Supporting Information

High Performance Low-dimensional Perovskite Solar Cells Based on One-dimensional Lead Iodide Perovskite

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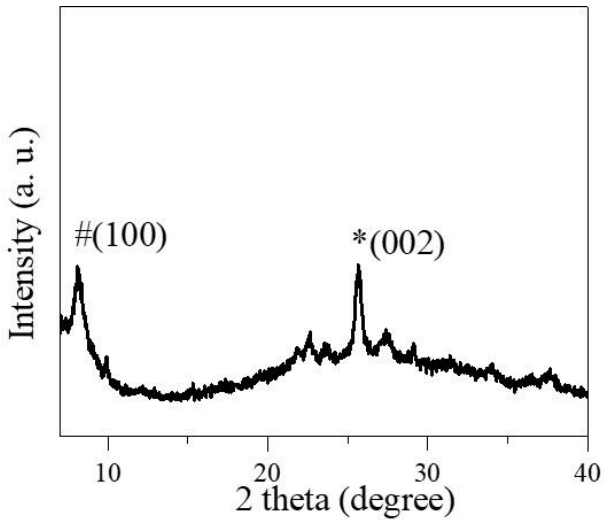

Figure S1. XRD patterns of 1D $BDAPbI_4$ perovskite thin film.

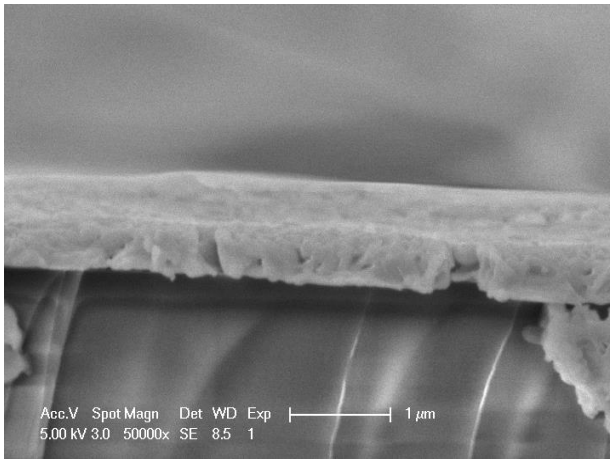

Figure S2. Cross-sectional SEM image of $BDAPbI_4$ perovskite thin film.

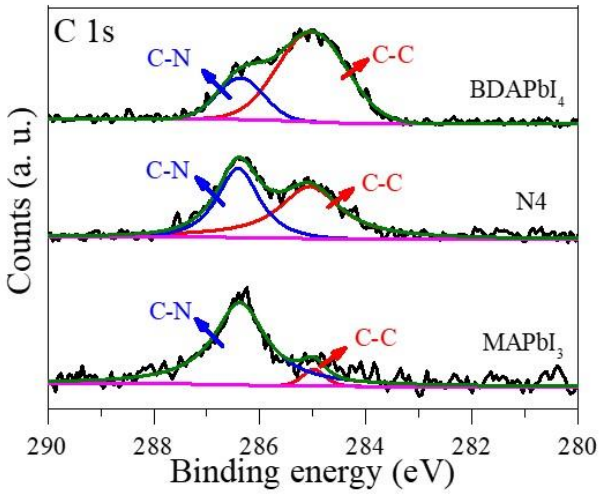

Figure S3. C 1s core level XPS spectra for the $BDAPbI_4$, N4 and $MAPbI_3$ perovskite thin films

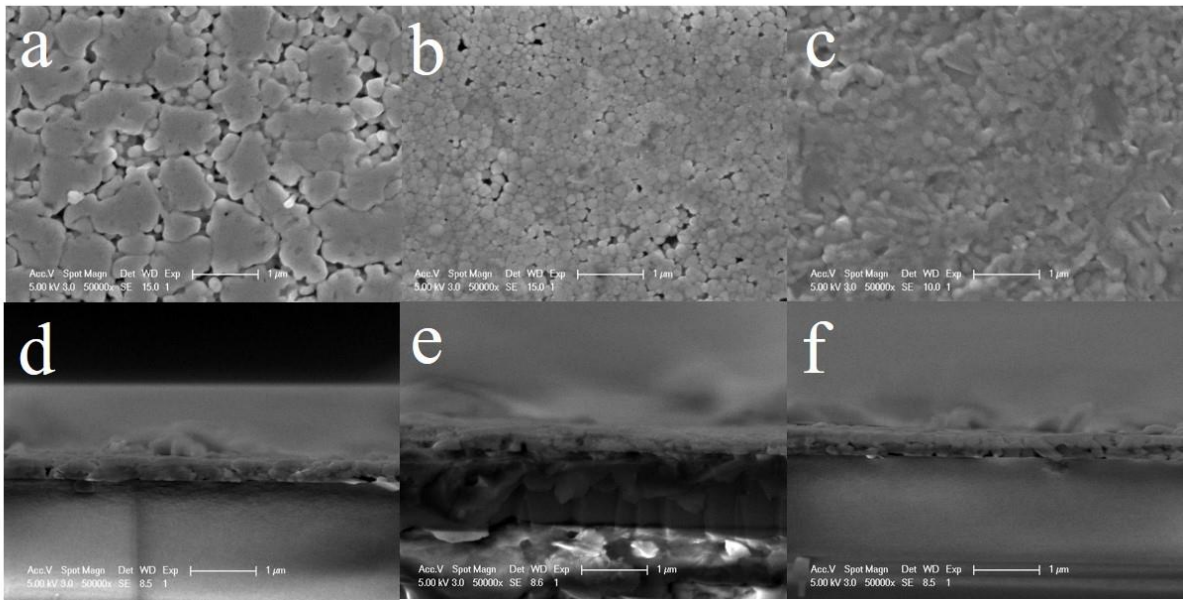

Figure S4. SEM and cross-sectional SEM image of (a, d) N2, (b, e) N3 and (d, f) N4 perovskite thin film.

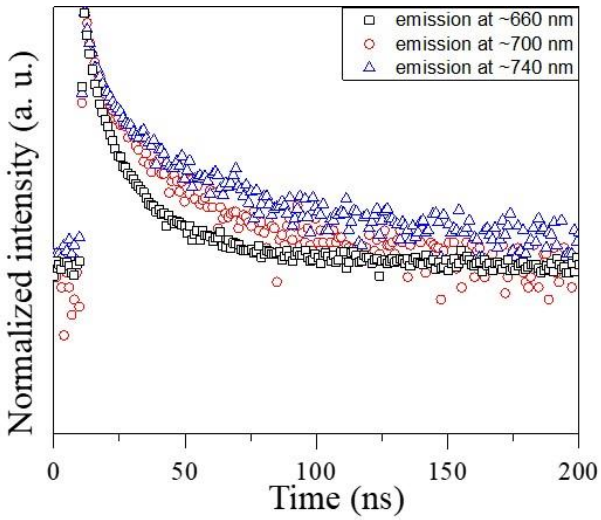

Figure S5. PL decays of emissions at 660, 700, 740 nm in N4 sample.

Table S1. Summary of the parameters from fits of the TRPL measurement. The fitting functions of exponential equation: $y = y_0 + A_1\exp(-\frac{t}{\tau_1}) + A_2\exp(-\frac{t}{\tau_2})$.

Peak position (nm)	A_1	τ_1 (ns)	A_2	τ_2 (ns)
660	0.70	2.01	0.28	11.02
700	0.74	3.16	0.25	22.05
740	0.69	3.03	0.26	26.66

Figure S6. Photo of $BDAPbI_4$ and $MAPbI_3$ single crystals grown from a solution of BDAI, MAI and Pb^{2+}.

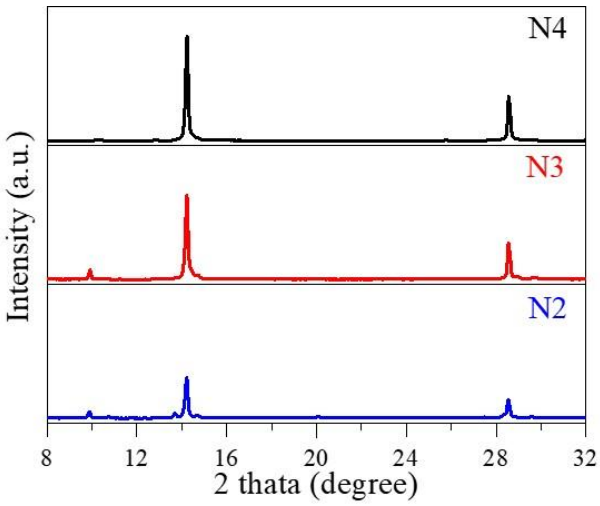

Figure S7. XRD patterns of N2, N3, and N4 samples with range from 8 to 32 degree.

Table S2. Summary of the parameters from fits of the TRPL measurement. The fitting functions of exponential equation: $y = y_0 + A_1\exp(-\frac{t}{\tau_1}) + A_2\exp(-\frac{t}{\tau_2})$.

Peak position (nm)	A_1	τ_1 (ns)	A_2	τ_2 (ns)
480	0.49	0.42	0.50	0.56
530	0.96	0.52	0.04	3.86
570	0.87	0.60	0.13	3.78
610	0.76	0.97	0.23	6.28
660	0.70	2.01	0.28	11.02

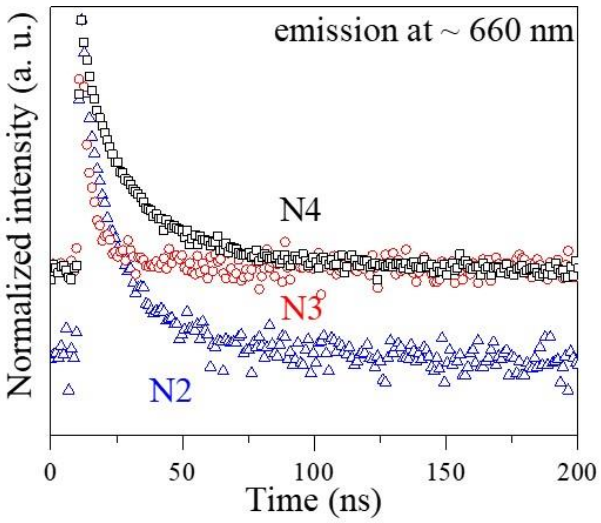

Figure S8. PL decays of emissions at 660 nm in N2, N3 and N4 samples.

Table S3. Summary of the parameters from fits of the TRPL measurement. The fitting functions of exponential equation: $y = y_0 + A_1\exp(-\frac{t}{\tau_1}) + A_2\exp(-\frac{t}{\tau_2})$.

sample	A_1	τ_1 (ns)	A_2	τ_2 (ns)
N2	0.87	0.82	0.13	2.13
N3	0.91	0.75	0.07	4.93
N4	0.70	2.01	0.28	11.02

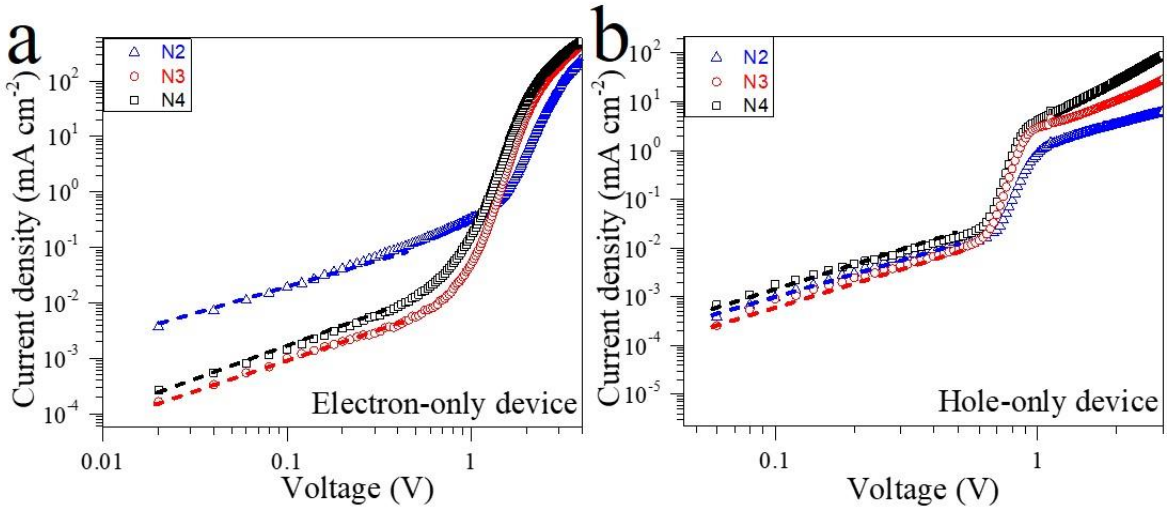

Figure S9. Dark *J–V* measurements of a) electron- and b) hole-only devices of N4, N3 and N2 samples.

Figure S9 shows the J–V curves of the electron and hole-only devices. The linear relation indicates an ohmic response of the device at low bias voltage, and the current quickly increases nonlinearly when the bias voltage exceeds the key point, demonstrating that the trap-states are completely filled. Further increase the bias voltage, the devices will operate in the trap-free space charge limit current (SCLC) region. The carrier mobility can be determined by the equation:

$$J = \frac{9\varepsilon\varepsilon_0\mu V^2}{8d^3};$$

Where, e is the elementary charge of the electron, d is the perovskite film thickness, ε is the relative dielectric constant, ε0 is the vacuum permittivity. Perovskite devices are more dominated in electron transport/electron traps, therefore, the J–V behaviors are different in FigureS9a and b.

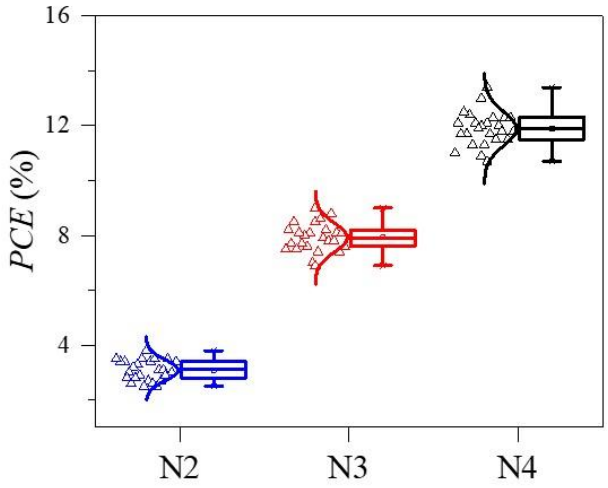

Figure S10. Statistics of *PCE* distribution of the PSCs with N2, N3, and N4 samples.

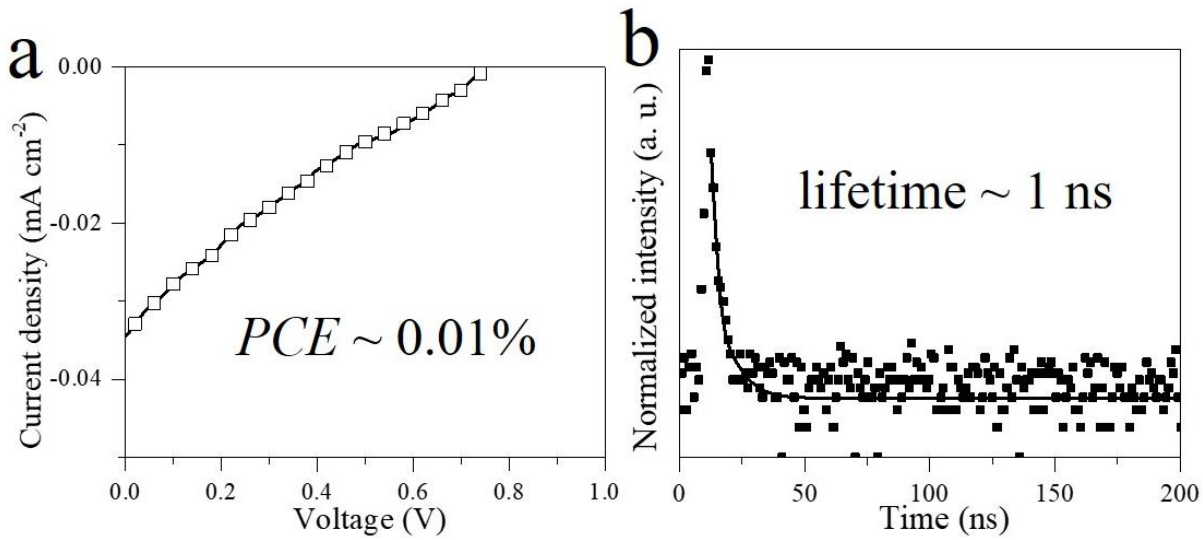

Figure S11. (a) J–V curve of 1D $BDAPbI_4$ perovskite solar cell. (b) PL decay profiles of 1D perovskite thin film.

Perovskite solar cells based on this 1D perovskite are also prepared. However, the efficiency of the device is only up to 0.01% (Figure S1a), which is due to the high energy absorption and large exciton binding energy. Figure S1b shows the decay of emission at 610 nm from the 1D perovskite thin film at room temperature, giving lifetime of ~2 ns, which indicates short carrier lifetime in the 1D perovskite.

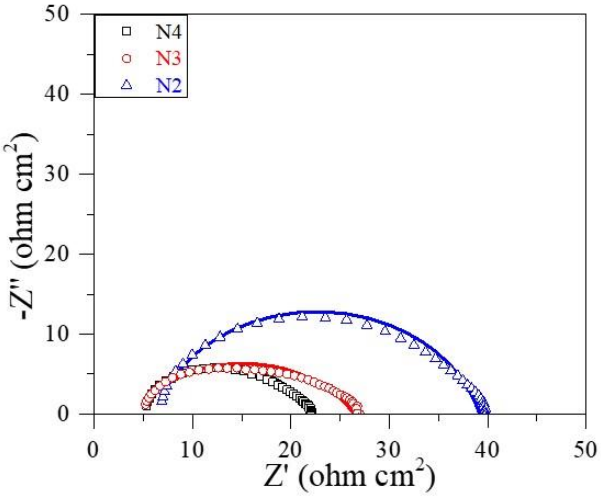

Figure S12. EIS spectra of N4, N3 and N2 PSCs measured at open circuit condition.

Table S4. Summary of the parameters from fits of the TRPL measurement. The fitting functions of exponential equation: $y = y_0 + A_1 \exp(-\frac{t}{\tau_1}) + A_2 \exp(-\frac{t}{\tau_2})$.

Substrate	A_1	τ_1 (ns)	A_2	τ_2 (ns)
Glass	0.70	2.01	0.28	11.02
PEDOT:PSS	0.86	1.31	0.14	6.5

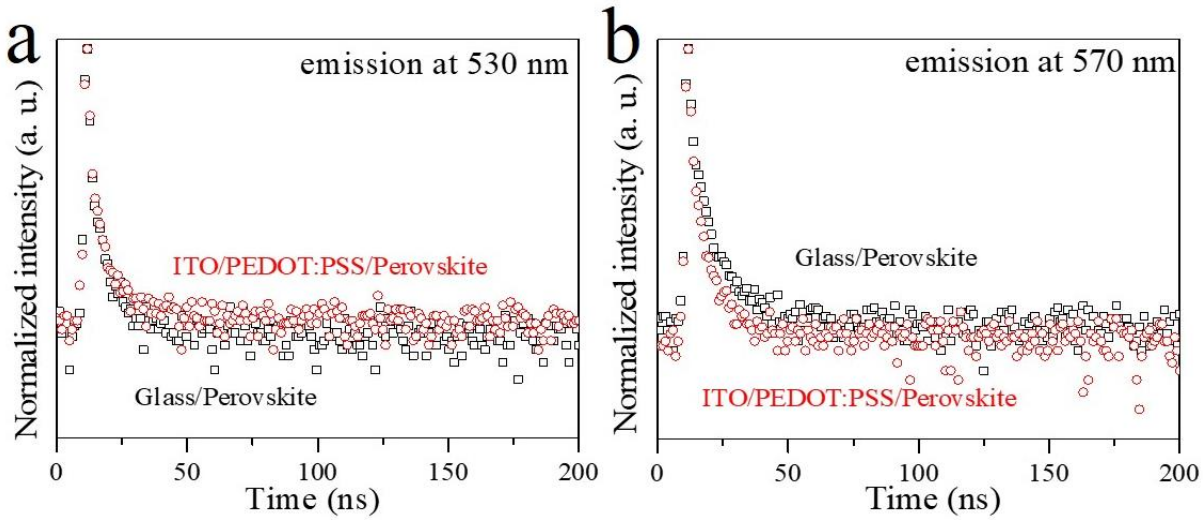

Figure S13. PL decay profiles of emission at (a) 530 and (b) 570 nm of N4 sample with/without HTL.

Table S5. Summary of the parameters from fits of the TRPL measurement. The fitting functions of exponential equation: $y = y_0 + A_1\exp(-\frac{t}{\tau_1}) + A_2\exp(-\frac{t}{\tau_2})$.

	A_1	τ_1 (ns)	A_2	τ_2 (ns)
530nm				
Glass	0.96	0.52	0.04	3.87
PEDOT:PSS	0.96	0.57	0.04	4.40
570 nm				
Glass	0.87	0.60	0.13	3.78
PEDOT:PSS	0.93	0.59	0.06	3.39