Electronic supplementary information

Fluorinated fused nonacyclic interfacial materials for efficient and stable perovskite solar cells

Kuan Liu[ab], Shuixing Dai[a], Fanqi Meng[a], Jiangjian Shi[b], Yusheng Li[b], Jionghua Wu[b], Qingbo Meng[b*] and Xiaowei Zhan[a*]

[a] *Department of Materials Science and Engineering, College of Engineering, Key Laboratory of Polymer Chemistry and Physics of Ministry of Education, Peking University, Beijing 100871, China. *E-mail: xwzhan@pku.edu.cn*

[b] *CAS Key Laboratory for Renewable Energy, Beijing Key Laboratory for New Energy Materials and Devices, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China. *E-mail: qbmeng@iphy.ac.cn*

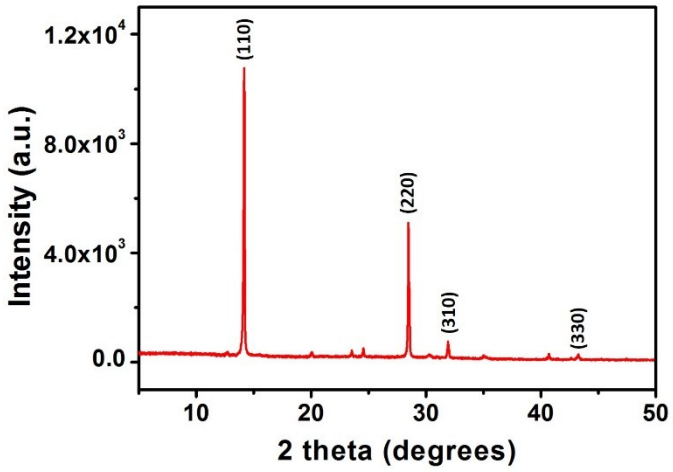

Fig. S1 XRD pattern of $MAPbI_{3-x}Cl_x$ based perovskite thin film on ITO/PEDOT:PSS substrate.

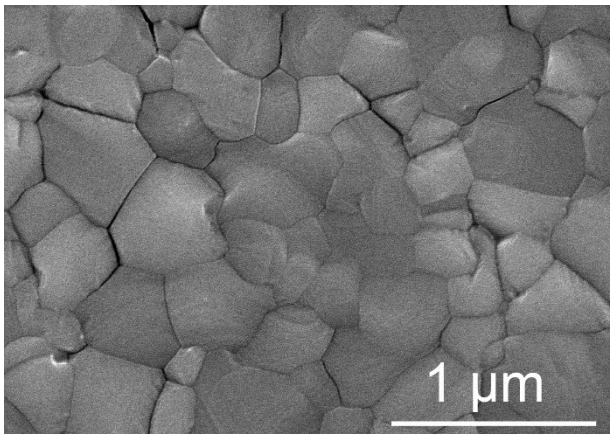

Fig. S2 SEM image of $MAPbI_{3-x}Cl_x$ based perovskite thin film on ITO/PEDOT:PSS substrate.

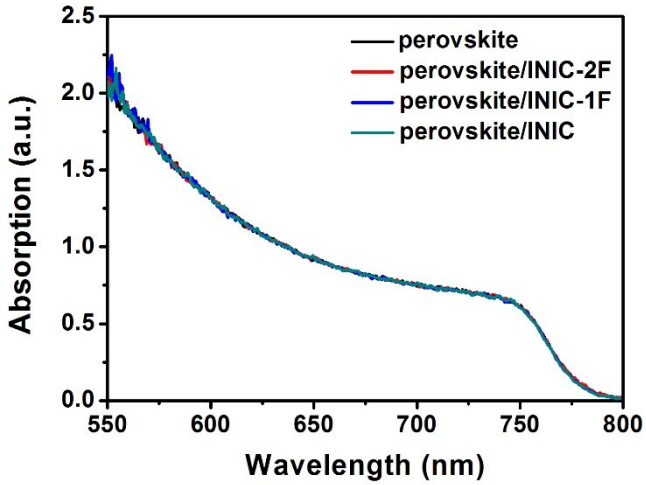

Fig. S3 UV-vis absorption spectra of the neat perovskite and INIC series coated perovskite films.

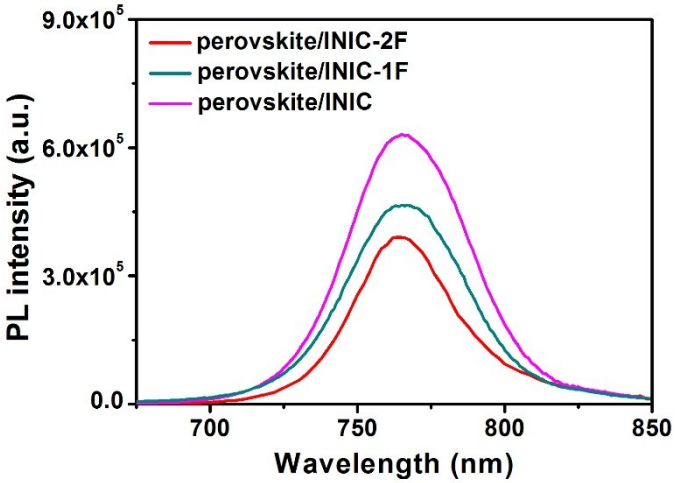

Fig. S4 Steady-state PL spectra of the INIC series coated perovskite films.

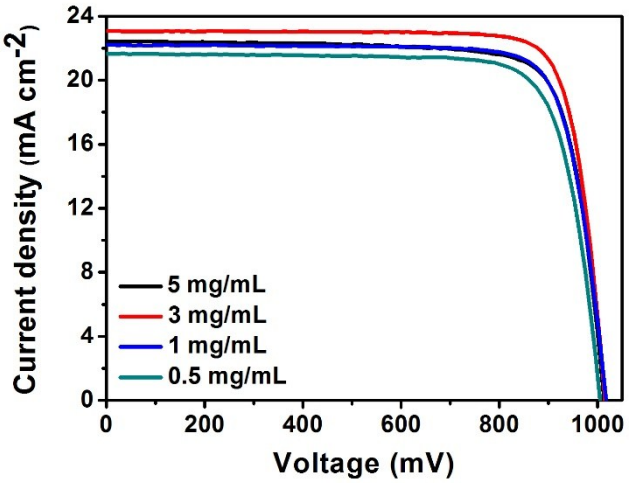

Fig. S5 *J-V* curves of modified devices with INIC-2F interfacial layer deposited with its solution under different concentrations.

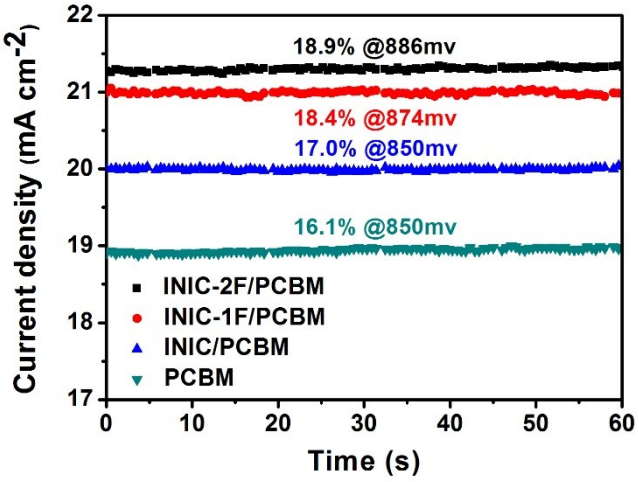

Fig. S6 Steady-state current density and power output of the best-performing modified devices with and without INIC series interfacial layer.

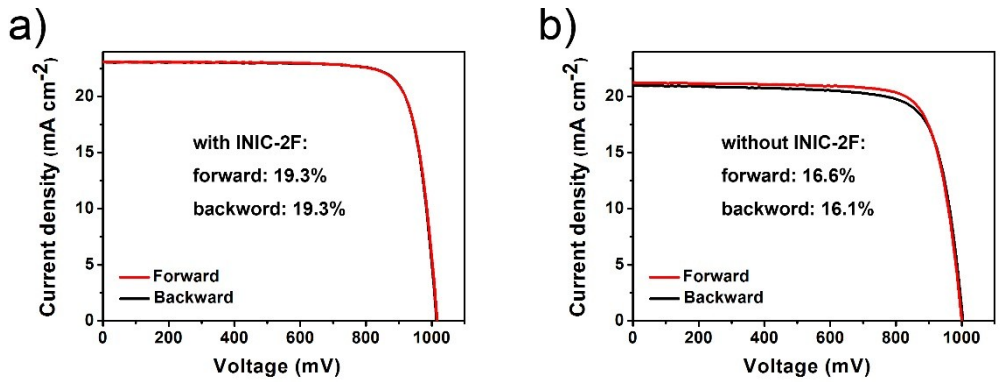

Fig. S7 The hysteresis effect in *J-V* curves of the inverted planar PSCs (a) with and (b) without INIC-2F interfacial layer.

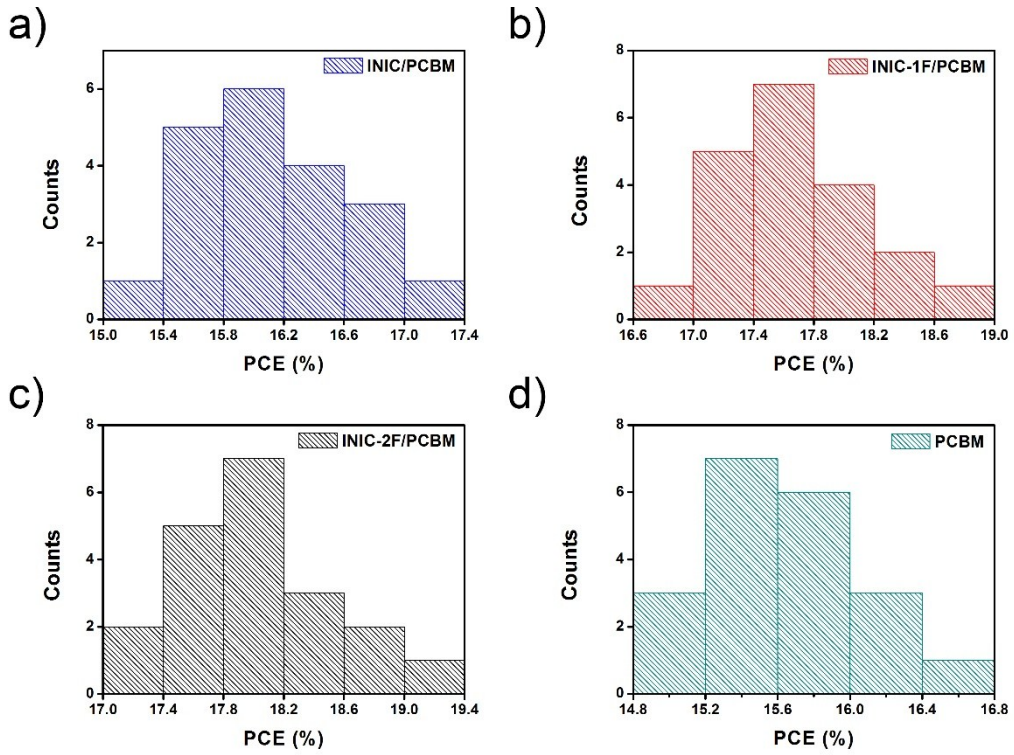

Fig. S8 Statistical PCE distribution histogram of 20 individual devices based on INIC series interfacial layers and the control devices without INIC series.

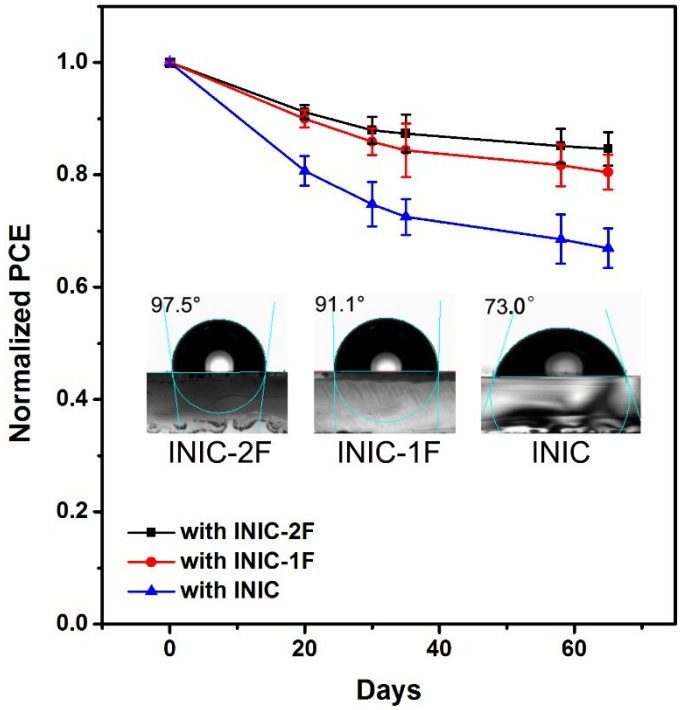

Fig. S9 Stability test of the unencapsulated devices based on INIC-2F, INIC-1F and INIC interfacial layer, stored under ambient condition (20 ± 5 °C, 20 ± 5 % relative humidity). Inset, water contact angle of the perovskite/INIC series thin films.

Table S1 Fitting parameters of bi-exponential decay function in time-resolved PL spectra.

Films	A_1	τ_1 (ns)	A_2	τ_2 (ns)	Average decay time τ (ns)[a]
Perovskite	0.53	165.25	0.53	165.27	165.26
Perovskite/INIC-2F	0.60	2.19	0.38	9.27	4.94
Perovskite/INIC-2F/PCBM	0.90	1.27	0.13	7.14	2.01

[a] Average decay time is calculated according to the equation: $\tau = (A_1\tau_1 + A_2\tau_2)/(A_1 + A_2)$.

Table S2 Fitting parameters of bi-exponential decay function in transient photovoltage measurement.

Films	A_1	τ_1 (ms)	A_2	τ_2 (ms)	Average decay time τ_v (ms)[a]
Perovskite	0.72	0.05	0.10	0.70	0.13
Perovskite/INIC-2F	0.59	0.07	0.36	0.32	0.16

[a] Average decay time is calculated according to the equation: $\tau_v = (A_1\tau_1 + A_2\tau_2)/(A_1 + A_2)$.

Table S3 Fitting parameters of bi-exponential decay function in transient photocurrent measurement.

Films	A_1	τ_1 (μs)	A_2	τ_2 (μs)	Average decay time τ_c (μs)[a]
Perovskite	0.78	0.92	0.78	0.92	0.92
Perovskite/INIC-2F	0.46	1.20	0.46	1.20	1.20

[a] Average decay time is calculated according to the equation: $\tau_c = (A_1\tau_1 + A_2\tau_2)/(A_1 + A_2)$

Table S4 Photovoltaic parameters of the modified devices with INIC-2F interfacial layer deposited with its solution under different concentrations.

Concentration (mg mL^{-1})	J_{SC} (mA cm^{-2})	V_{OC} (V)	FF (%)	PCE (%)
5	22.4	1.01	79.5	18.1
3	23.1	1.01	82.7	19.3
1	22.2	1.01	80.5	18.1
0.5	21.7	1.00	79.4	17.2