Supporting Information

All printable perovskite solar modules with 198 cm^2 active area and over 6% efficiency

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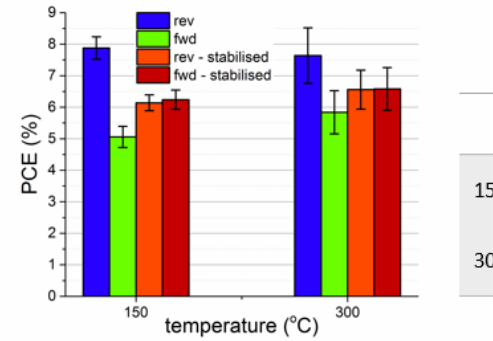

		Voc (V)	Jsc (mA/cm2)	FF (%)	PCE (%)
150 °C	Rev	0.856 ± 0.031	15.78 ± 1.89	59.14 ± 8.21	7.88 ± 0.36
	Fwd	0.852 ± 0.012	12.46 ± 0.88	47.80 ± 5.86	5.06 ± 0.34
300 °C	Rev	0.823 ± 0.053	17.88 ± 0.82	52.00 ± 7.04	7.64 ± 0.88
	Fwd	0.828 ± 0.034	15.62 ± 0.75	45.22 ± 5.96	5.84 ± 0.68

Figure S1. Power conversion efficiency of small cells with TiO_2 blocking layer sprayed at 150 °C and 300 °C respectively and average PV parameters (5 cells per type) showing comparable results. Masked area is 0.25 cm^2.

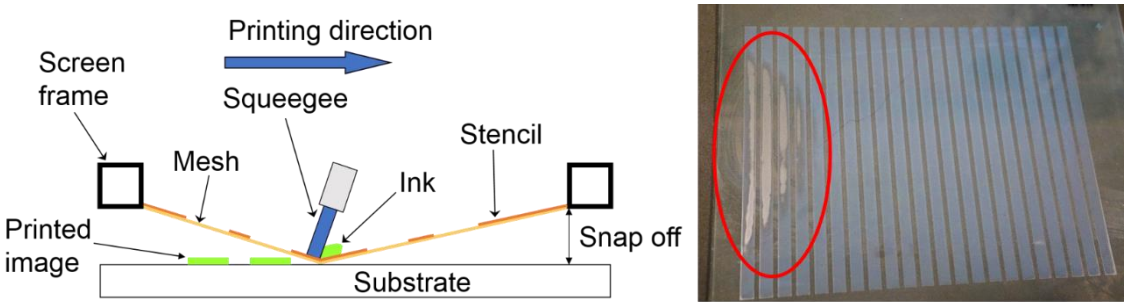

Figure S2. Basic screen print diagram showing the main printing settings (left) and picture of a common print defect (right), due to not optimised print speed and snap off for large areas, resulting in a horseshoe shaped area of lower ink transfer (red circle).

Table S1. Overall average thickness and roughness for each layer (top table) and measured values in different zones of each A4 substrate: L - left, M - middle, R - right and 1 – top, 2 – middle, 3 – bottom to demonstrate the consistency across the whole printed area. For TiO_2, an additional feature (A_P) was measured (as indicated in Figure 3) to quantify fully the height of the layer.

layer	Overall Avg Thickness (μm)	standard deviation	Overall Avg Ra (μm)	standard deviation	Overall Avg Rp (μm)	standard deviation
carbon	10.18	0.42	1.25	0.05	5.17	0.61
zirconia	1.13	0.07	0.06	0.00	0.57	0.08
titania	0.770	0.102	0.064	0.040	0.812	0.317
	0.923 (A_p)	0.092				

layer	thickness (µm)						Ra (µm) - average roughness						Rp (µm) - deviation from average for maximum peak					
		L	M	R	average	st dev		L	M	R	average	st dev		L	M	R	average	st dev
carbon	1	9.94	10.29	10.12	10.12	0.17	1	1.24	1.25	1.26	1.25	0.01	1	5.97	5.41	5.70	5.69	0.28
	2	10.02	10.29	9.68	10.00	0.30	2	1.25	1.26	1.15	1.22	0.06	2	5.10	4.67	5.18	4.98	0.27
	3	10.12	11.18	9.96	10.42	0.66	3	1.30	1.30	1.27	1.29	0.02	3	4.47	4.27	5.81	4.85	0.84
	average	10.03	10.59	9.92			average	1.26	1.27	1.23			average	5.18	4.78	5.56		
	st dev	0.089	0.515	0.220			st dev	0.031	0.028	0.068			st dev	0.756	0.576	0.338		
zirconia		L	M	R	average	st dev		L	M	R	average	st dev		L	M	R	average	st dev
	1	1.22	1.20	1.13	1.18	0.05	1	0.06	0.06	0.06	0.06	0.00	1	0.63	0.50	0.67	0.60	0.09
	2	1.07	1.12	1.03	1.07	0.05	2	0.06	0.06	0.06	0.06	0.00	2	0.52	0.64	0.48	0.55	0.08
	3	1.13	1.20	1.08	1.14	0.06	3	0.07	0.06	0.06	0.06	0.01	3	0.50	0.66	0.54	0.57	0.08
	average	1.14	1.17	1.08			average	0.06	0.06	0.06			average	0.55	0.60	0.56		
	st dev	0.075	0.046	0.050			st dev	0.006	0.000	0.000			st dev	0.070	0.087	0.097		
titania		L	M	R	average	st dev		L	M	R	average	st dev		L	M	R	average	st dev
	1	0.96	0.86	0.74	0.85	0.11	1	0.07	0.04	0.09	0.07	0.03	1	1.25	1.10	1.16	1.17	0.08
	2	0.80	0.65	0.76	0.74	0.08	2	0.06	0.03	0.05	0.05	0.02	2	0.50	0.40	0.70	0.53	0.15
	3	0.63	0.73	0.80	0.72	0.09	3	0.04	0.16	0.04	0.08	0.07	3	0.52	0.98	0.70	0.73	0.23
	average	0.80	0.75	0.77			average	0.06	0.08	0.06			average	0.76	0.83	0.85		
	st dev	0.165	0.106	0.031			st dev	0.015	0.072	0.026			st dev	0.427	0.374	0.266		
	Ap (µm)																	
		L	M	R	average	st dev												
	1	1.06	0.97	0.83	0.95	0.12												
	2	1.00	0.80	0.95	0.92	0.10												
	3	0.98	0.81	0.91	0.90	0.09												
	average	1.01	0.86	0.90														
	st dev	0.042	0.095	0.061														

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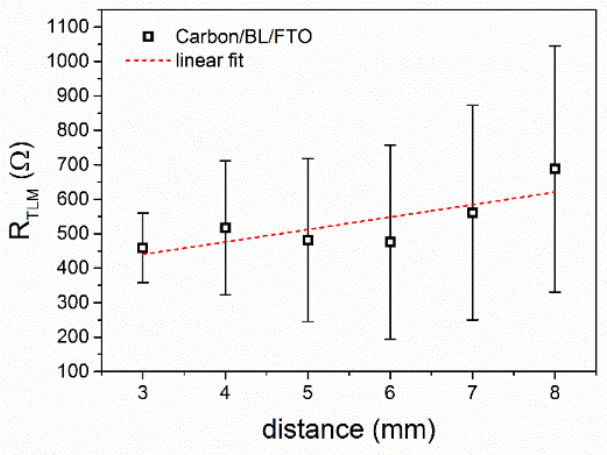

Figure S3. Measured TLM resistance values varying the contact distance for un-patterned BL samples, i.e. Carbon/BL/FTO with the carbon not directly in contact with the FTO.

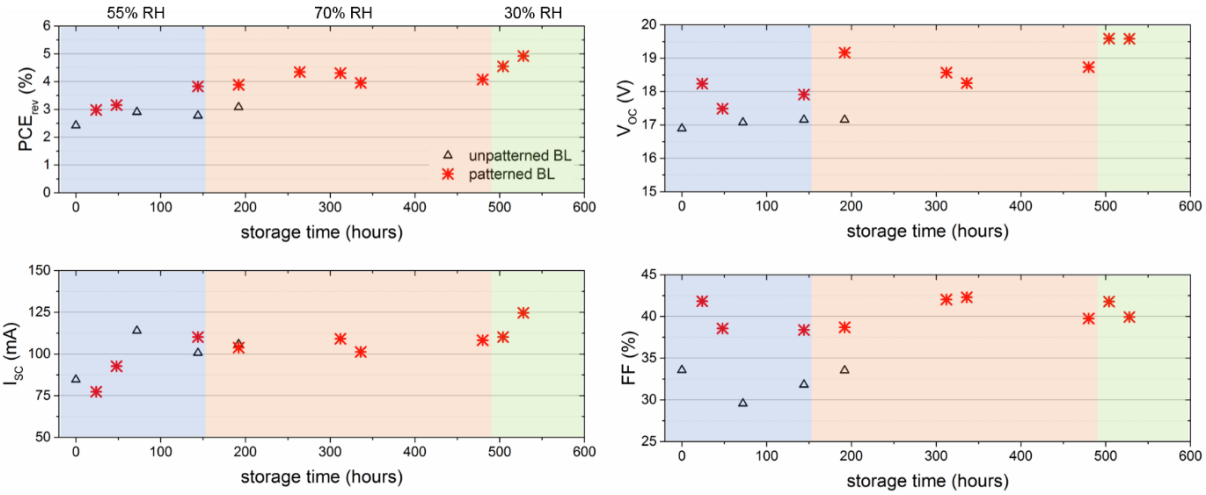

Figure S4. Temporal evolution of PV parameters for the best modules for each type, un-encapsulated and stored in the dark in air. After 144 hours at room temperature and ambient humidity, i.e. 55% RH, the modules were stored in a box with a saturated aqueous solution of NaCl ensuring 70% RH. The un-patterned module cracked during this phase. After almost 300 hours in this highly humid environment, storage continued in a box with silica desiccant at 30% RH ca.

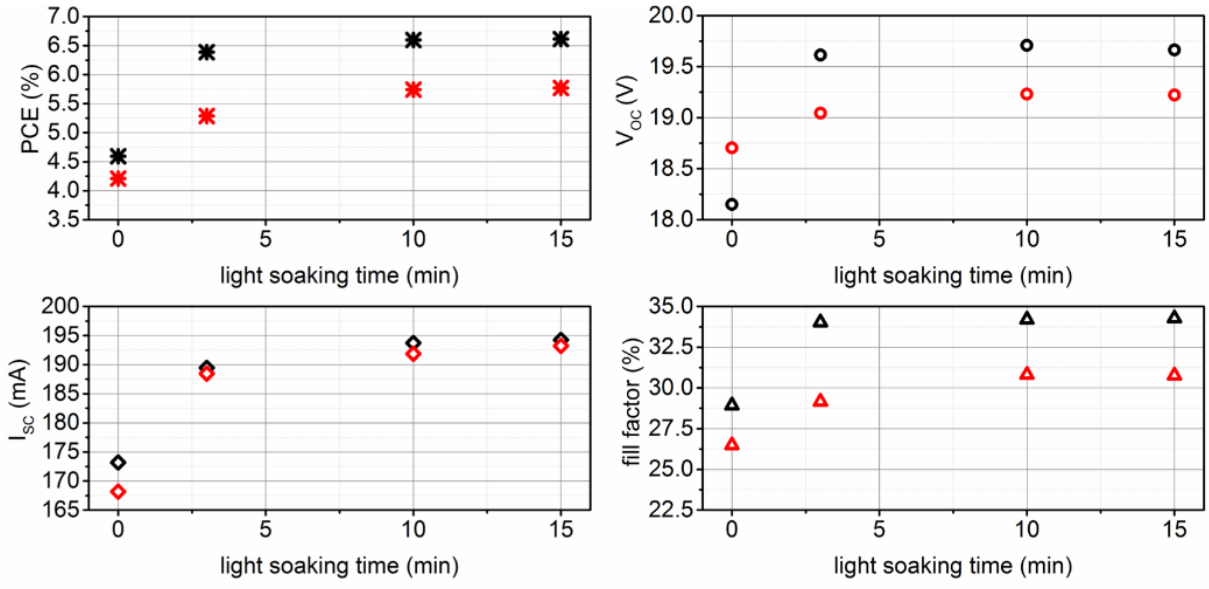

Figure S5. PV parameters for the best module with patterned BL after different light soaking times at open circuit prior to the I-V scans: the improvement of V_{OC}, J_{SC} and FF resulted in a 44% PCE improvement after 10 min of light soaking. Black and red symbols refer to the reverse and forward scan, respectively.

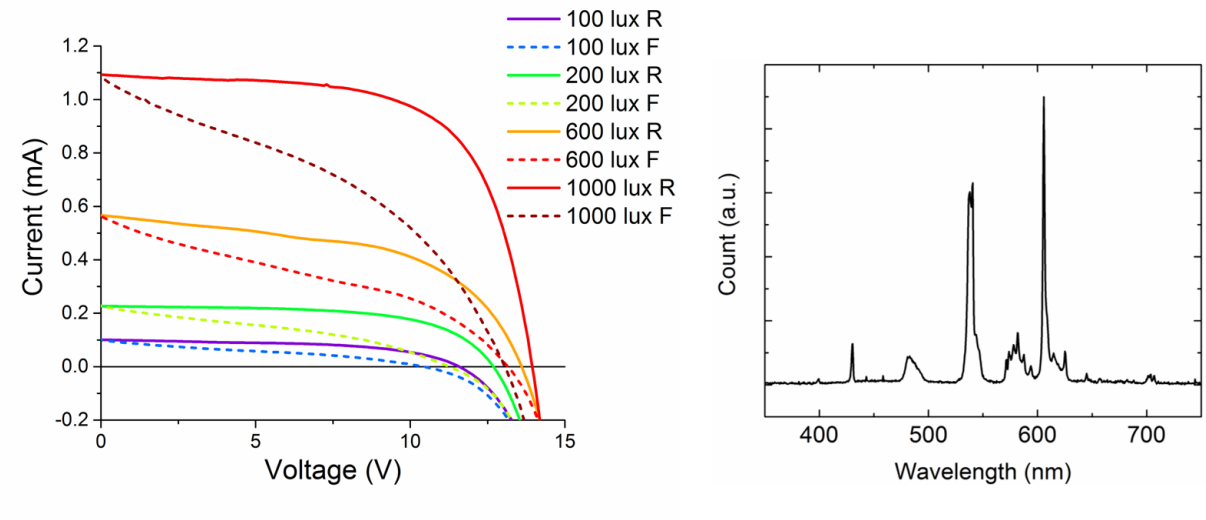

Figure S6. I-V curves (both reverse and forward scans) of the best module with patterned BL at different illumination levels under fluorescent lamps, whose spectrum is also reported. Being the illumination levels much lower than at 1 sun, the electric field in the bulk is lower and the ionic diffusion out of the double layers by the selective contacts to the bulk to screen it is less pronounced. A higher density of ions is left at the interface contributing to interfacial recombination, which is responsible for a higher degree of hysteresis than under 1 sun.[28]

Table S2. PV parameters for the best module with patterned BL at different illumination levels from fluorescent lamps.

Illumination [lux]	V_{OC} [V]		I_{SC} [mA]		FF [%]		P_{MAX} [mW]		PCE [%]	
	rev	fwd	rev	fwd	rev	fwd	rev	fwd	rev	fwd
100	11.6	10.5	0.1	0.1	54	30	0.6	0.3	11	5.9
200	12.7	11.2	0.2	0.2	62	35	1.8	0.9	16	8.2
600	13.8	13.6	0.7	0.7	59	32	5.7	3.1	17	9.4
1000	13.9	13.1	1.1	1.1	66	39	10	5.5	18	10