Electronic Supplementary Material (ESI) for New Journal of Chemistry.


# Organic Spacer Engineering in 2D/3D Hybrid Perovskites for Efficient and Stable Solar Cells

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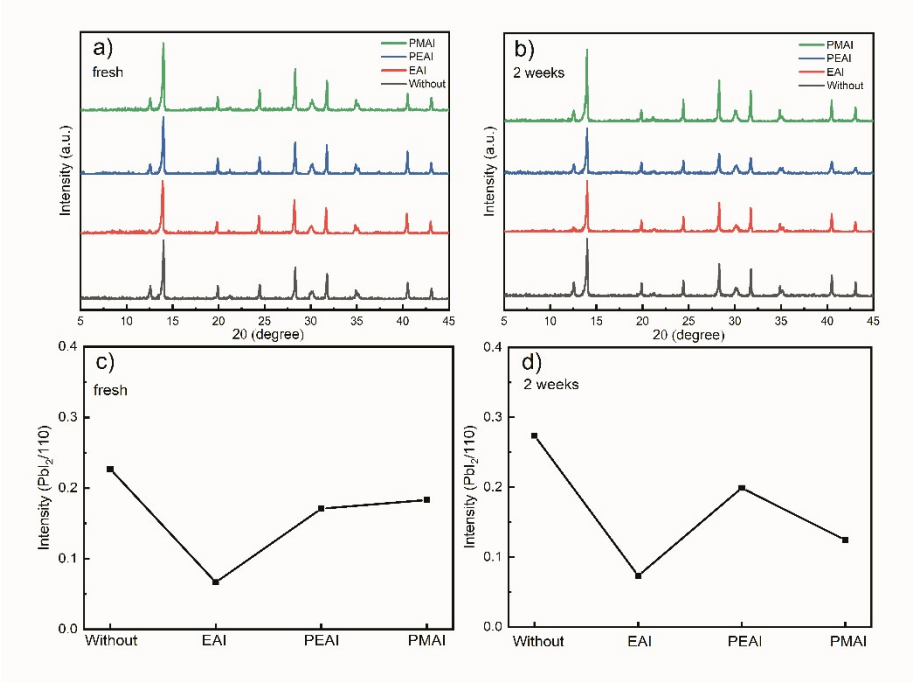


**Fig. S1** X-ray diffraction (XRD) pattens of perovskite films modified with different 2D capping layers，which were placed in the drying tower at room temperature for (a) 0 day and (b) 2 weeks. Dependence of XRD intensity ratio of $PbI_2$ and (110) peaks for (c) 0 day and (d) 2 weeks.

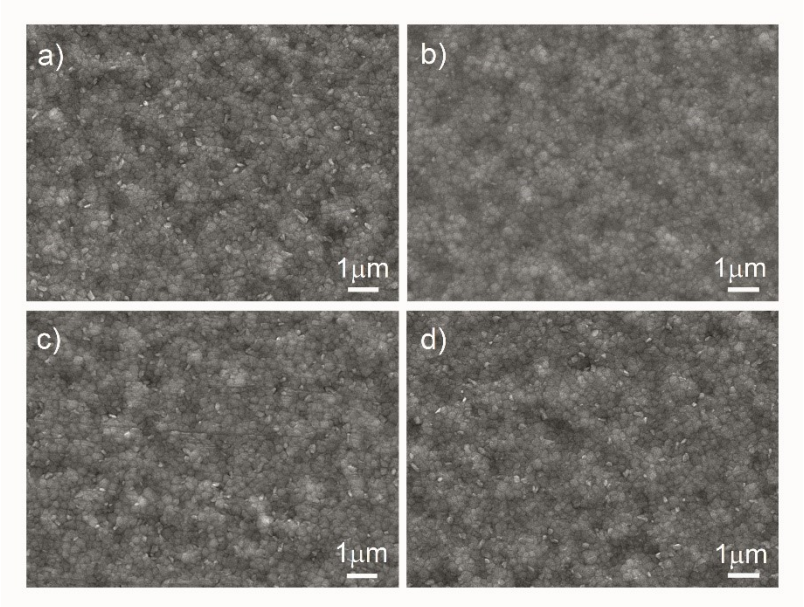


**Fig. S2** SEM images of 2D/3D perovskite films: (a) without, (b) EAI, (c) PEAI and (d) PMAI. The scale bar is 1 μm.

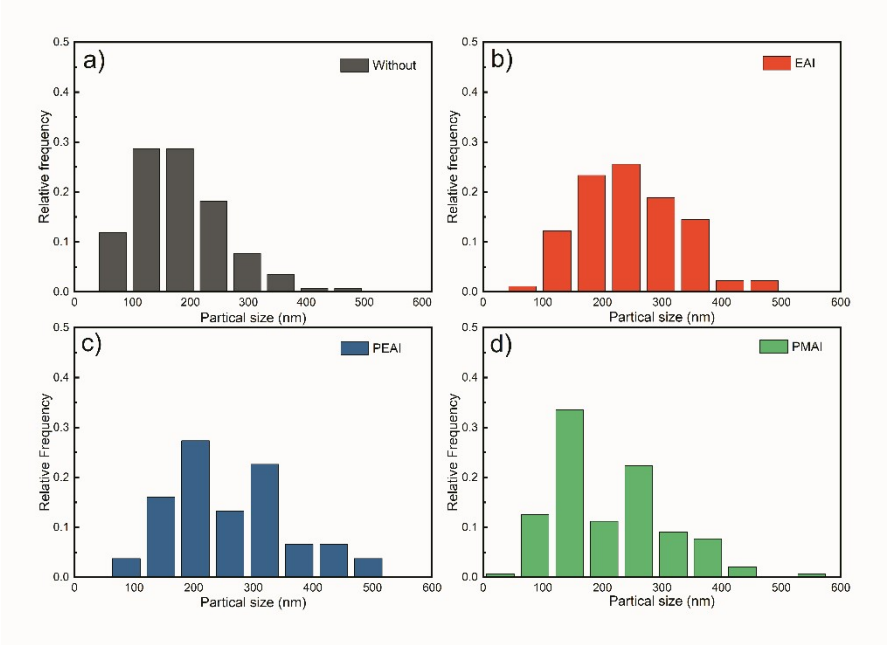


**Fig. S3** Frequency distribution histogram of particle size corresponding to SEM image.

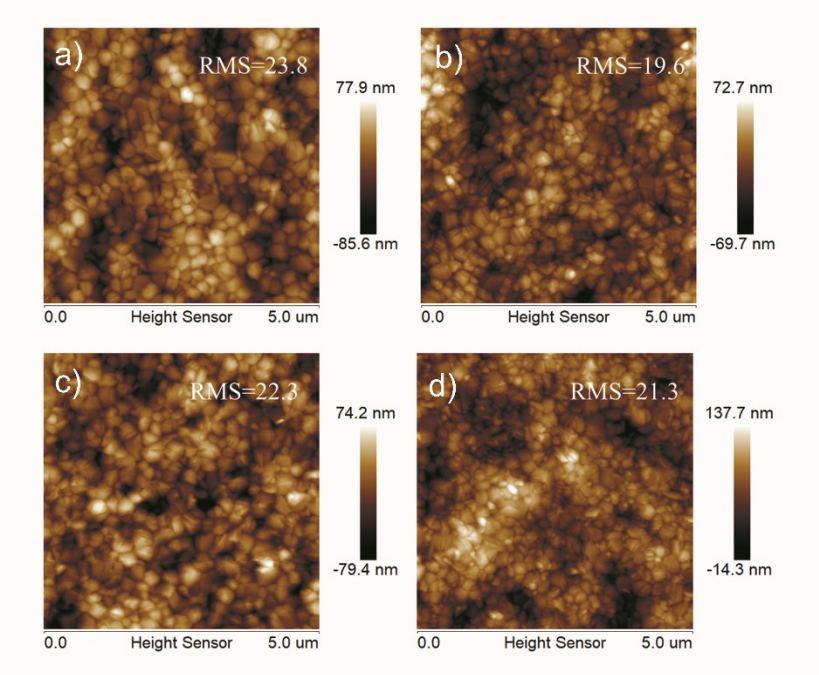


**Fig. S4** AFM images of 2D/3D perovskite films: (a) without, (b) EAI, (c) PEAI and (d) PMAI.

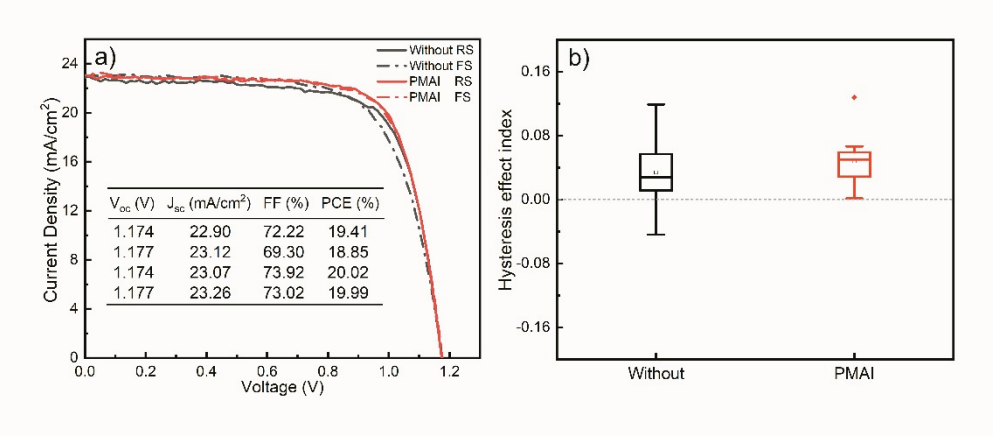


**Fig. S5** a) *J-V* curves of the champion PSCs without and with PMAI based 2D capping layer measured at reverse and forward scans. b) Hysteresis effect index of corresponding to the statistical photovoltaic device in Fig. 8.

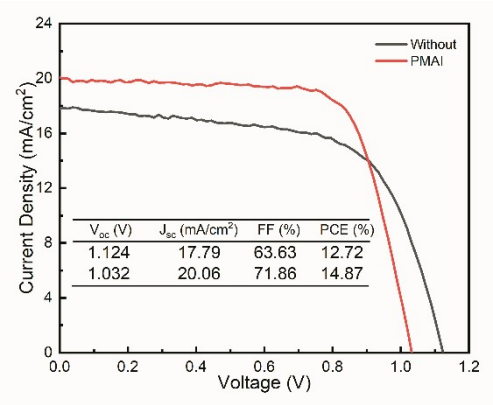


**Fig. S6** *J-V* curves of the PSCs without and with PMAI based capping layer after 186 days (4464 h). The devices stored in a drying tower at room temperature.

**Table S1** TRPL parameters fitted by a bi-exponential decay function[a]

| | $\tau_1$ (ns) | $A_1$ | $\tau_2$ (ns) | $A_2$ | $\tau_{ave}$ (ns)[b] |
|---|---|---|---|---|---|
| Without | 8.56 | 768.75 | 229.91 | 932.74 | 223.32 |
| EAI | 20.90 | 903.03 | 196.90 | 311.75 | 155.51 |
| PEAI | 52.11 | 1020.20 | 241.10 | 445.41 | 178.52 |
| PMAI | 63.65 | 961.23 | 358.72 | 606.29 | 293.94 |

[a] $Fitting\ fuction = A_1 e^{(-t/\tau_1)} + A_2 e^{(-t/\tau_2)}$

$$\tau_{ave} = \frac{\sum A_i \tau_i^2}{\sum A_i \tau_i}$$

[b]