

Supplementary Information

High-Performance Mixed-Dimensional Perovskite Solar Cells with Enhanced Stability against Humidity, Heat and UV Light

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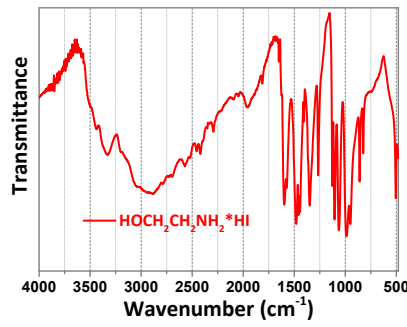


Fig. S1. FTIR spectrum of $\text{HOCH}_2\text{CH}_2\text{NH}_2 \cdot \text{HI}$. (Standard FTIR spectrum of $\text{HOCH}_2\text{CH}_2\text{NH}_2 \cdot \text{HCl}$ is shown in http://sdbs.db.aist.go.jp/sdbs/cgi-bin/direct_frame_top.cgi)

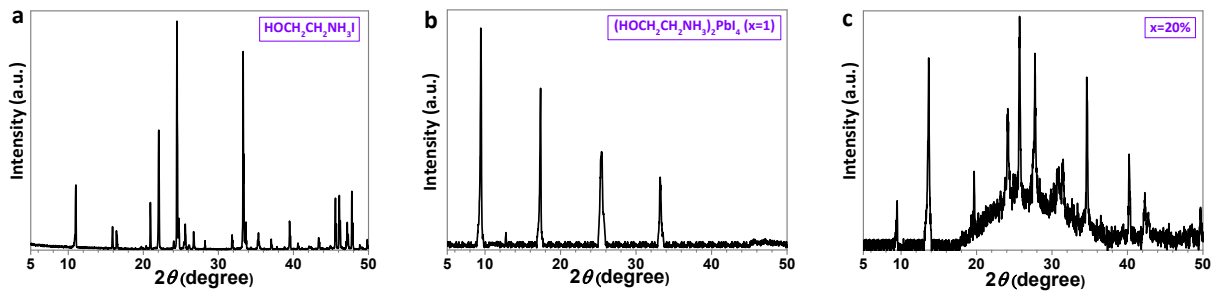


Fig. S2. XRD patterns of EAI, $(\text{EA})_2\text{PbI}_4$ ($x=1$) and $[(\text{EA})_2\text{PbI}_4]_{0.2}[(\text{FAPbI}_3)_{0.85}(\text{MAPbBr}_3)_{0.15}]_{0.8}$ ($x=20\%$) thin films.

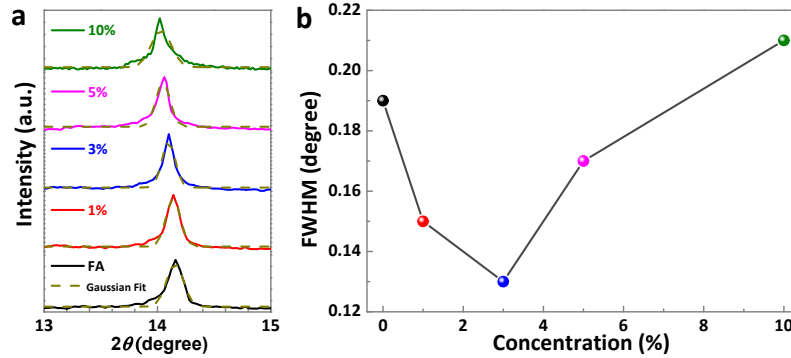


Fig. S3. (a) The magnified XRD patterns with gaussian fit and (b) the dependence of full width at half maximum (FWHM) for the (110) peaks.

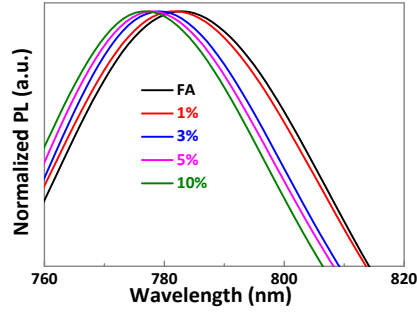


Fig. S4. Partially enlarged normalized PL spectra of $[(\text{EA})_2\text{PbI}_4]_x[(\text{FAPbI}_3)_{0.85}(\text{MAPbBr}_3)_{0.15}]_{1-x}$ ($x=0, 1\%, 3\%, 5\%, 10\%$) thin films.

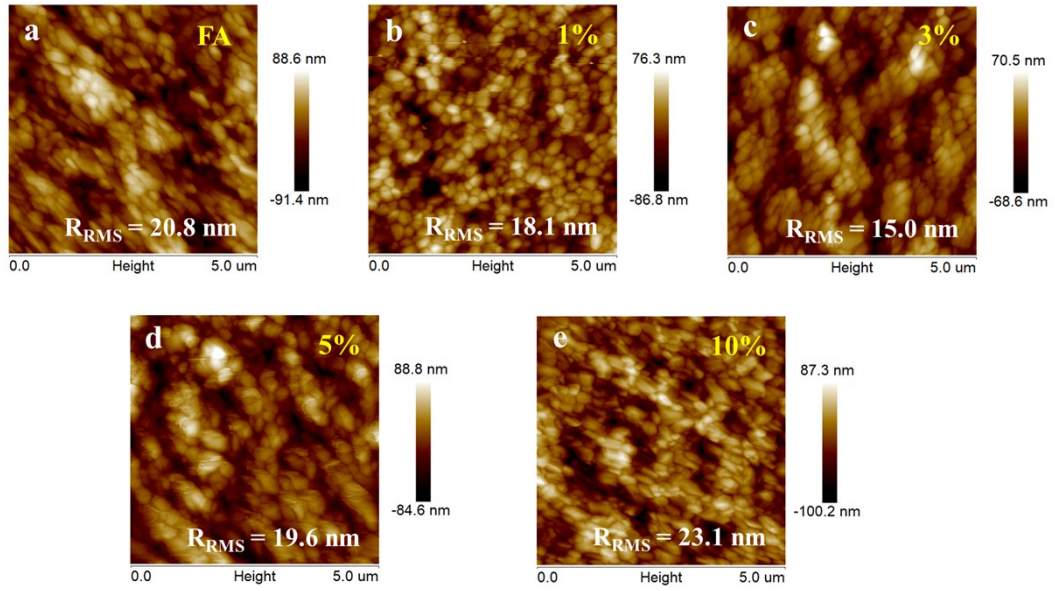


Fig. S5. AFM images of $[(\text{EA})_2\text{PbI}_4]_x[(\text{FAPbI}_3)_{0.85}(\text{MAPbBr}_3)_{0.15}]_{1-x}$ ($x=0, 1\%, 3\%, 5\%, 10\%$) films.

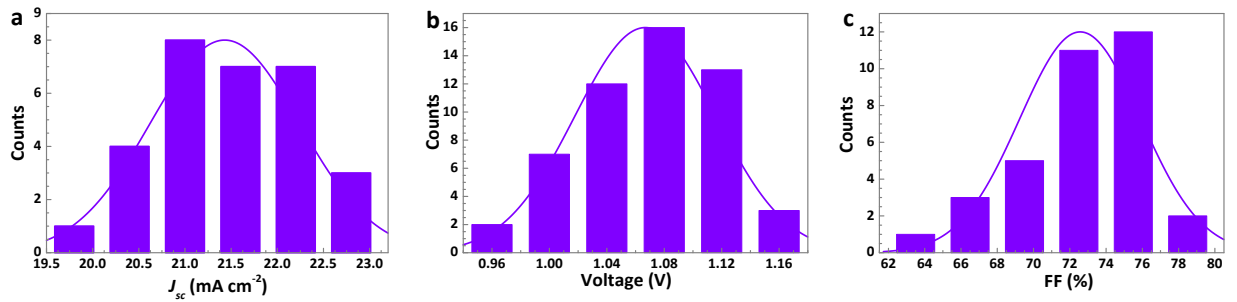


Fig. S6. (a) Short-circuit current density (J_{sc}), (b) Open circuit voltages (V_{oc}) and (c) Fill factor (FF) histogram fitted with a Gaussian distribution of the MD ($x=3\%$) perovskite devices over 30 measured devices.

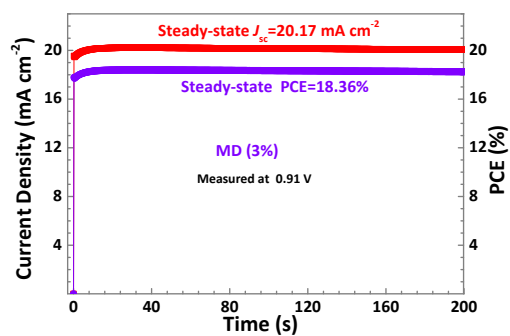


Fig. S7. Steady-state measurement of the photocurrent and PCE at the maximum power point of MD perovskite device.

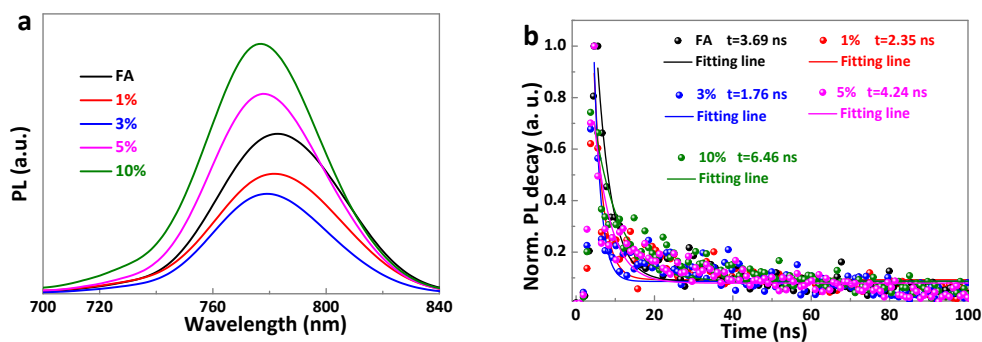


Fig. S8. (a) PL spectra and (b) TRPL decay spectra of $[(\text{EA})_2\text{PbI}_4]_x[(\text{FAPbI}_3)_{0.85}(\text{MAPbBr}_3)_{0.15}]_{1-x}$ ($x=0, 1\%, 3\%, 5\%, 10\%$) thin films on top of mesoporous TiO_2 layer.

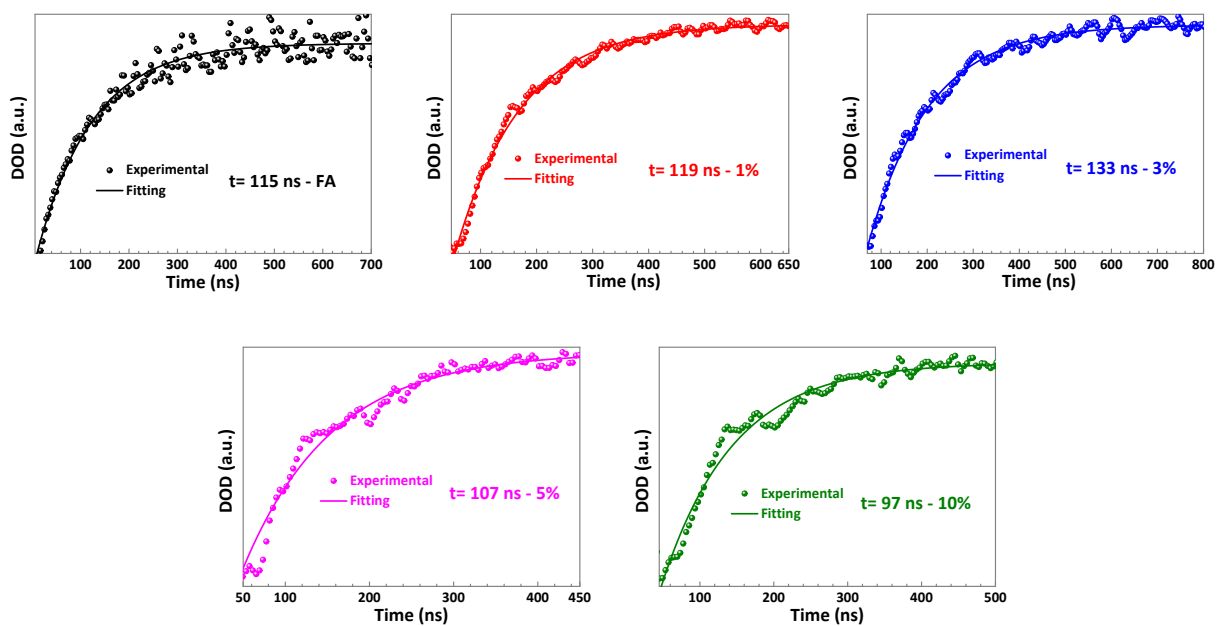


Fig. S9. Normalized TA responses of $[(\text{EA})_2\text{PbI}_4]_x[(\text{FAPbI}_3)_{0.85}(\text{MAPbBr}_3)_{0.15}]_{1-x}$ ($x=0, 1\%, 3\%, 5\%, 10\%$) thin films.

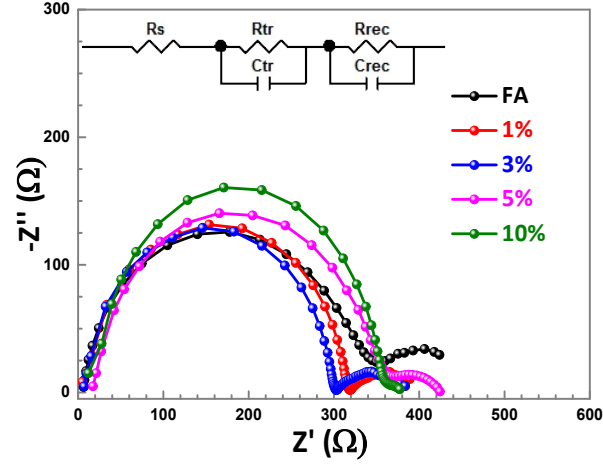


Fig. S10. Nyquist plots of $[(\text{EA})_2\text{PbI}_4]_x[(\text{FAPbI}_3)_{0.85}(\text{MAPbBr}_3)_{0.15}]_{1-x}$ ($x=0, 1\%, 3\%, 5\%, 10\%$) PSCs at $V=1.0$ V.

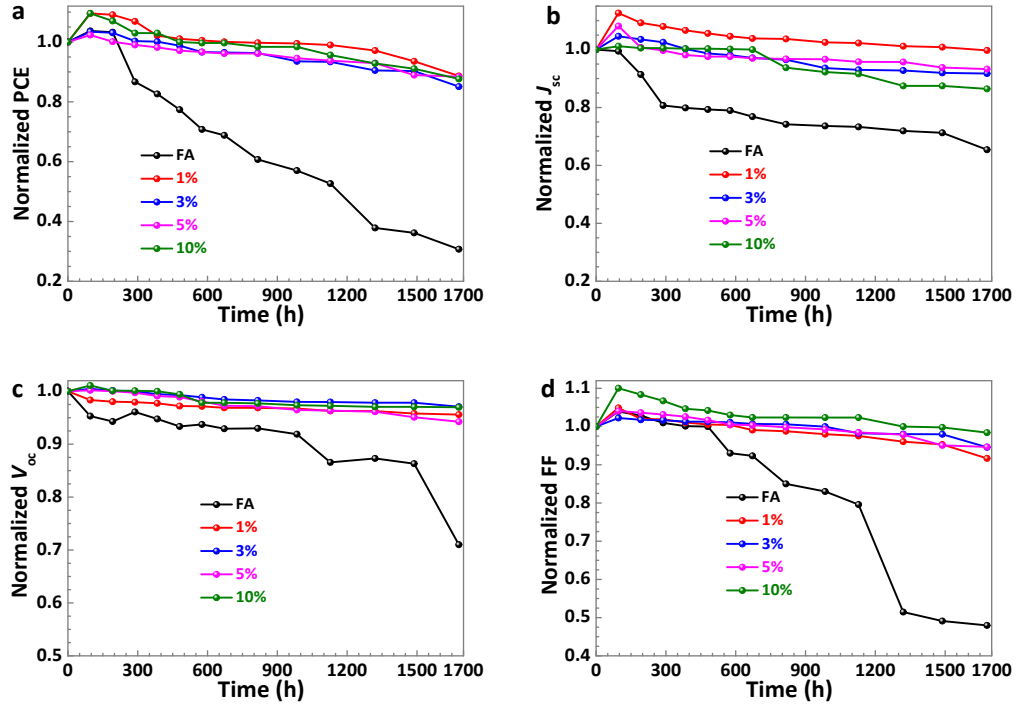


Fig. S11. Normalized (a) PCE, (b) short-circuit current density (J_{sc}), (c) open circuit voltages (V_{oc}) and (d) fill factor (FF) variation curves of unsealed normal and MD ($x=1\%, 3\%, 5\%, 10\%$) perovskite

devices under about 50% RH.

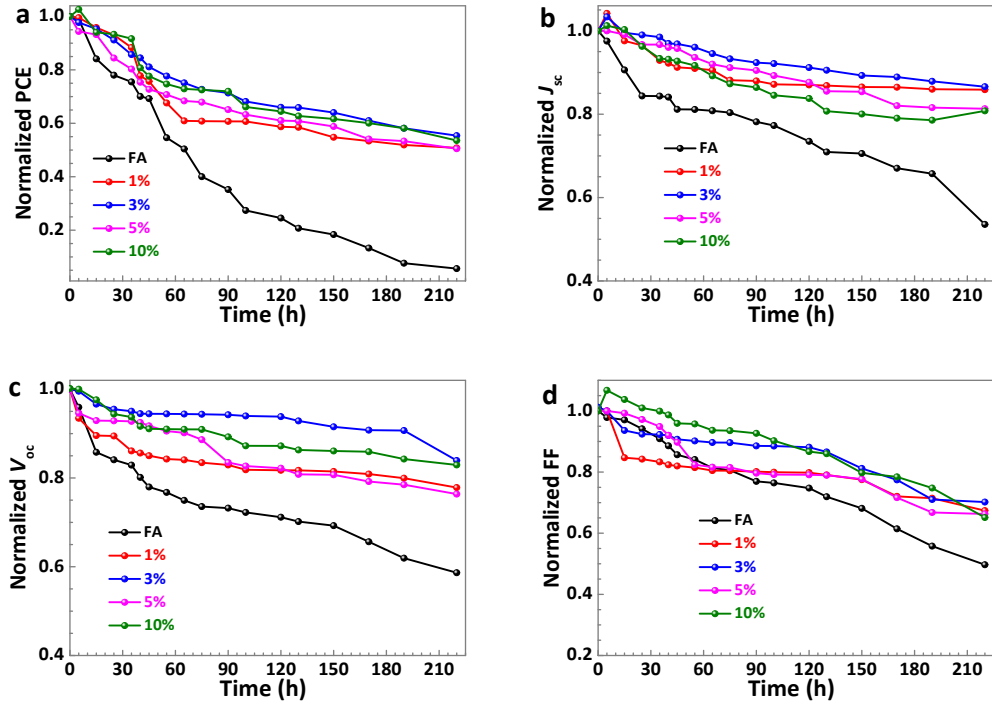


Fig. S12. Normalized (a) PCE, (b) short-circuit current density (J_{sc}), (c) open circuit voltages (V_{oc}) and (d) fill factor (FF) variation curves of unsealed normal and MD (x=1%, 3%, 5%, 10%) perovskite devices at 85 °C.

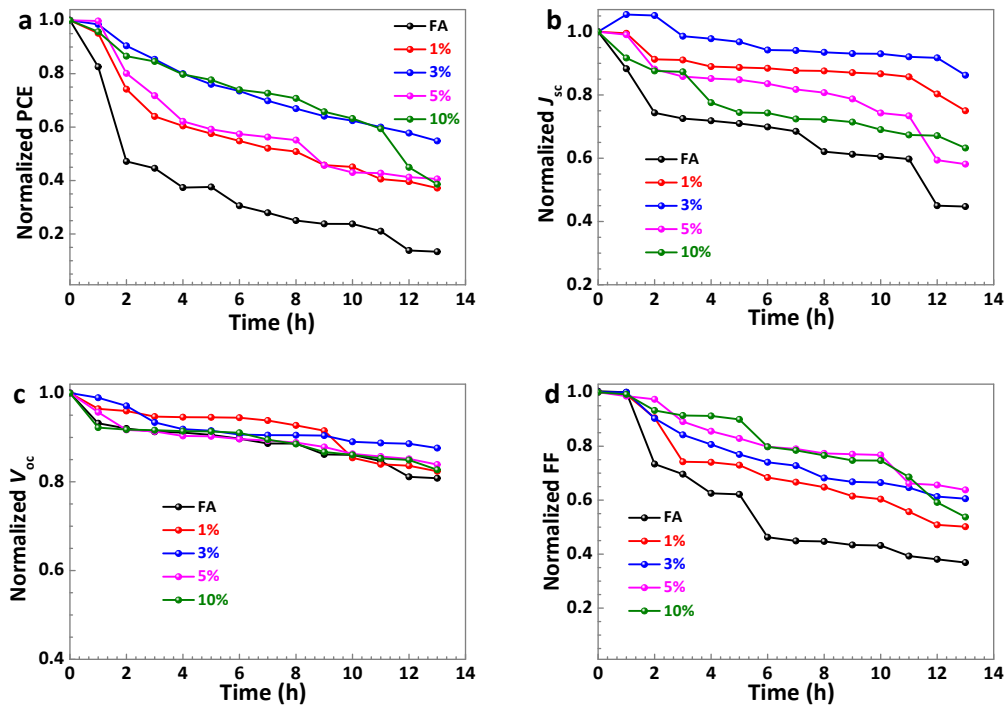


Fig. S13. Normalized (a) PCE, (b) short-circuit current density (J_{sc}), (c) open circuit voltages (V_{oc}) and (d) fill factor (FF) variation curves of unsealed normal and MD (x=1%, 3%, 5%, 10%) perovskite devices under continuous UV irradiation.

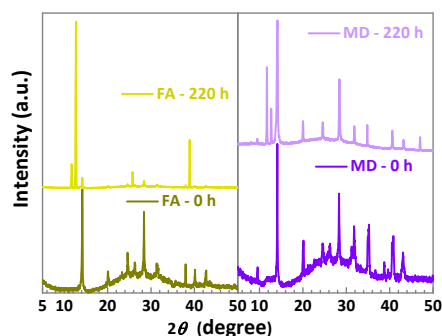


Fig. S14. XRD patterns of the normal and MD (x= 3%) perovskite films before and after exposing to 85 °C.

Table S1. Photovoltaic parameters of the normal and the MD (x=1%, 3%, 5%, 10% and 20%) perovskite solar cells.

Device	J_{sc} (mA cm ⁻²)	V_{oc} (V)	FF (%)	PCE (%)
FA	22.39	1.06	67.97	16.17
1%	22.14	1.09	74.03	17.91
3%	22.20	1.10	77.13	18.79
5%	19.78	1.12	71.79	15.86
10%	17.55	1.13	66.69	13.20
20%	15.39	1.13	68.40	11.92

Table S2. Photovoltaic parameters of the normal and the MD (x=3%) perovskite devices under reverse and forward scan directions.

Device	J_{sc} (mA cm ⁻²)	V_{oc} (V)	FF (%)	PCE (%)
FA-Reverse	22.39	1.06	67.97	16.17
FA-Forward	18.75	1.07	70.16	14.09

3%-Reverse	22.20	1.10	77.13	18.79
3%-Forward	22.33	1.09	76.19	18.56