Supporting Information

17% Efficient Perovskite Solar Mini-module via Hexamethylphosphoramide (HMPA)-adduct-based Large-area D-bar Coating

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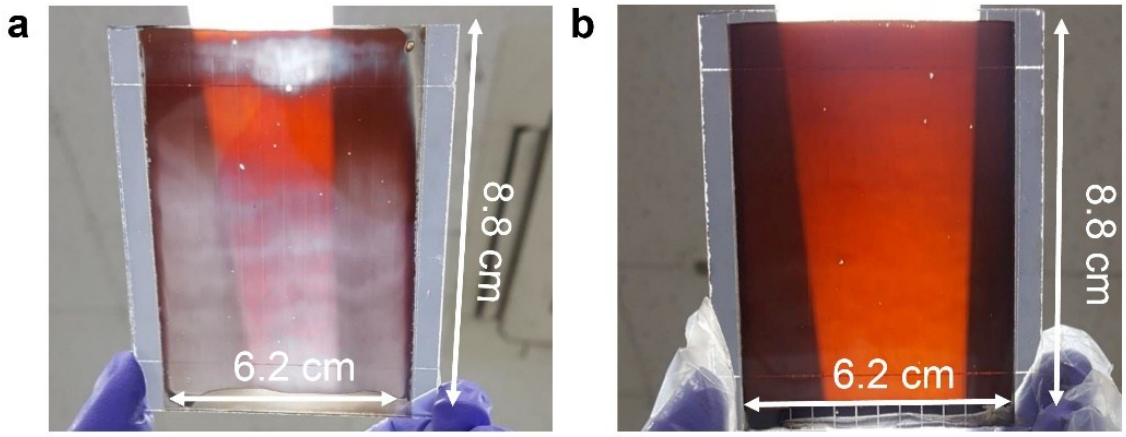

Figure S1. Digital photographs of the D-bar coated and 150 °C-annealed perovskite films formed from (a) the DMSO-contained and (b) the HMPA-contained precursor solution. The substrate size was 8.8 cm × 6.2 cm. FTO side was exposed (the perovskite films were faced on the backside fluorescent light).

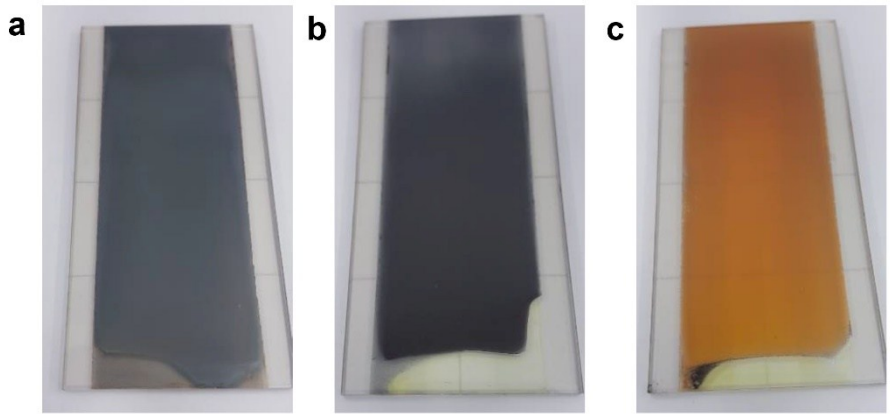

Figure S2. Digital photographs of the as-coated non-annealed films formed from the precursor solution (a) without Lewis base additive and with Lewis base additive of (b) DMSO or (c) HMPA.

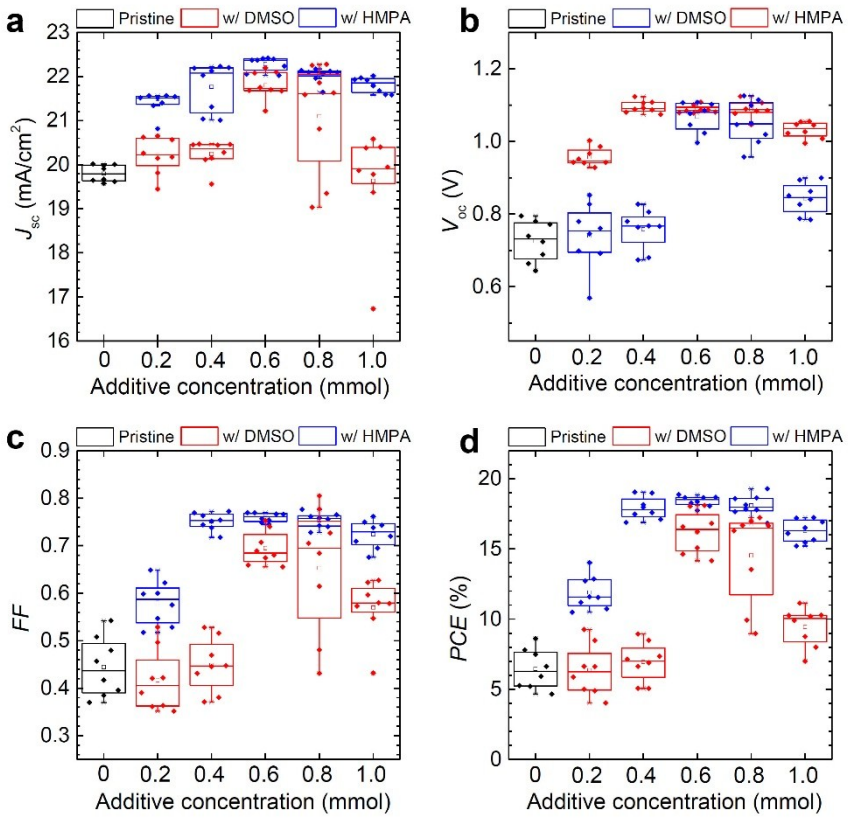

Figure S3. Statistical photovoltaic parameters depending on Lewis base additive concentration. (a) Short-circuit photocurrent density (J_{sc}), (b) open-circuit voltage (V_{oc}), (c) fill factor (*FF*), and (d) power conversion efficiency (*PCE*). *J-V* data were obtained under AM 1.5G simulated 1 sun illumination at a scan rate of 0.26 V/s. The active area was 0.125 cm^2. Reverse scanned data are presented.

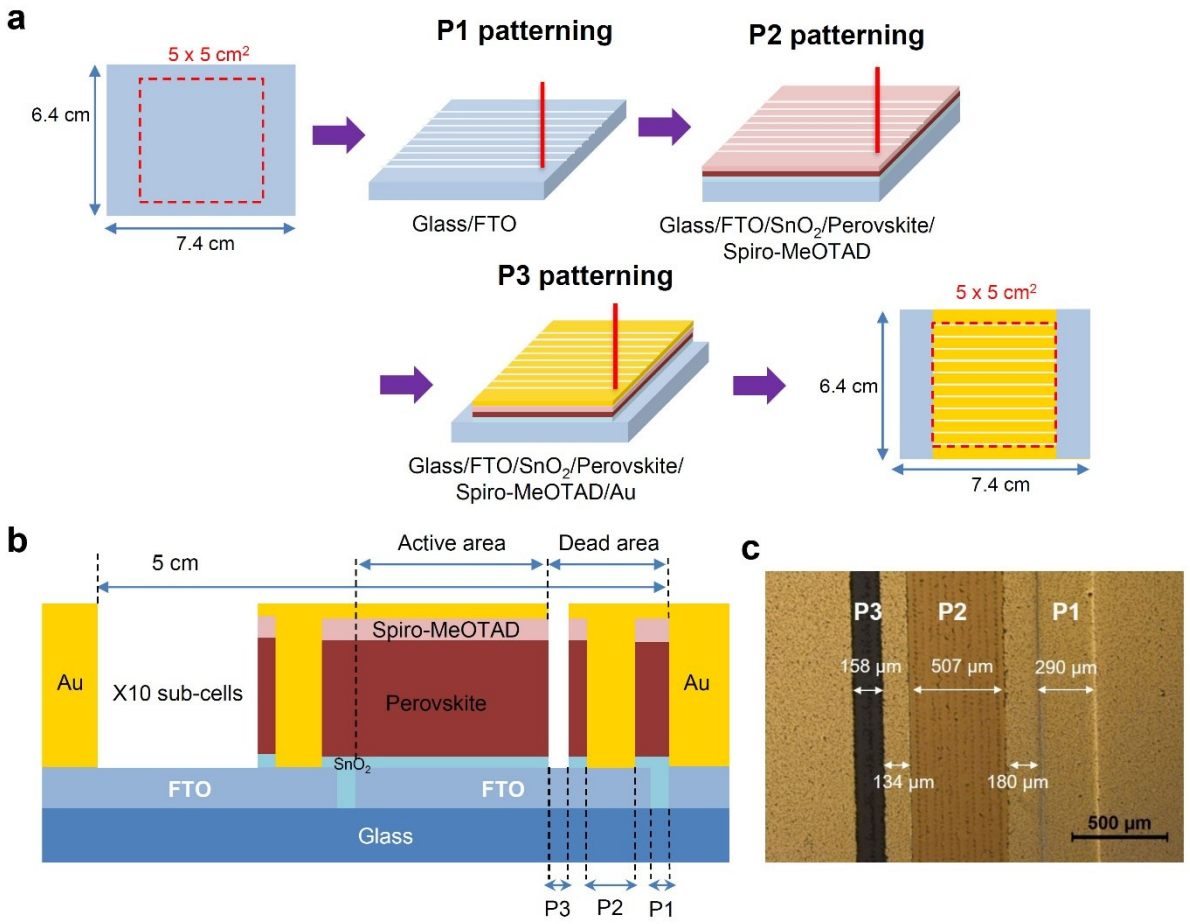

Figure S4. Schematic illustration of (a) the fabrication process and (b) the structure of the perovskite mini-module with 10 sub-cells connected in series. (c) Optical microscopic image of P1, P2, and P3 lines scribed on the mini-module.

Table S1. Amplitude (A) and carrier lifetime (τ) obtained by fitting the time-resolved photoluminescence (TRPL) data for the D-bar coated and 150 °C-annealed $(FAPbI_3)_{0.875}(CsPbBr_3)_{0.125}$ films formed from the precursor solution without (pristine) and with Lewis base of DMSO or HMPA. Perovskite films were deposited on a plane glass substrate. Average life time (τ_{ave}) was calculated from $(A_1\tau_1^2+A_2\tau_2^2)/(A_1\tau_1+A_2\tau_2)$.

	A_1	τ_1 (ns)	A_2	τ_2 (ns)	τ_{ave} (ns)
Pristine	600.09 (57.05%)	12.3	451.80 (42.95%)	138.4	125.1
w/ DMSO	478.69 (46.55%)	16.5	549.60 (53.45%)	814.5	800.7
w/ HMPA	399.87 (40.72%)	19.1	581.38 (59.28%)	1052.3	1039.6

Table S2. Statistical photovoltaic parameters depending on Lewis base additive concentration. *J-V* data were obtained under AM 1.5G simulated 1 sun illumination at a scan rate of 0.26 V/s. The active area was 0.125 cm^2. Reverse scanned data are listed.

Concentration (mmol)	J_{sc} (mA/cm^2)	V_{oc} (V)	*FF*	PCE (%)
Pristine (0.0)	19.80 ± 0.19	0.726 ± 0.056	0.444 ± 0.062	6.45 ± 1.42
DMSO (0.2)	20.21 ± 0.42	0.740 ± 0.089	0.417 ± 0.065	6.35 ± 1.80
DMSO (0.4)	20.24 ± 0.31	0.758 ± 0.055	0.449 ± 0.056	6.95 ± 1.40
DMSO (0.6)	21.80 ± 0.32	1.068 ± 0.042	0.695 ± 0.036	16.20 ± 1.48
DMSO (0.8)	21.10 ± 1.27	1.051 ± 0.059	0.653 ± 0.135	14.54 ± 3.35
DMSO (1.0)	19.63 ± 1.24	0.843 ± 0.043	0.570 ± 0.062	9.44 ± 1.39
HMPA (0.2)	21.41 ± 0.25	0.957 ± 0.025	0.580 ± 0.046	11.89 ± 1.21
HMPA (0.4)	21.77 ± 0.55	1.095 ± 0.016	0.751 ± 0.018	17.91 ± 0.80
HMPA (0.6)	22.28 ± 0.16	1.088 ± 0.011	0.759 ± 0.010	18.41 ± 0.38
HMPA (0.8)	22.04 ± 0.17	1.089 ± 0.023	0.753 ± 0.016	18.10 ± 0.75
HMPA (1.0)	21.81 ± 0.17	1.031 ± 0.022	0.724 ± 0.030	16.29 ± 0.80

Table S3. Photovoltaic parameters of the 5 × 5 cm^2 mini-module based on DMSO and HMPA adduct induced perovskite films, measured at reverse scan (scan rate = 2.53 V/s) under one sun illumination.

w/ DMSO	J_{sc} (mA/cm^2)	V_{oc} (V)	*FF*	PCE (%)	Active area (cm^2)
1	2.065	9.076	0.447	8.38	19.28
2	2.109	10.585	0.606	13.53	19.24
3	2.096	10.564	0.601	13.31	18.74
4	2.074	10.072	0.591	12.34	19.24
Average	2.086	10.074	0.561	11.89	

w/ HMPA	J_{sc} (mA/cm^2)	V_{oc} (V)	*FF*	PCE (%)	Active area (cm^2)
1	2.090	10.298	0.583	12.54	18.09
2	2.232	10.810	0.705	17.01	18.66
3	2.128	10.148	0.644	13.91	19.54
4	2.104	10.691	0.684	15.39	19.64
Average	2.139	10.477	0.648	14.71	