

Supporting Information

Surface modulation for highly efficient and stable perovskite solar cells

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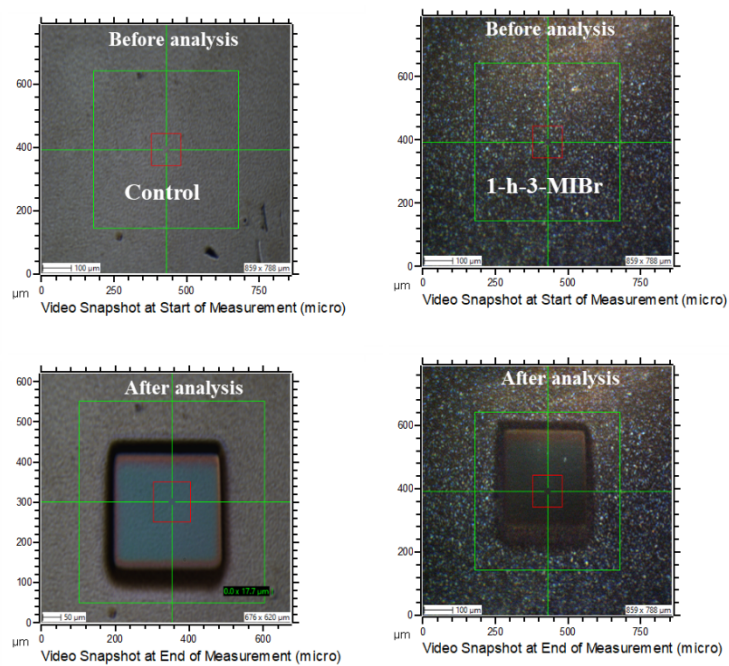


Figure S1. The photos of samples before and after sputter etching. The red square is the detected region.

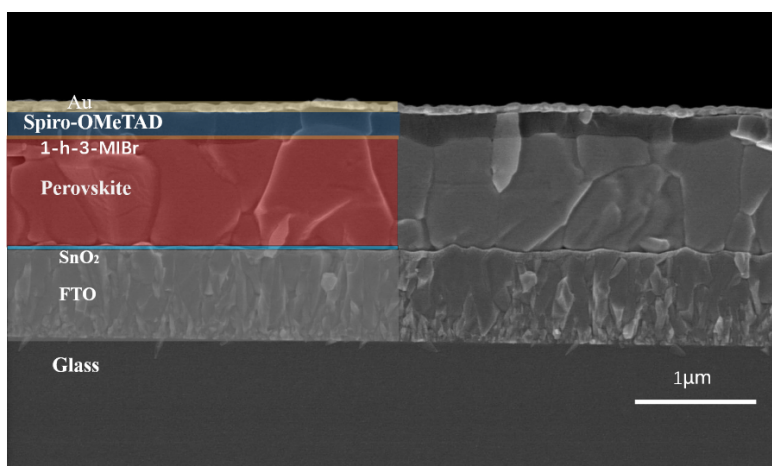


Figure S2. Cross-sectional SEM image of the completed device with 1-h-3-MIBr.

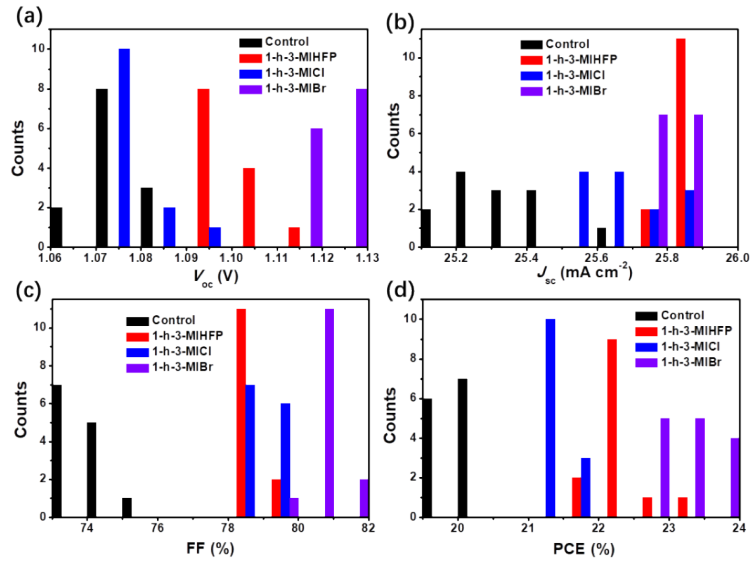


Figure S3. Statistical photovoltaic parameters of devices, including histograms of the (a) V_{oc} , (b) J_{sc} , (c) FF, and (d) PCE. Note that the data were collected from 13 devices. The devices were measured outside the glove box under simulated AM 1.5G solar irradiation at 100 mW cm^{-2} with an aperture area of 0.1 cm^2 .

Table S1. PCE of two-step PSCs

Ref.	Perovskite	PCE (%)	year
1	FAPbI ₃	21.2	2022 ¹
2	FAPbI ₃	23.65	2022 ²
3	FAPbI ₃	19.04	2022 ³
4	(FAPbI ₃) _{1-x} (MAPbBr ₃) _x	18.09	2022 ⁴
5	(FAPbI ₃) _{0.97} (MAPbBr ₃) _{0.03}	24.27	2022 ⁵
6	FAPbI ₃	22.64	2022 ⁶
7	(FAPbI ₃) _{1-x} (MAPbBr ₃) _x	22.5	2021 ⁷
8	FAPbI ₃	25.6	2022 ⁸
9	FAPbI ₃	21.51	2021 ⁹
10	MA _{0.07} FA _{0.93} PbI ₃	22.5	2021 ¹⁰
11	FAPbI ₃	18.41	2020 ¹¹
12	FA _{0.95} CS _{0.05} PbI ₃	23.46	2022 ¹²
13	(FAPbI ₃) _{0.90} (MAPbBr ₃) _{0.10}	22.81	2023 ¹³
14	(MAFA)Pb(IBr) ₃	20.4	2022 ¹⁴
15	(FAPbI ₃) _{0.9} (MAPbBr ₃) _{0.1}	21.02	2022 ¹⁵
16	FAPbI ₃	21.89	2023 ¹⁶
17	FAPbI ₃	20.42	2022 ¹⁷
18	FA _{0.9} MA _{0.1} PbI ₃	22.26	2022 ¹⁸
19	(FAPbI ₃) _{0.97} (MAPbBr ₃) _{0.03}	23.11	2022 ¹⁹
20	FA _{0.9} MA _{0.1} I _{2.7} Br _{0.3}	22.07	2022 ²⁰
This work	FA _{0.95} MA _{0.05} I ₃	23.32	2023

Table S2. The key parameters of PSCs without passivation layers.

Number	V_{oc} (V)	J_{sc} (mA cm ⁻²)	FF (%)	PCE (%)
1	1.08	25.68	75.87	21.08
2	1.08	25.49	74.91	20.65
3	1.08	25.43	74.81	20.55
4	1.08	25.41	74.80	20.49
5	1.08	25.37	74.67	20.38
6	1.07	25.37	74.57	20.33
7	1.07	25.36	73.90	20.13
8	1.07	25.27	73.89	20.05
9	1.07	25.26	73.88	20.03
10	1.07	25.25	73.85	20.00
11	1.07	25.24	73.85	19.99
12	1.07	25.19	73.57	19.82

13	1.07	25.17	73.31	19.72
Average	1.08 ± 0.01	25.35 ± 0.14	74.30 ± 0.70	20.25 ± 0.28

Table S3. The key parameters of PSCs with 1-h-3-MIHFP.

Number	V_{oc} (V)	J_{sc} (mA cm ⁻²)	FF (%)	PCE (%)
1	1.11	25.89	79.34	22.81
2	1.11	25.88	79.03	22.70
3	1.11	25.88	78.97	22.66
4	1.11	25.87	78.86	22.61
5	1.10	25.87	78.81	22.47
6	1.10	25.85	78.71	22.38
7	1.10	25.84	78.66	22.33
8	1.10	25.83	78.66	22.33
9	1.10	25.83	78.56	22.29
10	1.10	25.81	78.52	22.26
11	1.10	25.80	78.49	22.24
12	1.10	25.79	78.45	22.22
13	1.10	25.79	78.42	22.21
Average	1.10 ± 0.01	25.84 ± 0.04	78.73 ± 0.27	22.42 ± 0.21

Table S4. The key parameters of PSCs with 1-h-3-MICl.

Number	V_{oc} (V)	J_{sc} (mA cm ⁻²)	FF (%)	PCE (%)
1	1.09	25.79	79.95	22.50
2	1.08	25.79	79.55	22.20
3	1.08	25.66	79.16	21.96
4	1.08	25.66	79.11	21.92
5	1.08	25.63	79.07	21.88
6	1.08	25.61	79.05	21.86
7	1.08	25.58	78.97	21.80
8	1.08	25.56	78.74	21.72
9	1.08	25.55	78.63	21.67
10	1.08	25.54	78.46	21.61
11	1.08	25.52	78.35	21.57
12	1.08	25.52	78.22	21.52
13	1.08	25.51	78.07	21.44
Average	1.08 ± 0.01	25.61 ± 0.10	78.87 ± 0.54	21.82 ± 0.29

Table S5. The key parameters of PSCs with 1-h-3-MIBr.

Number	V_{oc} (V)	J_{sc} (mA cm ⁻²)	FF (%)	PCE (%)
1	1.12	25.84	80.95	23.32
2	1.10	25.83	80.48	22.94
3	1.10	25.81	79.76	22.72
4	1.10	25.79	79.75	22.63
5	1.10	25.75	79.02	22.38
6	1.10	25.70	78.99	22.32
7	1.10	25.54	78.74	22.09
8	1.09	25.53	78.35	21.88
9	1.09	25.46	78.08	21.73
10	1.09	25.45	77.94	21.62
11	1.09	25.44	77.89	21.58
12	1.08	25.41	77.48	21.33
13	1.07	25.40	76.94	20.99
Average	1.10 ± 0.01	25.61 ± 0.18	78.80 ± 1.18	22.12 ± 0.68

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