

Electronic Supplementary Information

Fabrication of high coverage MASnI_3 perovskite films for stable, planar heterojunction solar cells

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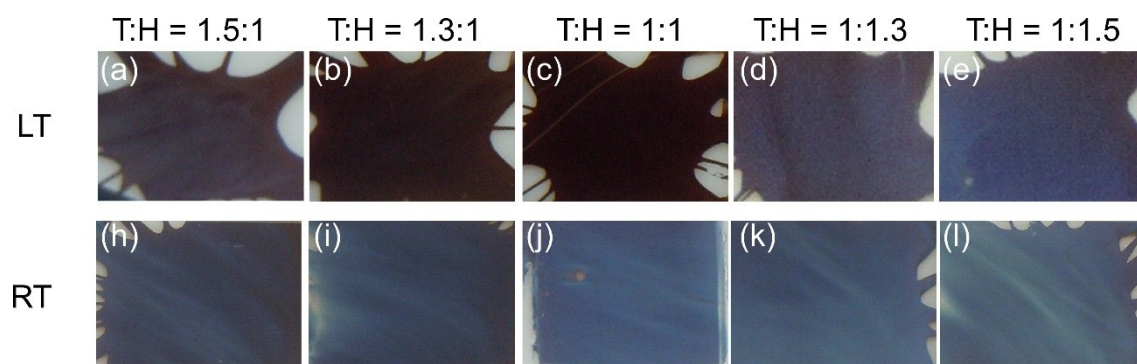


Fig. S1 Photographs of the perovskite films fabricated with different ratios of toluene and hexane on the PEDOT:PSS coated glass substrate. The toluene:hexane ratio was changed from 1.5:1 (a, h) to 1:1.5 (e, l) at different temperatures, namely at 13 °C (LT, a–e) and at 25 °C (RT, h–l).

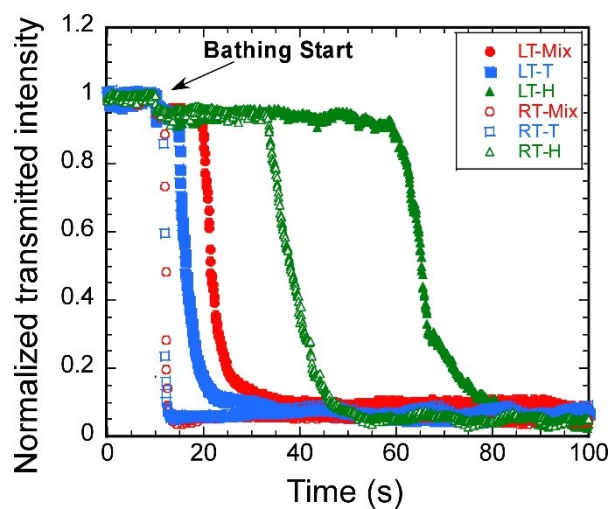


Fig. S2 Temporal change of transmittance of the perovskite films during bathing in the different anti-solvent conditions. The solid and open symbols indicate the temperature of the anti-solvents, namely 13 °C (LT-) and 25 °C (RT-), respectively. Whether toluene and hexane (Mix), toluene (T), or hexane (H) was used as the co-solvent was indicated by circles, squares, or triangles, respectively.

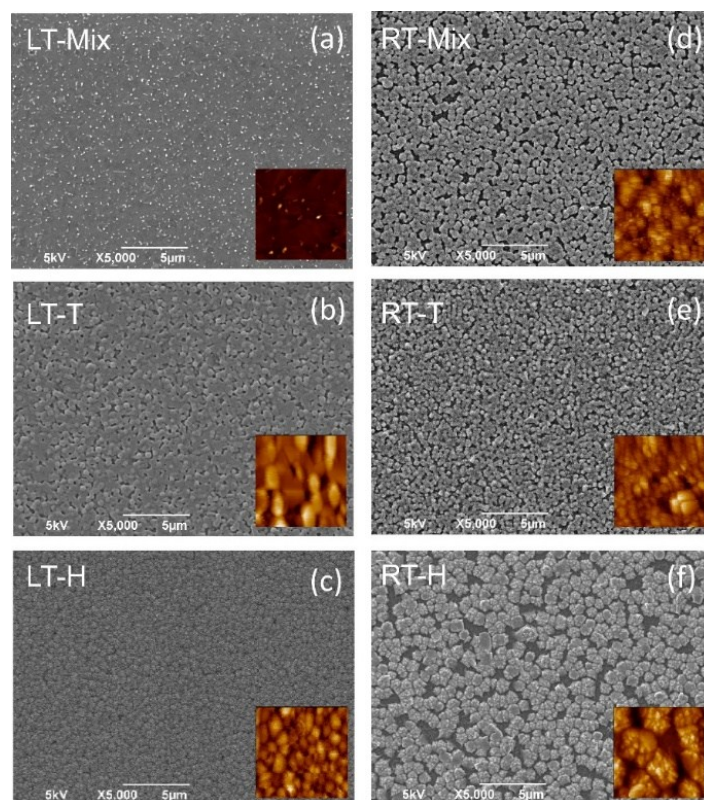


Fig. S3 Scanning electron microscopy (SEM) images and atomic force microscopy (AFM) images for the different conditions. LT-Mix (a), LT-T (b), and LT-H (c) indicate using mixed solvent, toluene, and hexane, respectively, at a temperature of 13 °C (LT-). RT-Mix (d), RT-T (e), and RT-H (f) indicate using mixed solvent, toluene, and hexane, respectively, at a temperature of 25 °C (RT-). The scales of AFM images were $3\ \mu\text{m} \times 3\ \mu\text{m}$.

Table S1 The thickness and surface roughnesses for different anti-solvent conditions. The R_q indicates the root mean square value.

	LT-Mix	LT-T	LT-H	RT-Mix	RT-T	RT-H
Thickness (nm)	126	195	214	238	268	216
Roughness : R_q (nm)	7.3	41	19	31	32	65

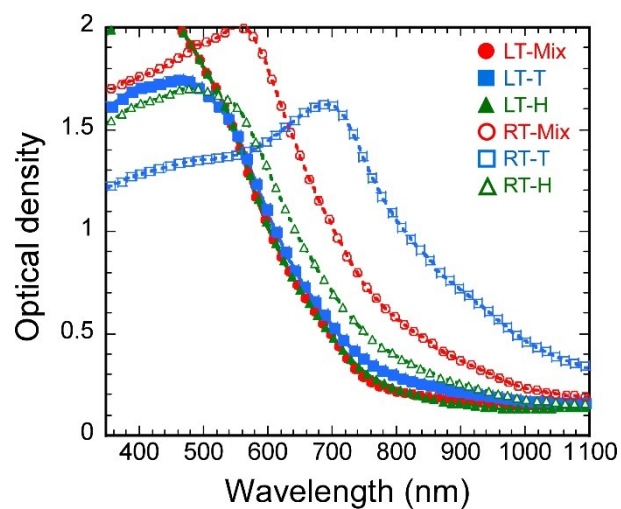


Fig. S4 Optical densities of perovskite films fabricated with the different anti-solvent conditions. The solid and open symbols indicate the temperature of the anti-solvents at 13 °C (LT-) and 25 °C (RT-), respectively. Whether toluene and hexane (Mix), toluene (T), or hexane (H) was used as the co-solvent is indicated by circles, squares, or triangles, respectively.

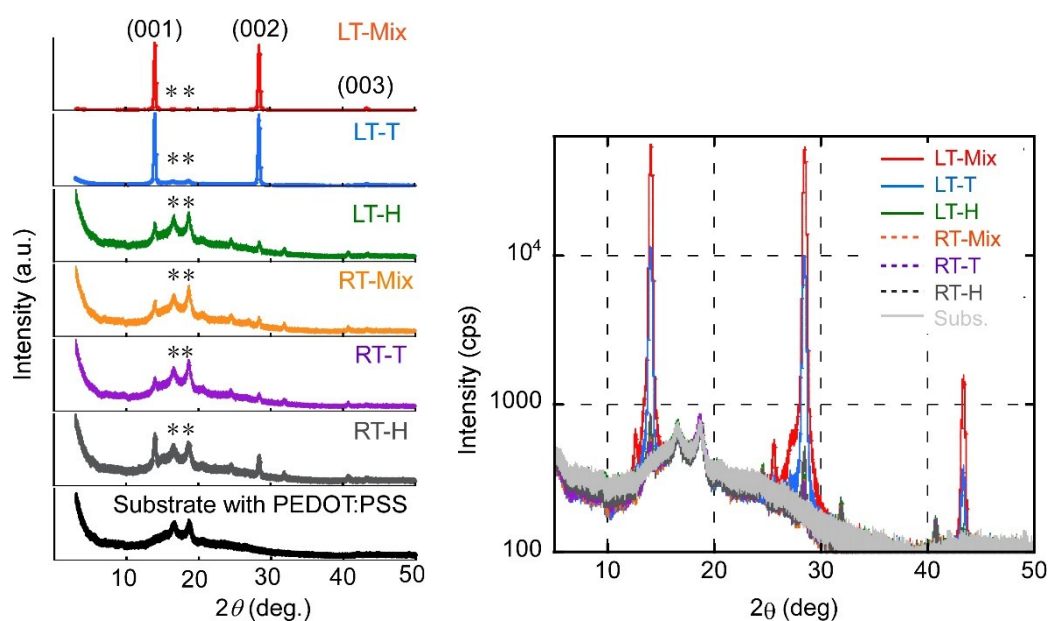


Fig. S5 (a) The X-ray diffraction spectra for the LT-Mix (red), LT-T (blue), LT-H (green), RT-Mix (orange), RT-T (purple), and RT-H (gray) conditions, as well as the substrate-only spectrum (Black). The asterisks indicate the peaks originating from the substrate with the dome type cover, which was employed protect the perovskite film from exposure to air. The semi-log plots of the data are shown in (b).

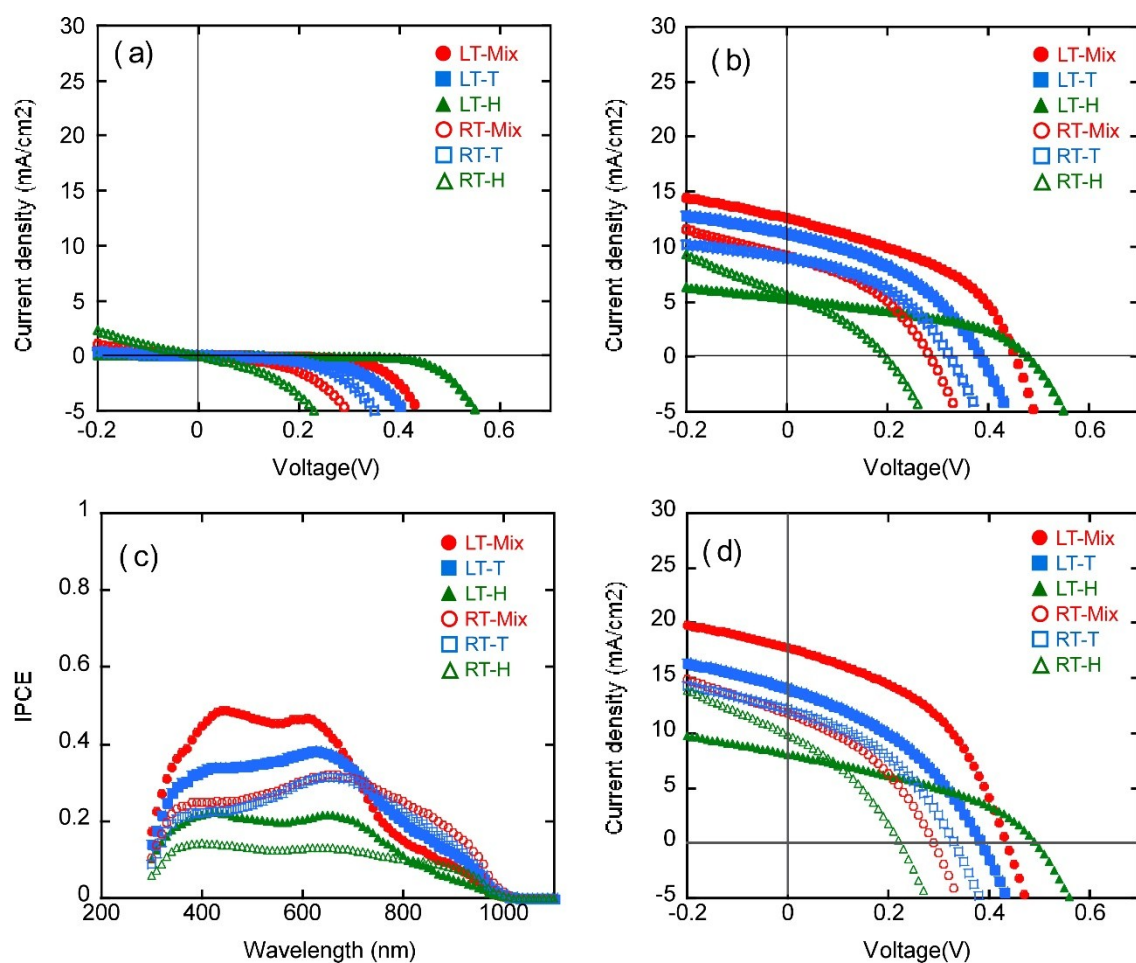


Fig. S6 Current–voltage characteristics and incident photon to electron conversion efficiency (IPCE) for the best performing cell under each anti-solvent condition. (a) Dark current (i.e., without light illumination). (b, d) Photocurrent measured with (1.8 mm × 1.8 mm) and without shadow mask (2 mm × 2 mm) under AM1.5 simulated sunlight of 100 mW/cm². (c) IPCE spectrum for different anti-solvent conditions.

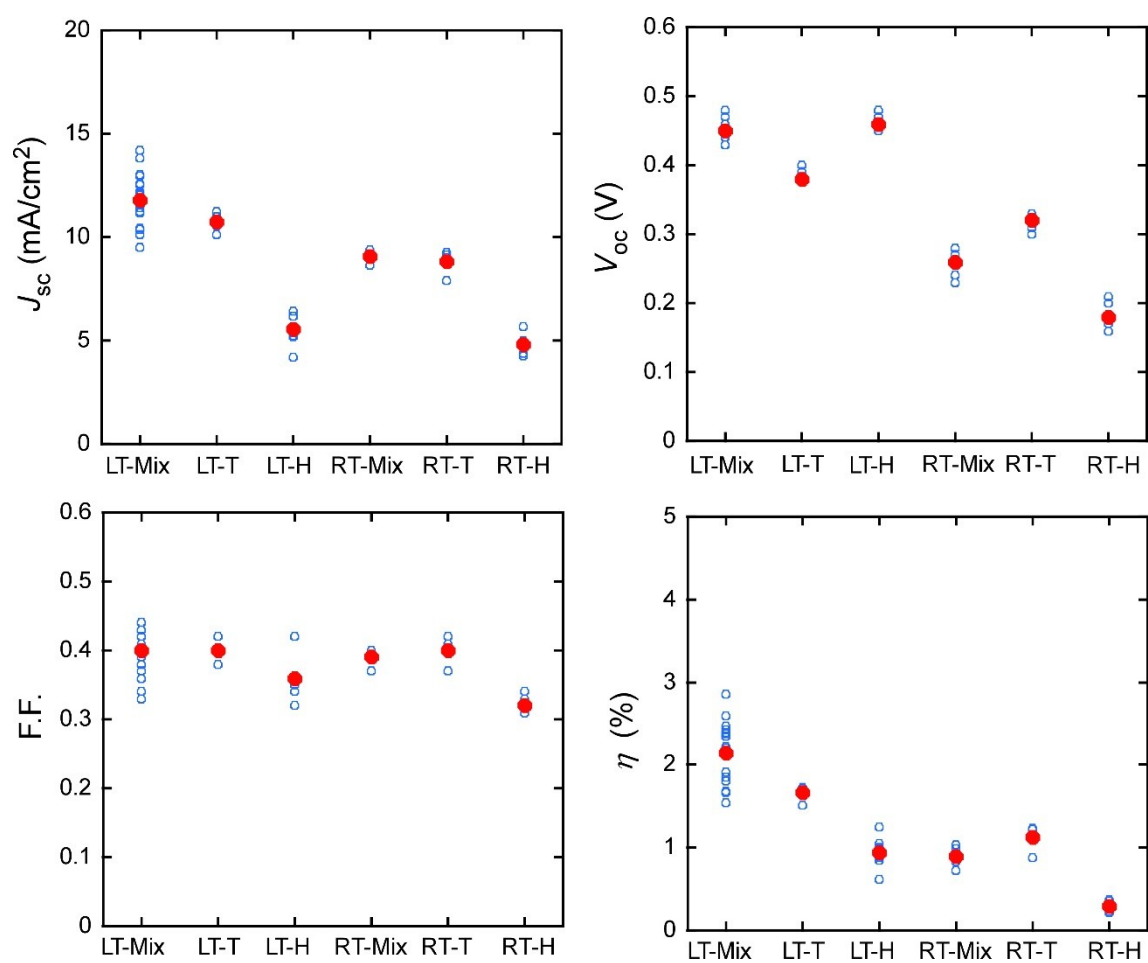


Fig. S7 Key photovoltaic parameters for different anti-solvent conditions. The measured and averaged values are indicated by open and solid circles, respectively. The evaluated number of cells was 20 for LT-Mix and between 4 and 8 for the other condition, respectively. The average values with their standard deviations are summarized in Table ESI-2.

Table S2 Key photovoltaic parameters for different anti-solvent conditions. The parameters were measured with the shadow mask in place. The measured number of cells was 20 for LT-Mix and between 4 and 8 for the other conditions.

	LT-Mix	LT-T	LT-H	RT-Mix	RT-T	RT-H
J_{sc} (mA/cm ²)	11.82 ± 1.20	10.73 ± 0.51	5.55 ± 0.71	9.05 ± 0.32	8.83 ± 0.62	4.84 ± 0.67
V_{oc} (V)	0.45 ± 0.01	0.38 ± 0.01	0.46 ± 0.01	0.26 ± 0.03	0.32 ± 0.01	0.18 ± 0.02
F.F.	0.40 ± 0.03	0.40 ± 0.02	0.36 ± 0.04	0.39 ± 0.01	0.40 ± 0.02	0.32 ± 0.01
η (%)	2.14 ± 0.35	1.66 ± 0.10	0.94 ± 0.18	0.89 ± 0.14	1.12 ± 0.16	0.29 ± 0.08

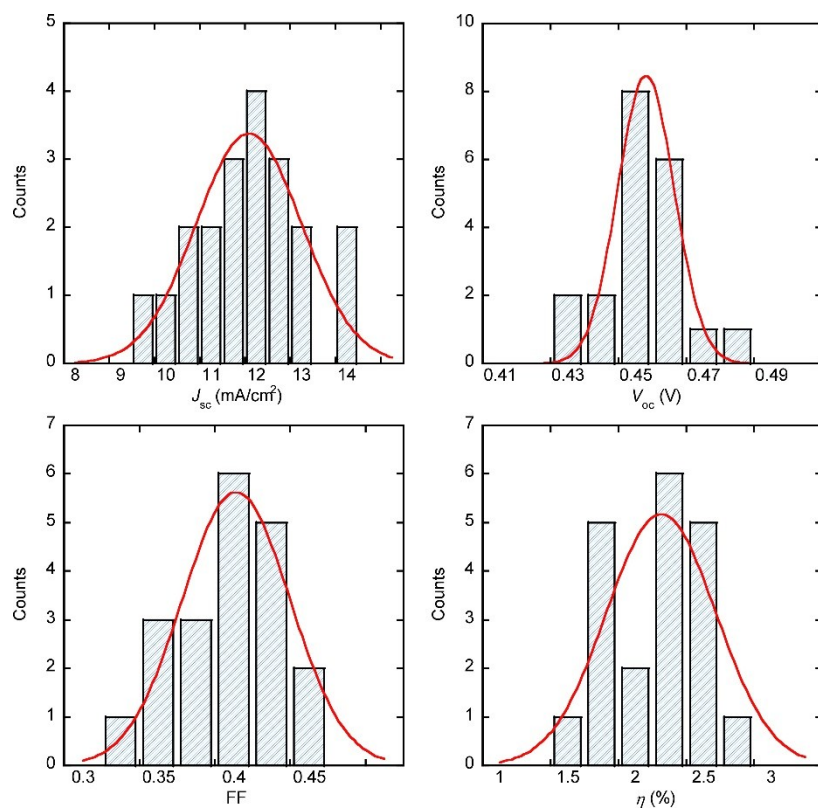


Fig. S8 Histograms of the photovoltaic parameters of 20 LT-Mix cells.

Table S3 Comparison of our photovoltaic device results with previously reported performances.

	J_{sc} (mA/cm ²)	V_{oc} (V)	FF	η (%)
^a Modified SB	11.82 \pm 1.20	0.45 \pm 0.01	0.40 \pm 0.03	2.14 \pm 0.35
^b LT-VASP	15.1 \pm 3.08	0.22 \pm 0.04	0.35 \pm 0.03	1.16 \pm 0.42
^c Excess SnI ₂	12.30 \pm 0.48	0.43 \pm 0.06	0.40 \pm 0.05	2.13 \pm 0.53
^d Additive	23.44 \pm 1.4	0.28 \pm 0.02	0.56 \pm 0.04	3.71 \pm 0.38
^e FDC	20.69 \pm 0.95	0.45 \pm 0.02	0.58 \pm 0.03	5.41 \pm 0.46

a) Modified solvent bathing method. (Average of 20 cells)

b) Low temperature vapor assisted solution process (Average of 12 cells)¹

c) Employing PCBM for acceptor (Average of 14 cells)²

d) Pyrazine was used as an additive (Average of 36 cells)³

e) Diethyl ether was employed as an anti-solvent in FDC (Average of 30 cells)⁴

References

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