Electronic Supplementary Information (ESI) for

Highly stable and efficient carbon electrode-based perovskite solar cell *via* interfacial growth of 2D perovskite

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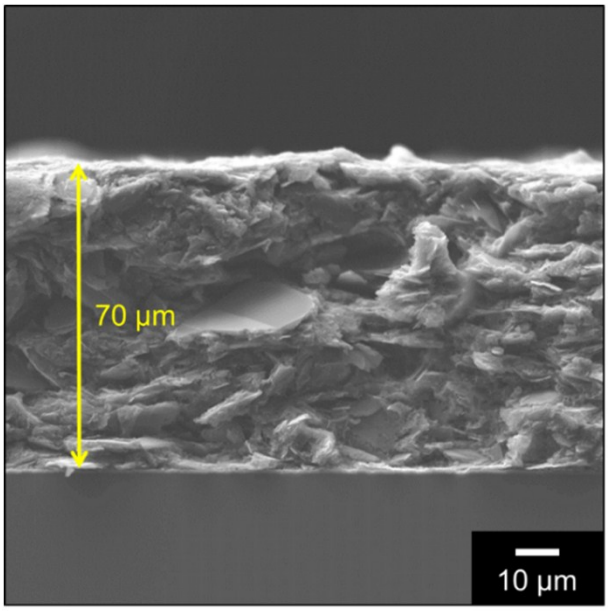

Figure S1. Cross-sectional FE-SEM image of the carbon electrode.

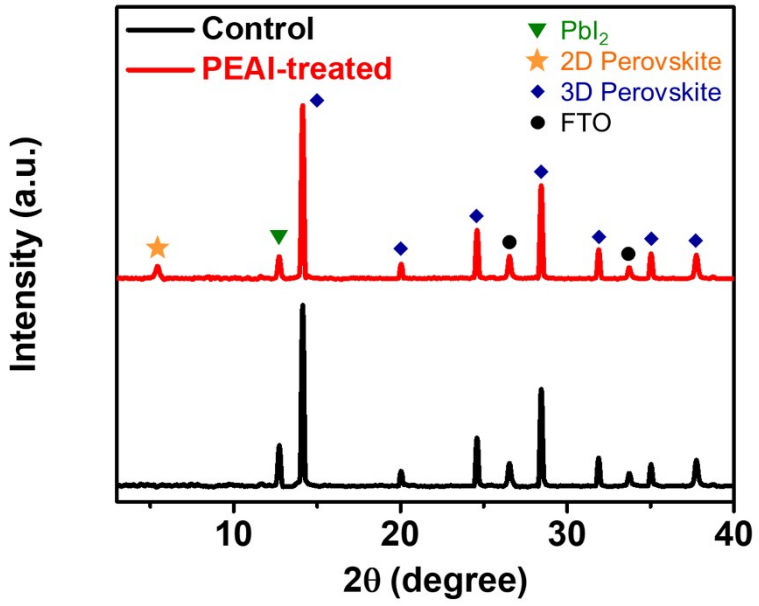

Figure S2. XRD patterns of the perovskite films w/o and with PEAI treatment. Note that the carbon layer was peeled back to reveal the perovskite layer underneath for measurement.

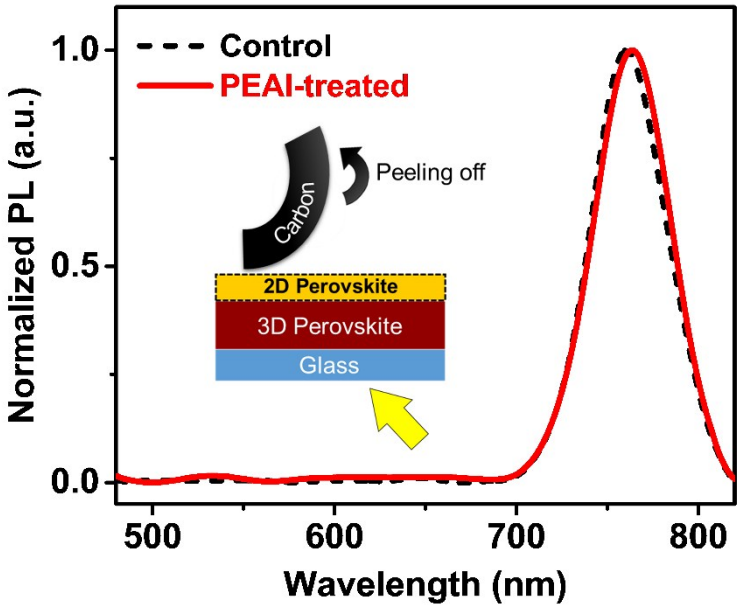

Figure S3. Steady-state PL spectra of the perovskite films w/o and with PEAI treatment. Samples were excited from the glass side by light irradiation at 430 nm. The carbon layer was peeled back to eliminate its quenching effect.

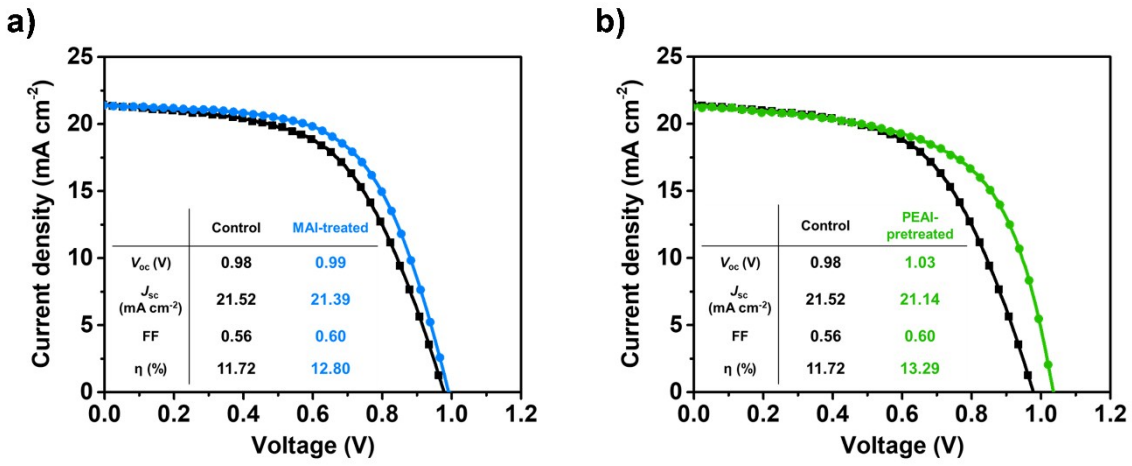

Figure S4. *J–V* characteristic comparison for carbon-based PSCs (a) with MAI treatment and (b) PEAI pre-treatment.

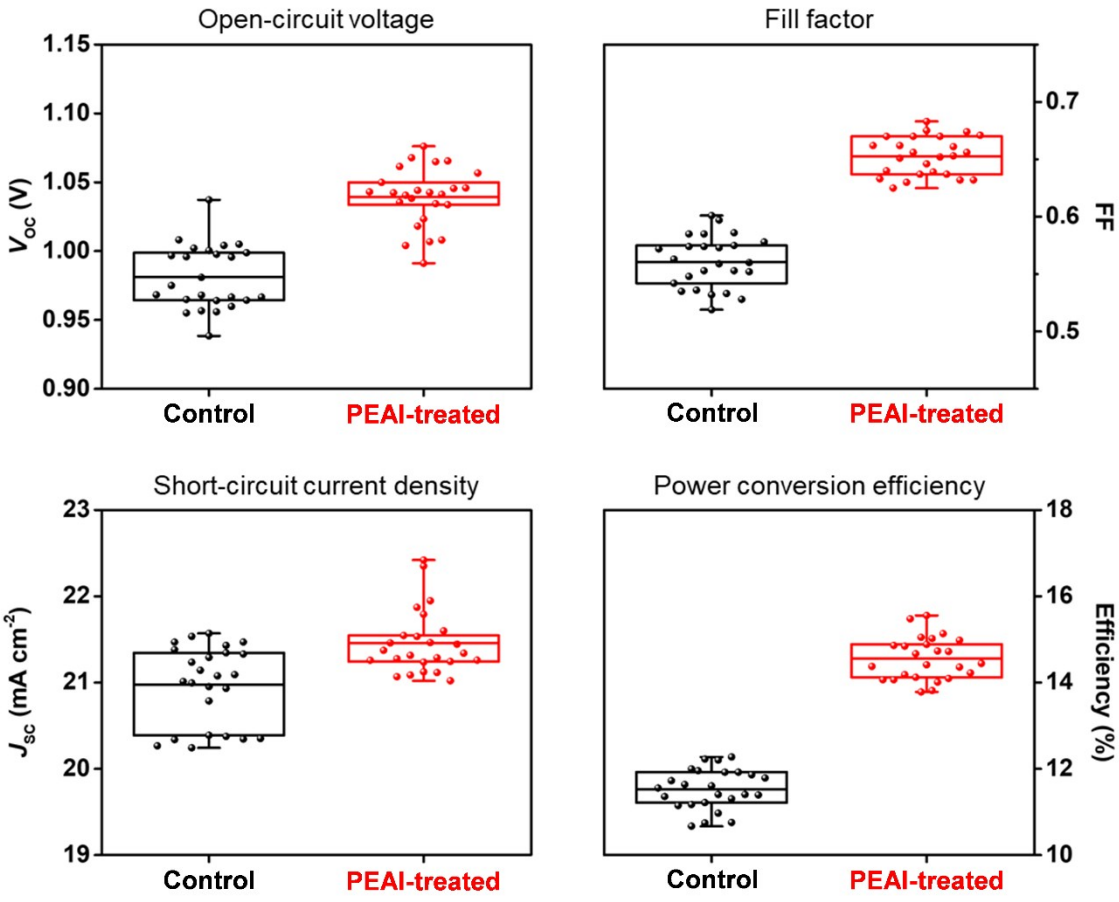

Figure S5. Distribution of photovoltaic parameters (V_{OC}, FF, J_{SC}, and PCE) of carbon-based PSCs w/o and with PEAI treatment. The mean values are marked as solid line in the boxes.

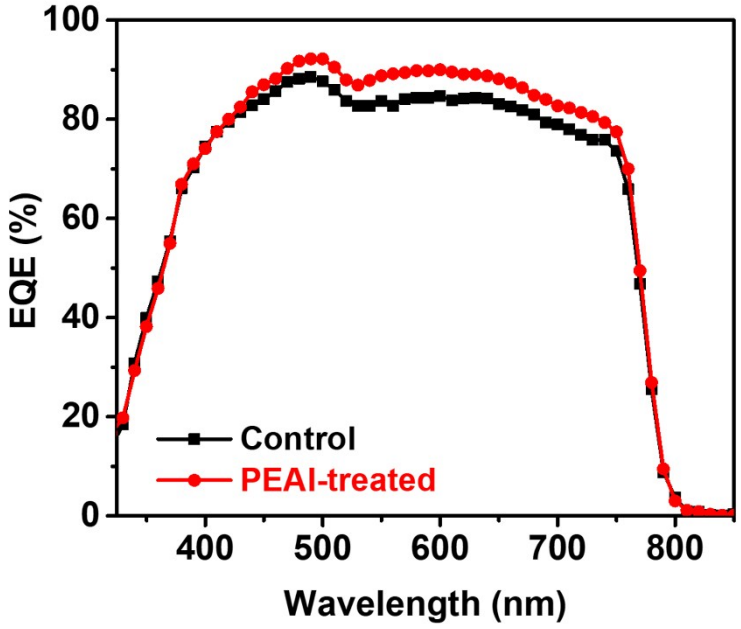

Figure S6. Incident photon-to-current efficiency (IPCE) spectra for carbon-based PSCs w/o and with PEAI treatment. The integrated *J*sc are 20.54 and 21.56 mA cm^{-2}, respectively.

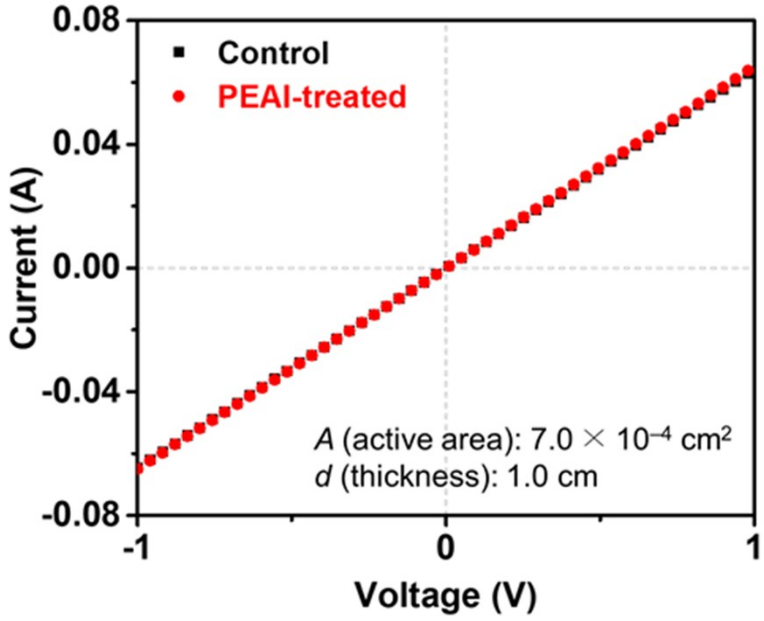

Figure S7. Current–voltage (*I*–*V*) characteristics for carbon electrodes w/o and with PEAI treatment.

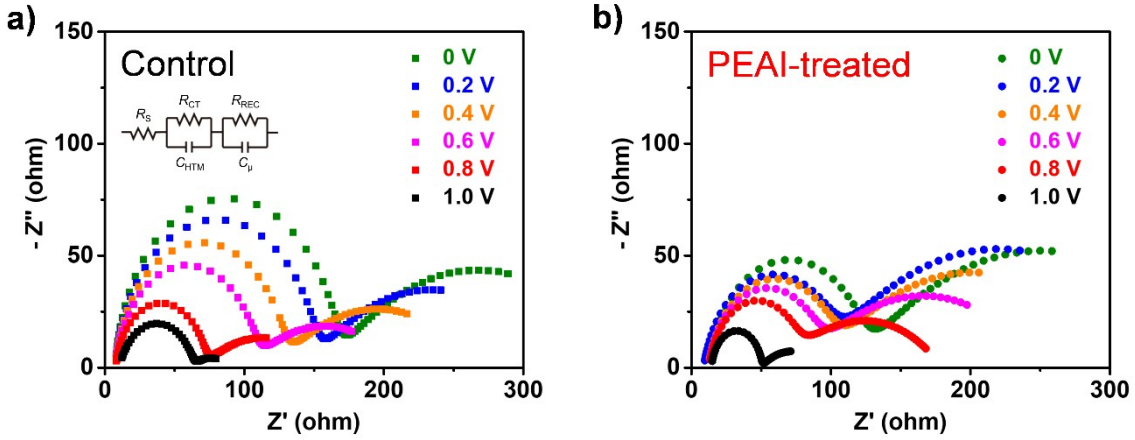

Figure S8. Nyquist plots for PSCs (a) w/o and (b) with PEAI treatment measured under illumination at different applied bias ranged from 0 V to 1.0 V. The scanning frequency ranged from 1 Hz to 1 MHz. The inset shows the equivalent circuit.

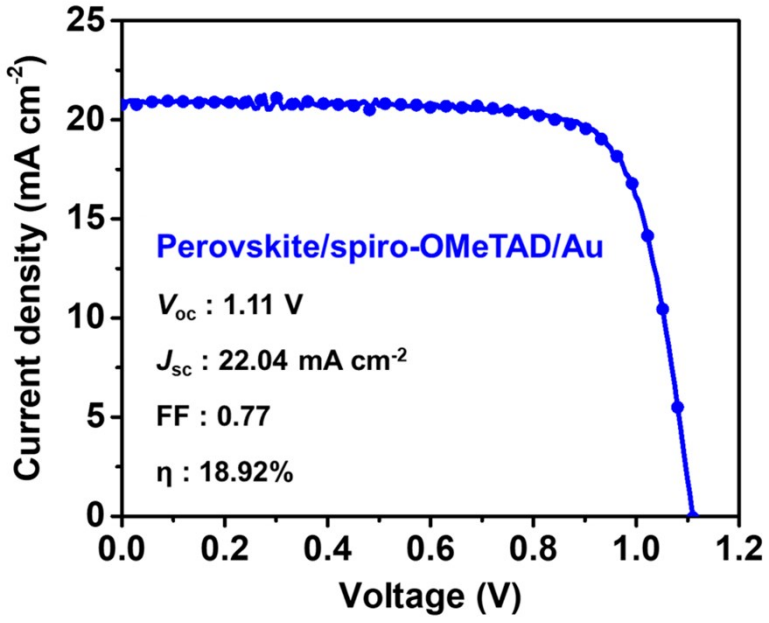

Figure S9. *J–V* characteristic for a conventional PSC with FTO/TiO_2/3D perovskite/spiro-OMeTAD/Au structure.

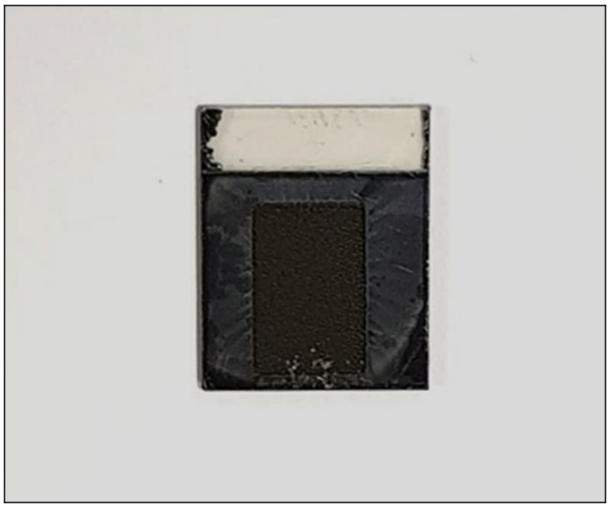

Figure S10. A digital photograph of our carbon-based PSC with PEAI treatment.

Table S1. Time-resolved PL decay parameters for the perovskite films w/o and with PEAI treatment. The bi-exponential decay equation was used for fitting the curves.

Sample	τ_1 (ns)	τ_2 (ns)	[a)] τ_{avg} (ns)	A_1	A_2
Glass/3D perovskite	3.1	83.0	81.7	0.21	0.47
Glass/3D perovskite/carbon	4.8	43.3	41.3	0.30	0.60
Glass/3D perovskite/2D interlayer	2.4	95.6	95.2	0.09	0.46
Glass/3D perovskite/2D interlayer/carbon	4.8	39.2	36.9	0.32	0.55

[a)] $\tau_{avg} = \Sigma_i A_i\tau_i^2 / \Sigma_i A_i\tau_i$

Table S2. Electrochemical impedance spectroscopy (EIS) parameters for the PSCs w/o and with PEAI treatment, obtained from the Nyquist plots in Figure S8.

Device	V_{app} (V)	R_S (ohm)	R_{CT} (ohm)	R_{REC} (ohm)
Control	0	7.46	1.55×10^2	2.09×10^2
	0.2	7.37	1.41×10^2	1.71×10^2
	0.4	7.41	1.17×10^2	1.41×10^2
	0.6	7.43	0.97×10^2	1.05×10^2
	0.8	7.39	0.62×10^2	0.88×10^2
	1.0	10.4	0.52×10^2	0.25×10^2
PEAI-treated	0	11.8	1.08×10^2	2.62×10^2
	0.2	8.53	0.86×10^2	2.51×10^2
	0.4	11.8	0.84×10^2	2.12×10^2
	0.6	12.0	0.72×10^2	1.65×10^2
	0.8	12.3	0.57×10^2	1.10×10^2
	1.0	14.3	0.45×10^2	0.35×10^2