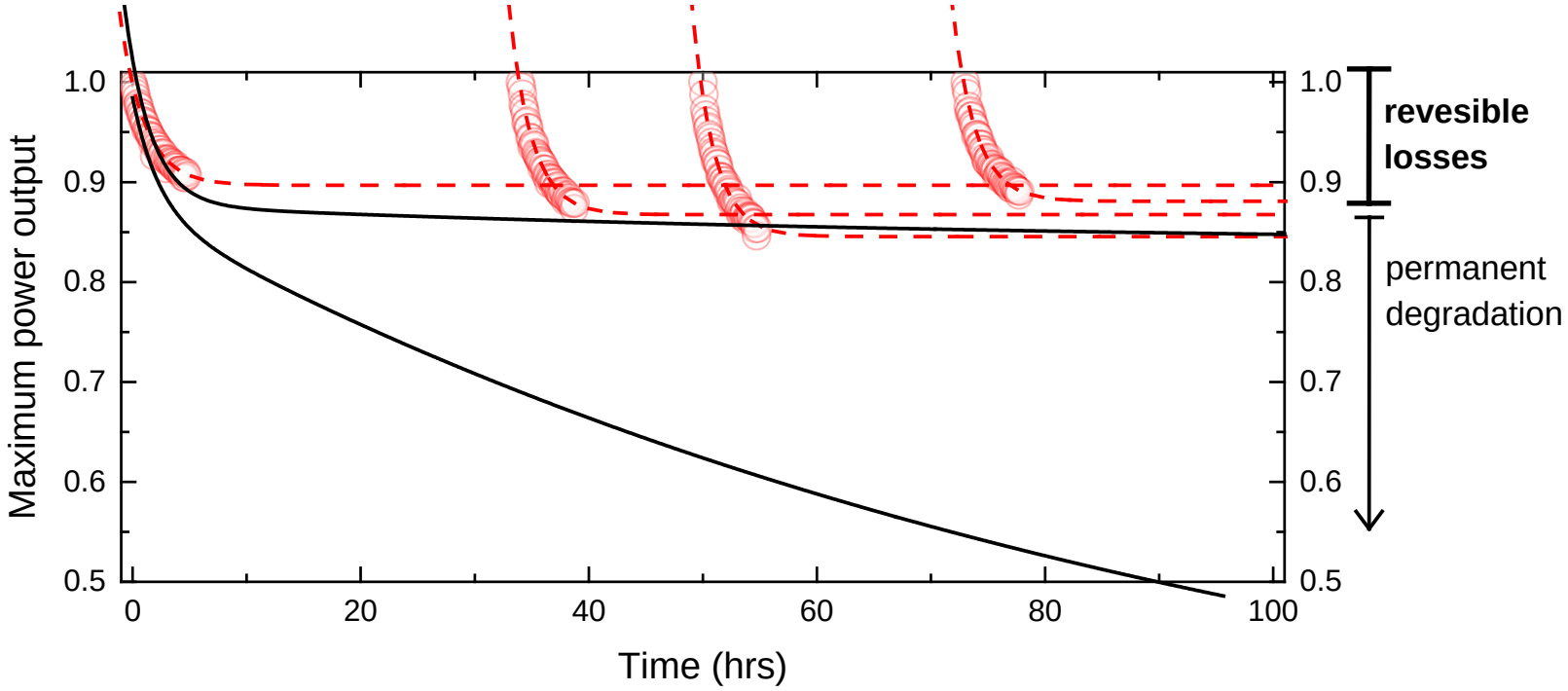


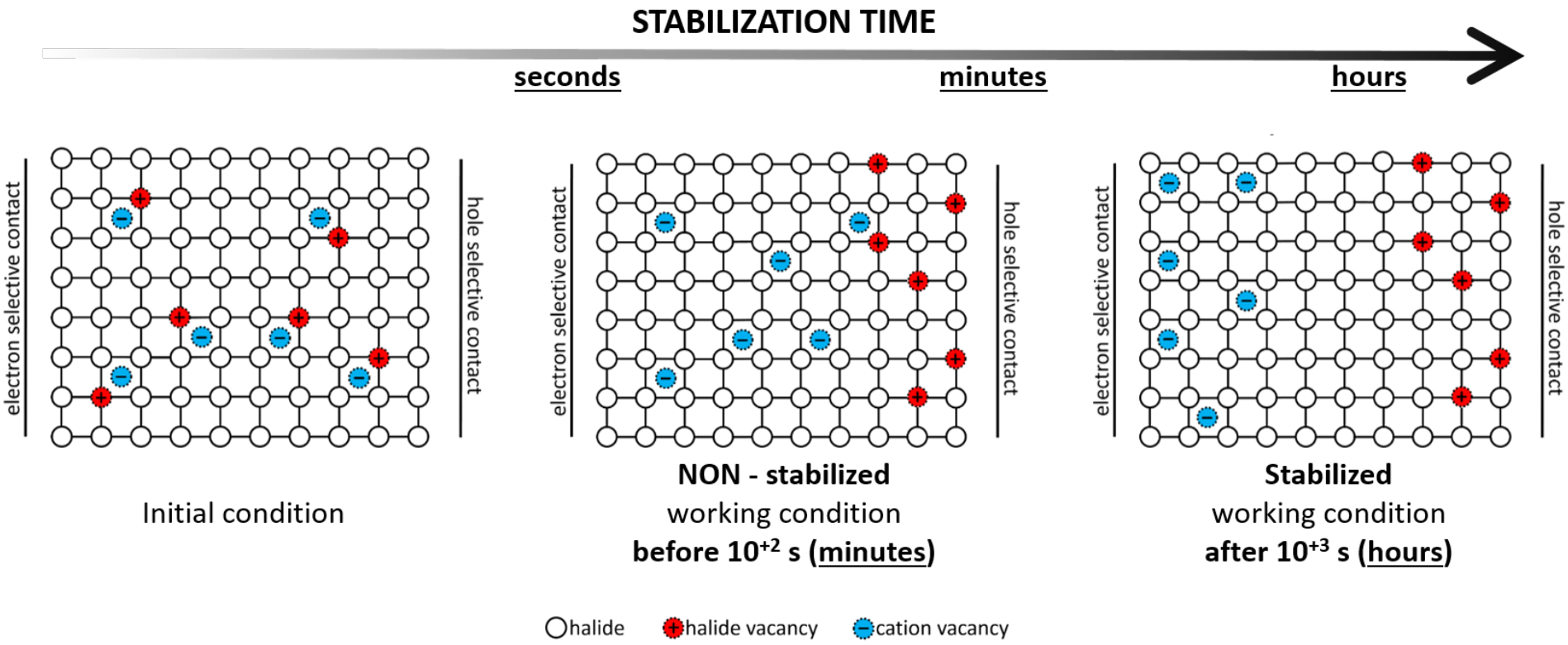
The early rapid decay in the MPP is always the same regardless the device long-term stability



The early rapid decay is reversible



Ionic defects evolution



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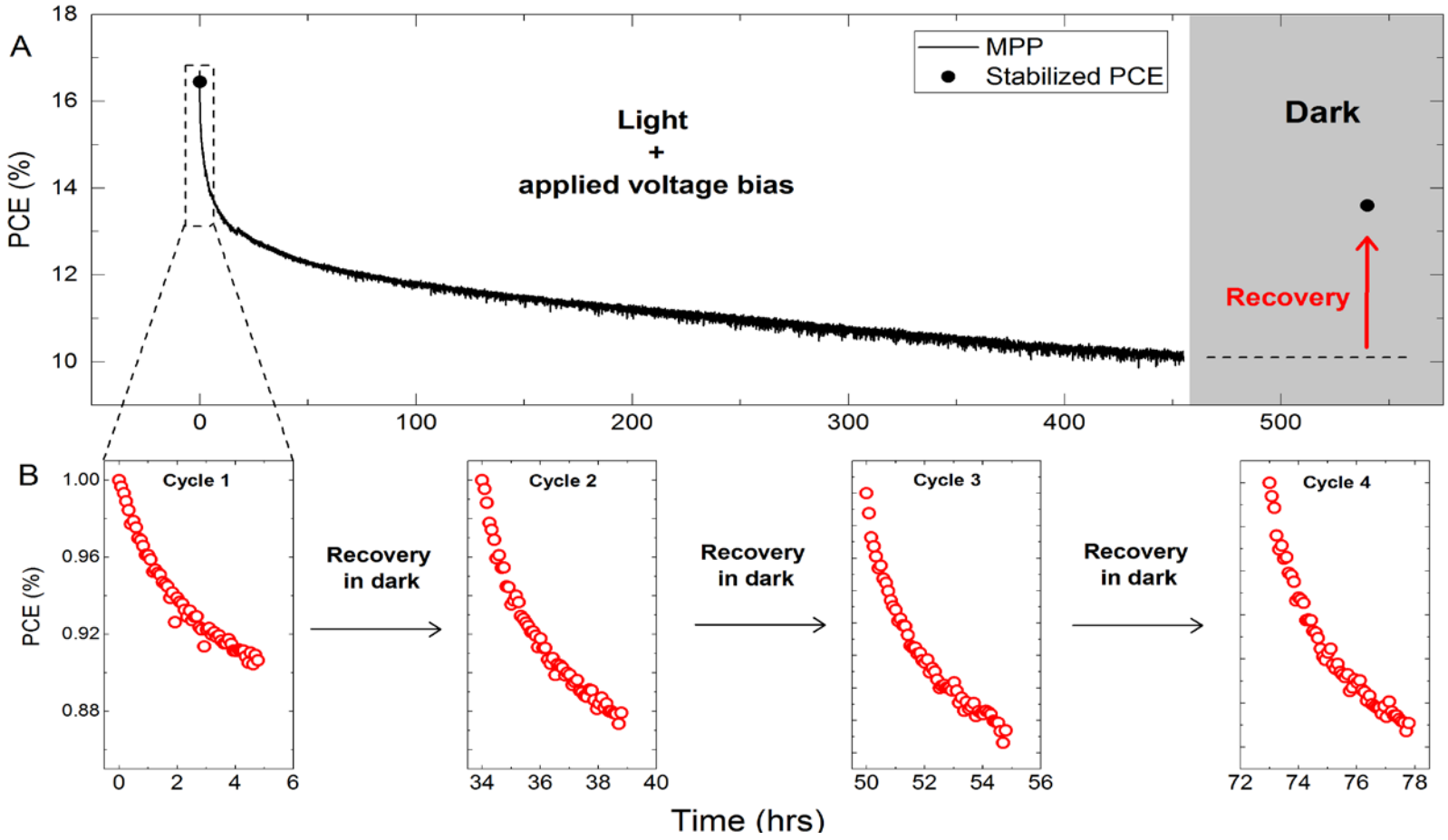
Cation vacancies migrating on significantly longer timescales (above 10^{+3} s) than halide vacancies (from 10^{-1} to 10^{+2} s) induce reversible performance losses that abate the initial efficiency of state-of-the-art PSCs by about 10-15%.

Efficiency recovers after a dark rest: reversible losses



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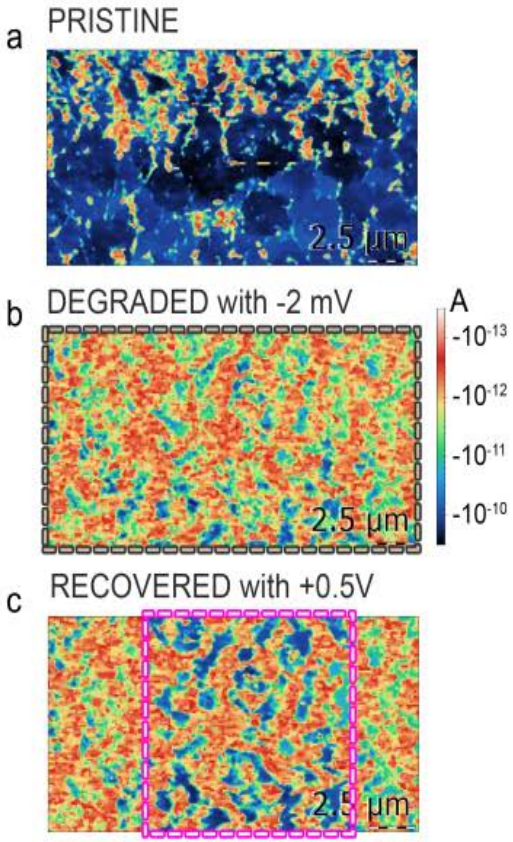
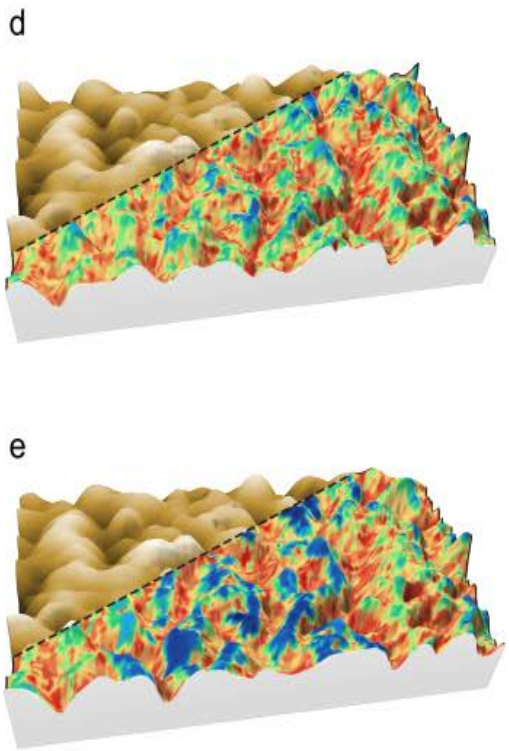
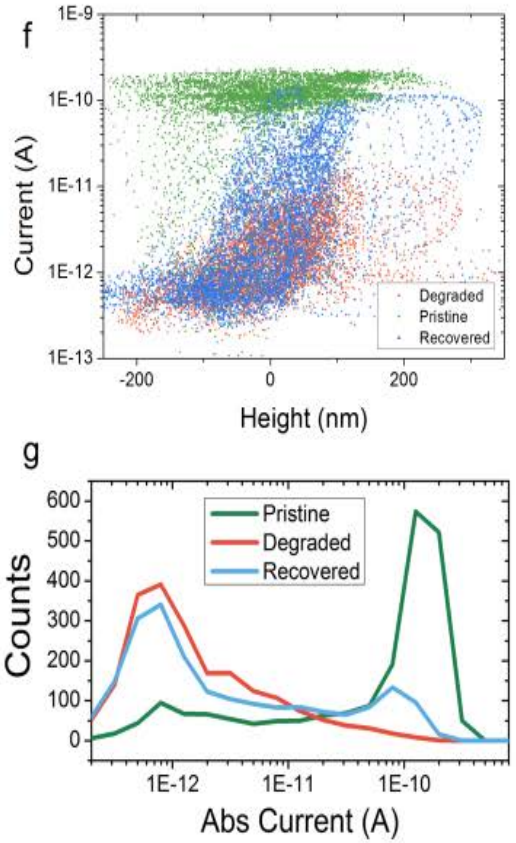
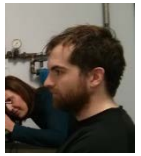
Reversible in the bulk, NON-reversible at the boundaries of the perovskite crystals





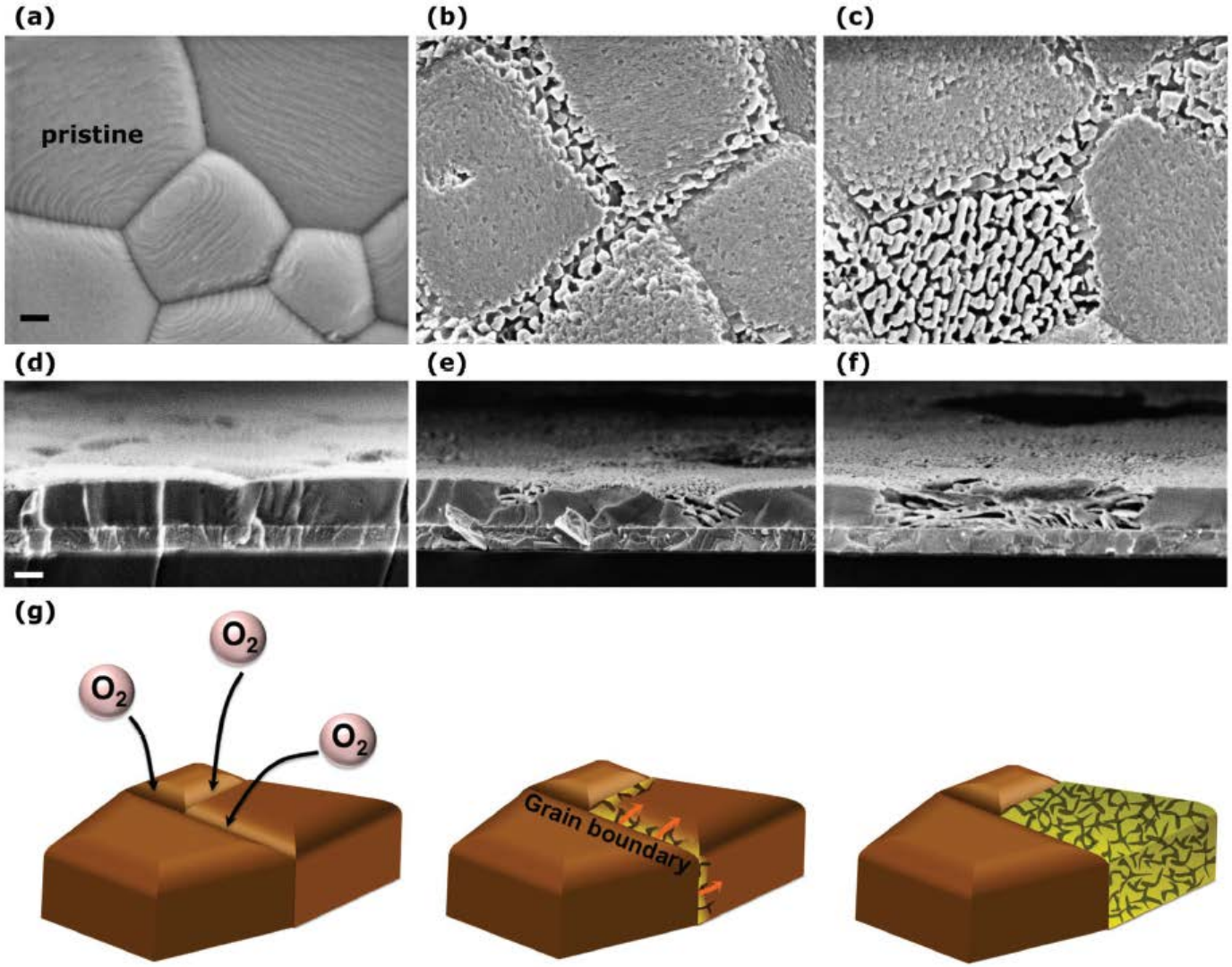




Mariano Campoy, Andreas Gomez
Materials Science Institute of Barcelona

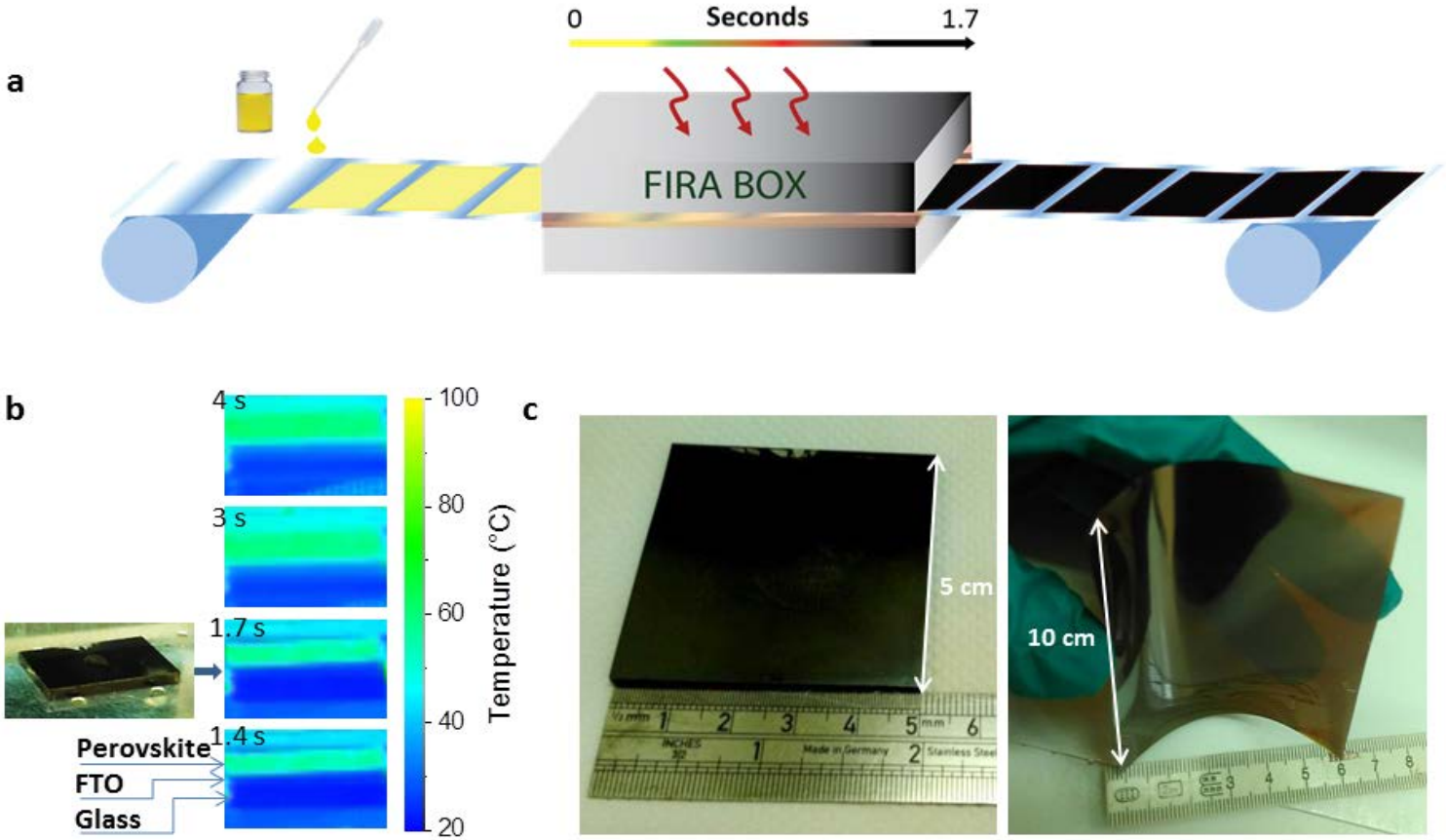
Antonio Abate, PhD

Grain boundaries trigger the degradation



Sun et al., Adv. Energy Mater. 2017, 1700977

Aiming for large crystals using Flash infrared annealing (FIRA)



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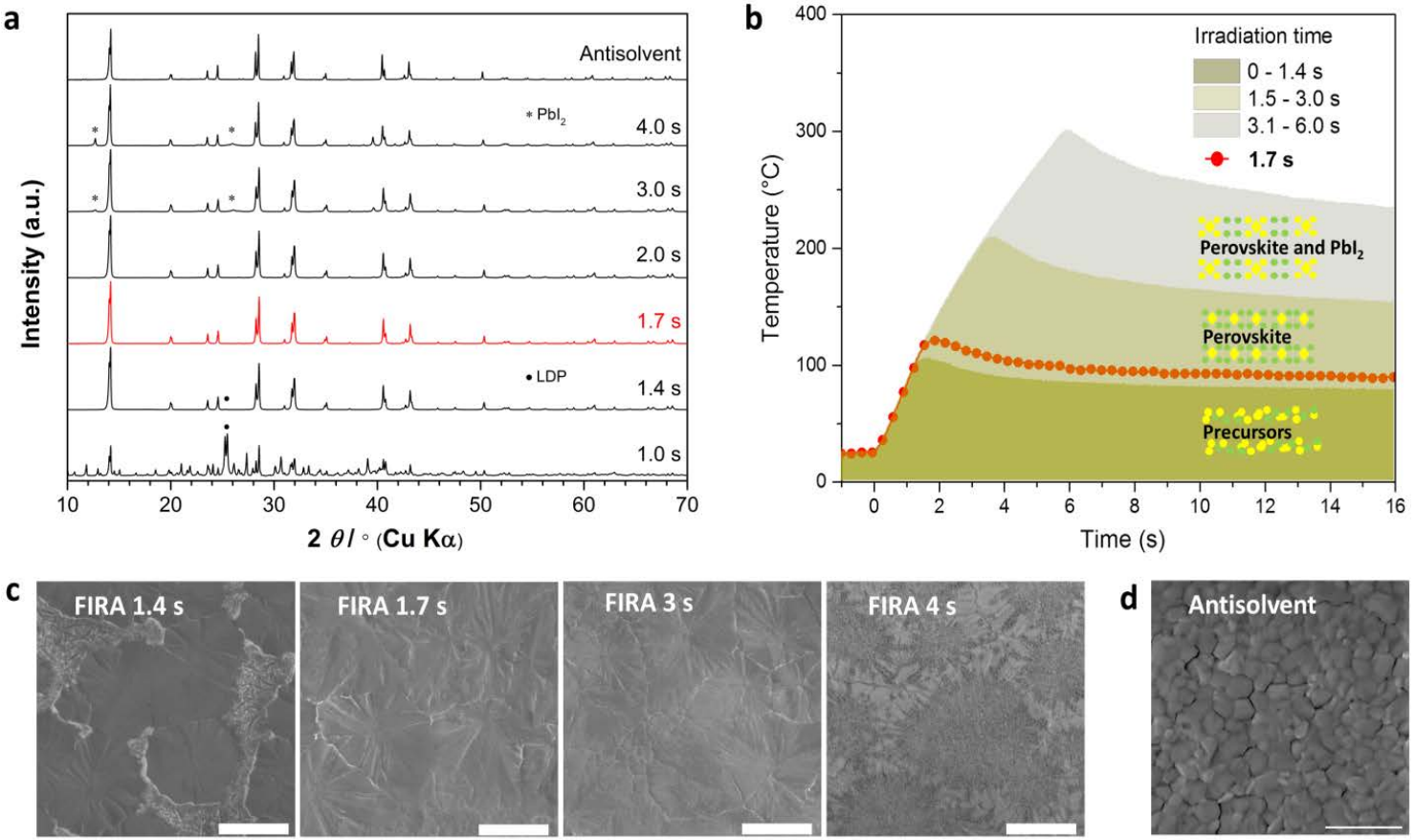
FIRA-induced large crystals



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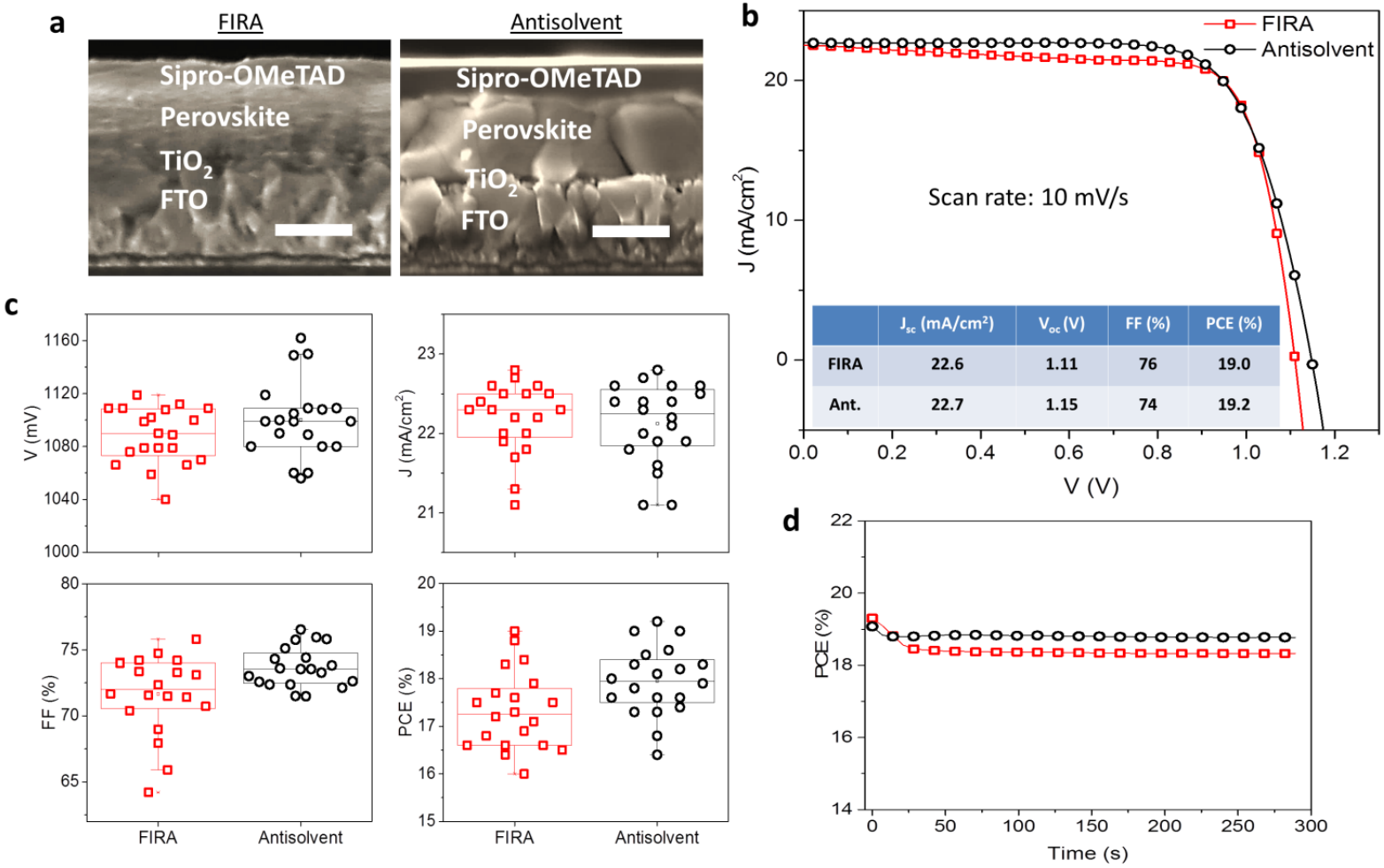
FIRA as good as state-of-the-art



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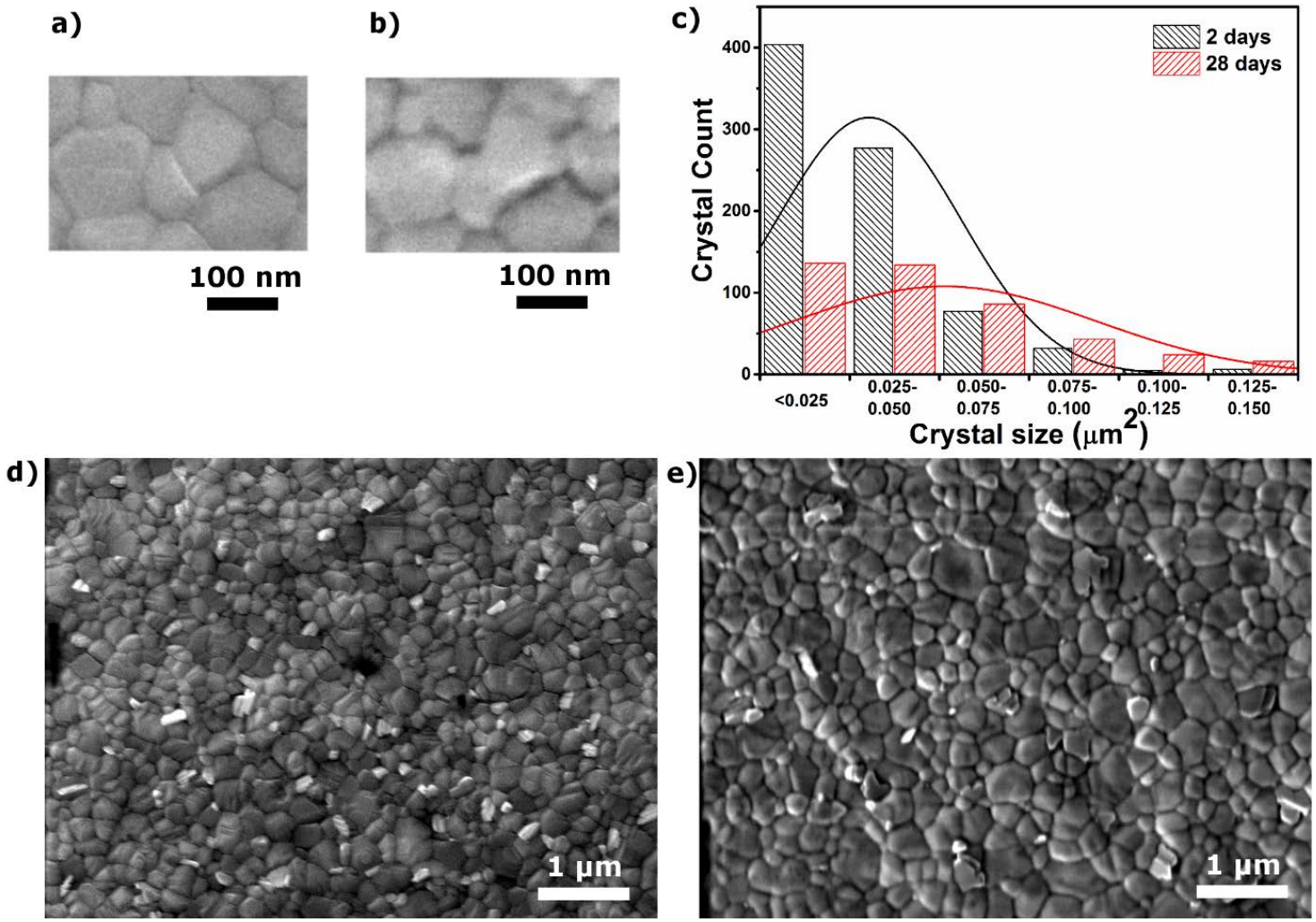
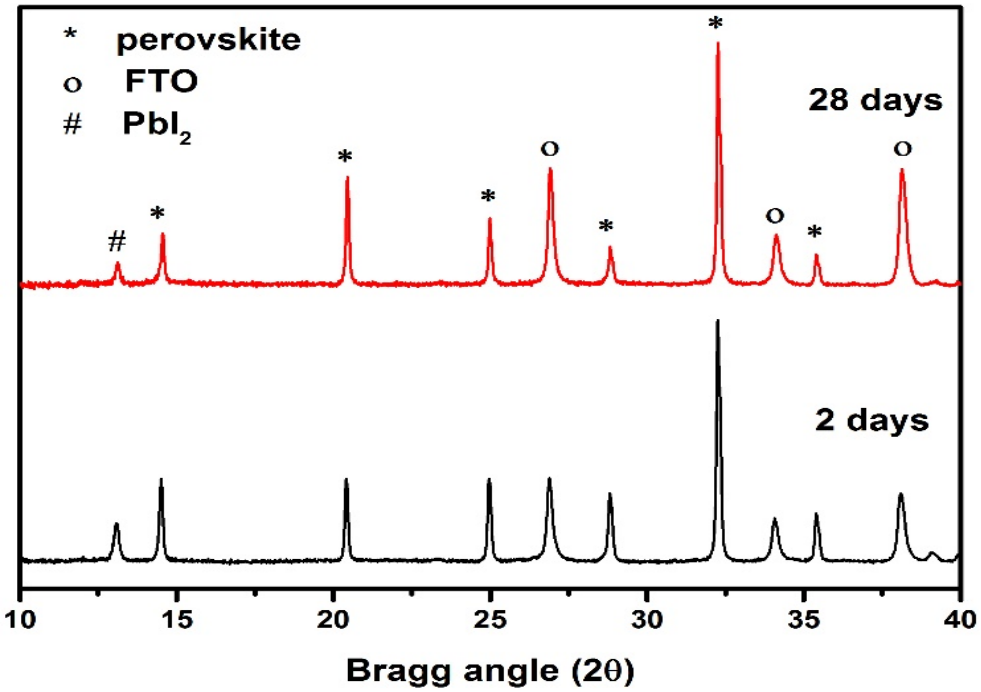
Smaller crystals spontaneously merge into larger



Bart Roose, University of Cambridge

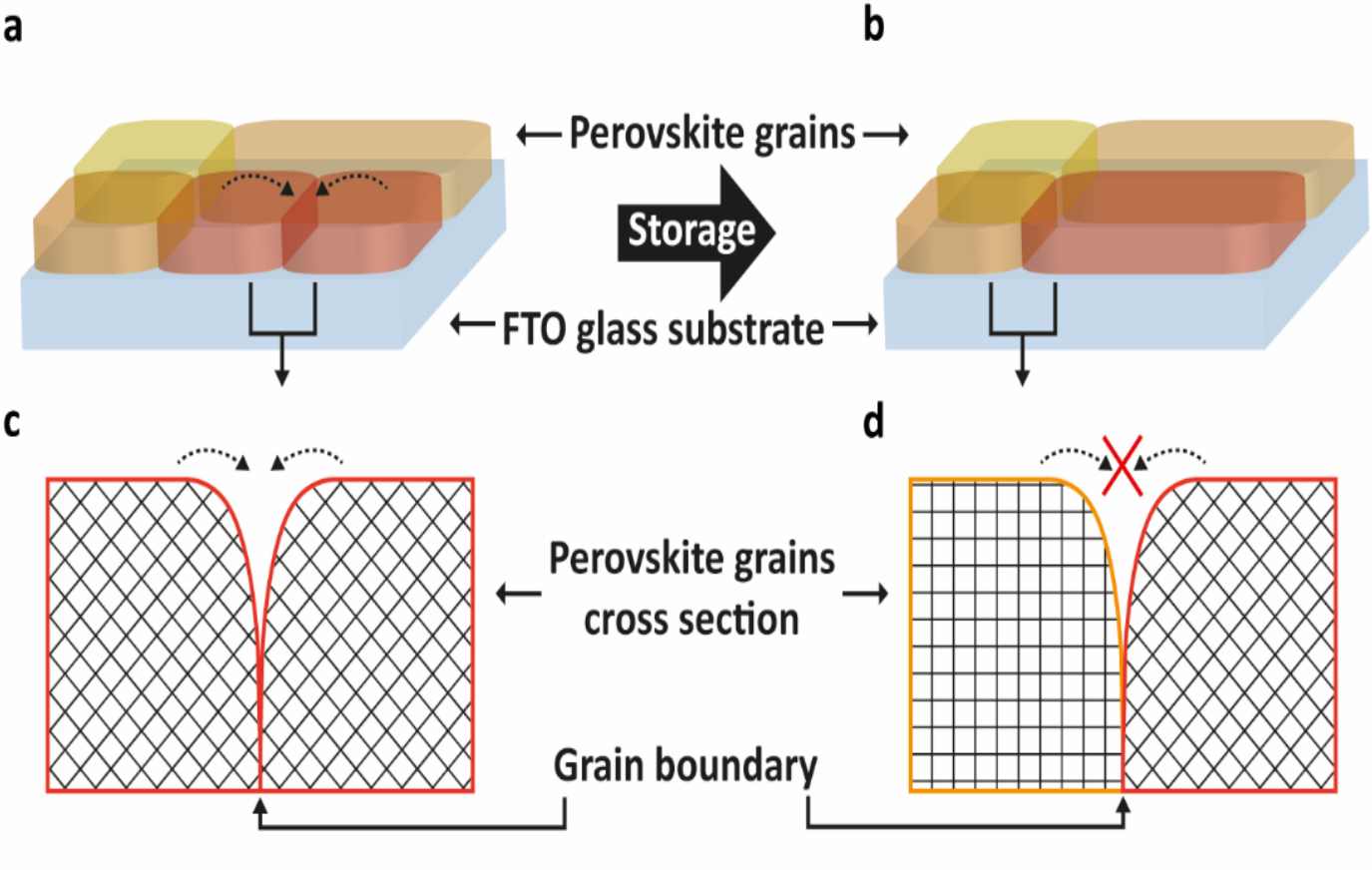
Antonio Abate, PhD

XRD supports spontaneous formation of larger crystalline domains



Angle (2θ)	hkl	Intensity 2 days	Intensity 28 days	Size 2 days (nm)		Size 28 days (nm)
14.5	002, 110	0.34	0.21	270 ± 10		380 ± 10
20.4	112, 020	0.34	0.44	440 ± 10		840 ± 40
25.0	022	0.34	0.27	340 ± 10		1400 ± 100
28.8	004, 220	0.28	0.16	330 ± 10		340 ± 10
32.3	114, 222, 130	1.00	1.00	300 ± 10		380 ± 10
35.4	024, 132	0.20	0.12	160 ± 10		190 ± 10

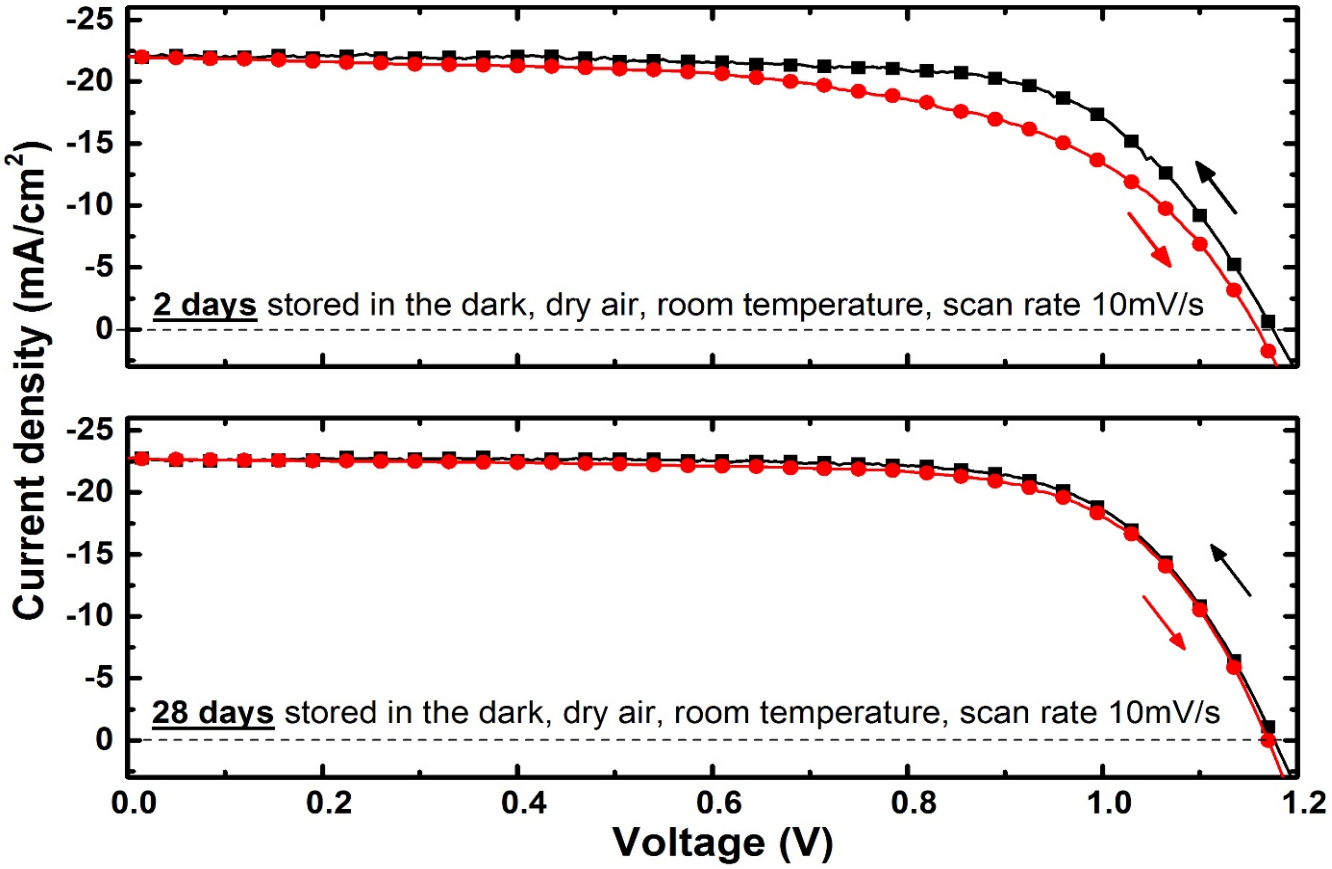
Perovskite crystal coalescence mechanism



Amita Ummadisingu, EPFL

Antonio Abate, PhD

Ageing does not necessarily mean performance losses



	Scan Direction	V_{oc} (V)	J_{sc} (mA/cm²)	FF (%)	PCE (%)	Light intensity (mW/cm²)
2 days	FB to SC	1.175	22.0	70.3	18.7	97.1
	SC to FB	1.159	21.9	59.5	15.6	
28 days	FB to SC	1.176	22.7	72.5	19.3	100.5
	SC to FB	1.170	22.7	70.6	18.7	

Controlling the crystal size distribution within the perovskite film is important to enhance stability. Small crystallites and grain boundaries trigger degradation.

Questions?