Supporting information for

Moisture tolerant solar cells by encapsulating 3D perovskite with long-chain alkylammonium cation-based 2D perovskite

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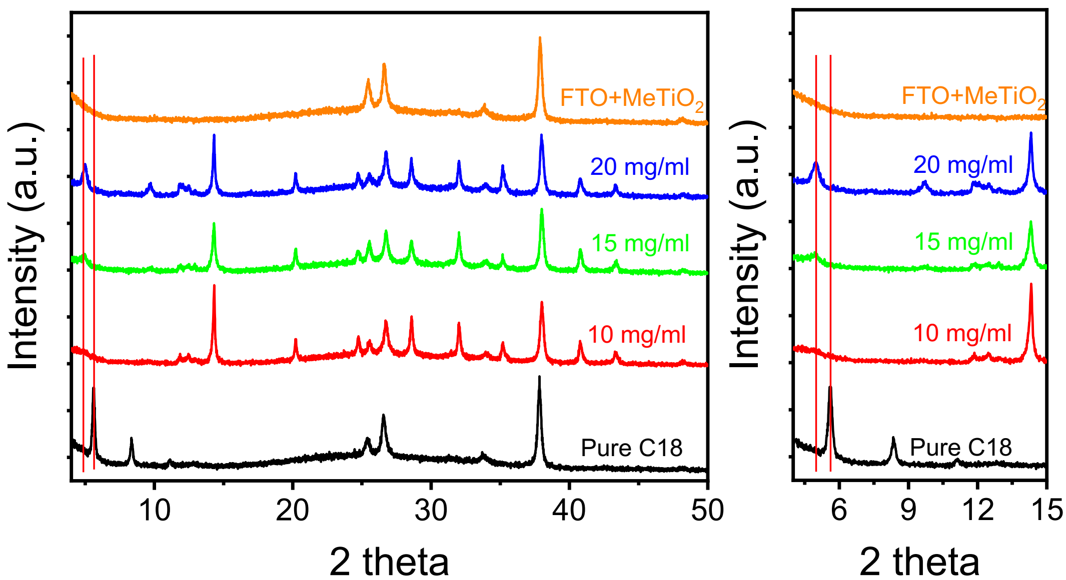
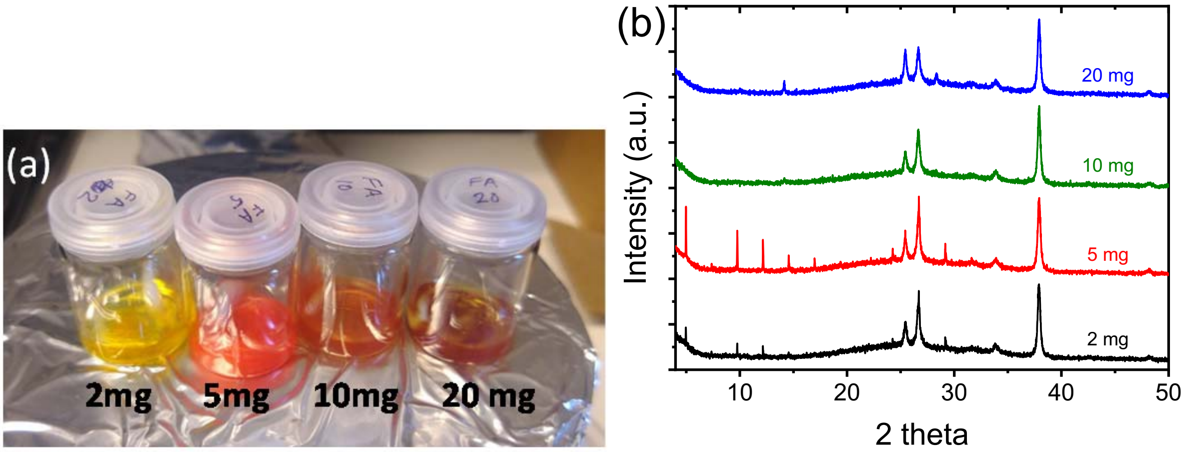
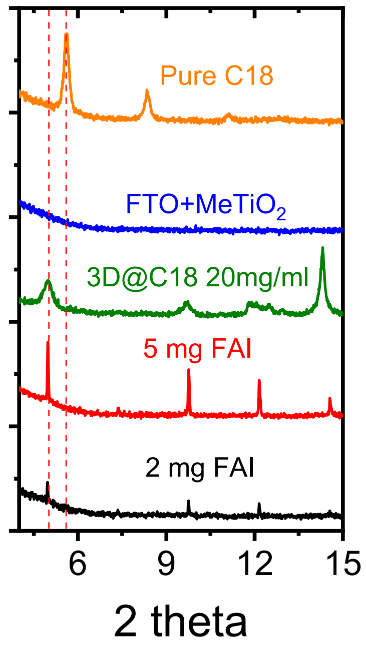


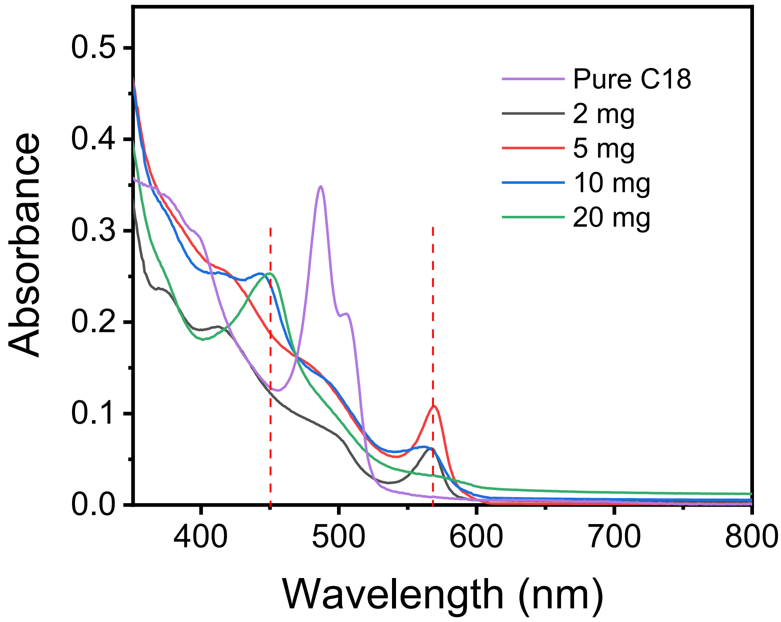
Supplementary Figure 1. XRD patterns of 3D perovskite thin films coated with different concentrations of C18 in THF. The magnified view of the XRD pattern shows an emergence of a new diffraction peak (approx. 4.988 2theta) at a higher concentration of C18 in THF which is shifted to lower 2 theta angles by 0.64 compared to the main diffraction peak of pure 2D perovskite. For pure 2D perovskite thin-film the solution of 2D perovskite in THF was spin-coated on $MeTiO_2$ layer whereas for concentration variation the 2D perovskite solution was spin-coated on the top of the 3D perovskite layer.



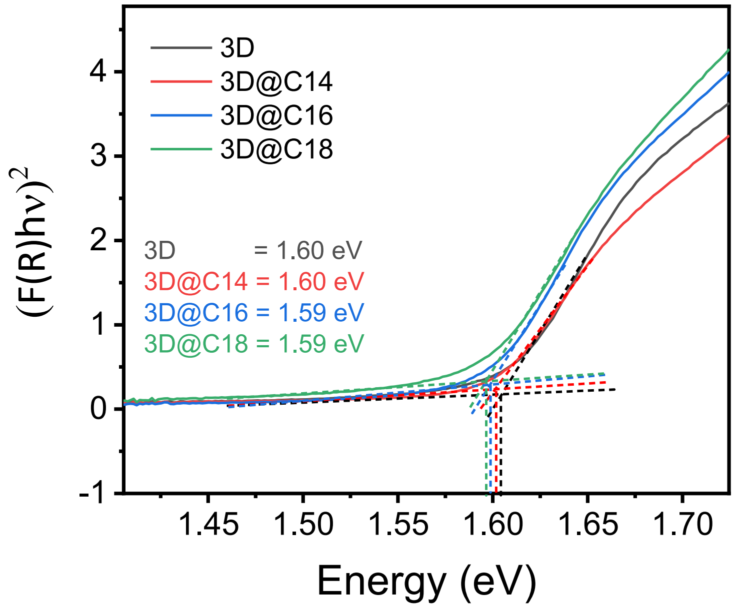
Supplementary Figure 2. Solutions of different concentrations (2 mg, 5 mg, 10 mg and 20 mg FAI in 20 mg C18 in 2 mL THF) of FAI mixed C18 2D perovskite. XRD patterns of FA Substituted C18 2D perovskites spin-coated on FTO+$MeTiO_2$ substrate.



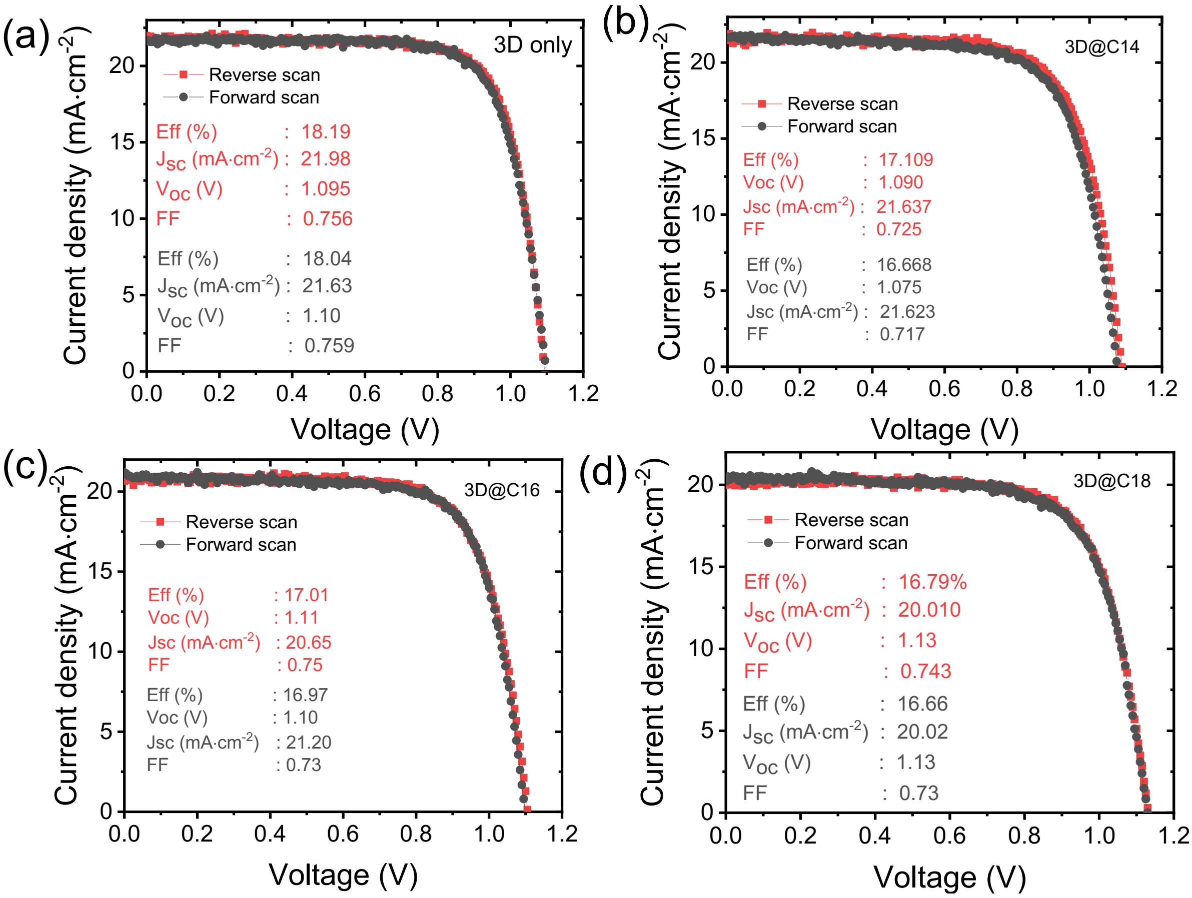
Supplementary Figure 3. Magnified view of the XRD patterns showing the diffraction patterns of FA substituted C18 2D perovskite matches well with that of the diffraction peaks of 3D@C18 thin film.



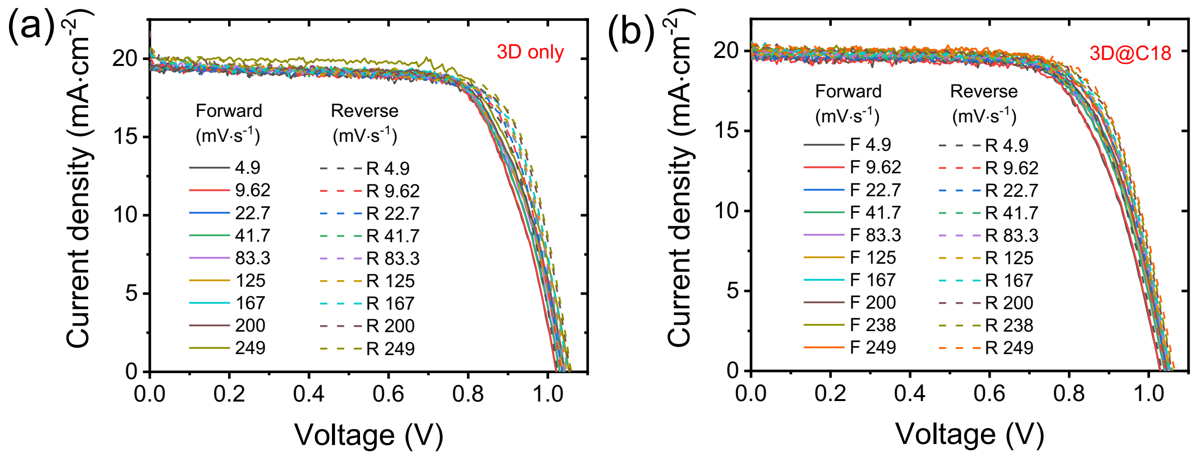
Supplementary Figure 4. Absorption spectra of different concentrations of FA substituted C18 2D perovskite. The two peaks in the absorption spectra of pure C18 2D perovskite are due to the coexistence of two crystallographic phases. When the 2D perovskite thin film is annealed above the phases transition temperatures, then even after cooling to room temperature the presence of high temperature phase can be observed. The peak at lower wavelengths corresponds to the high temperature phase whereas the hump at higher wavelength is associated with the room temperature phase. The similar behaviour can be observed in C14 and C16 based 2D perovskites.



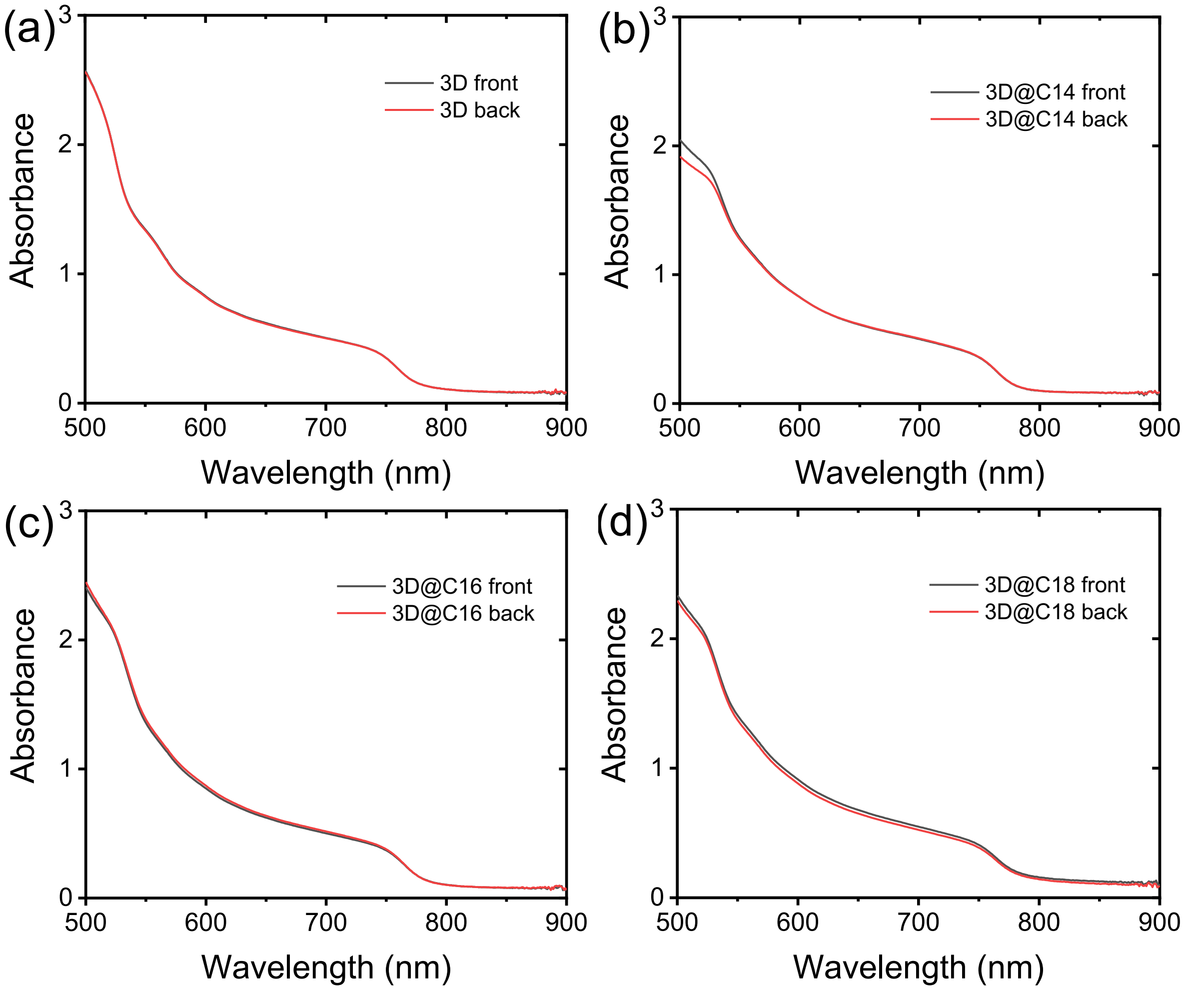
Supplementary Figure 5. Tauc plots of 3D only and 2D perovskite coated thin films.



Supplementary Figure 6. J-V curves of 3D only and 2D perovskite coated solar cell devices scanned in both forward and reverse directions.



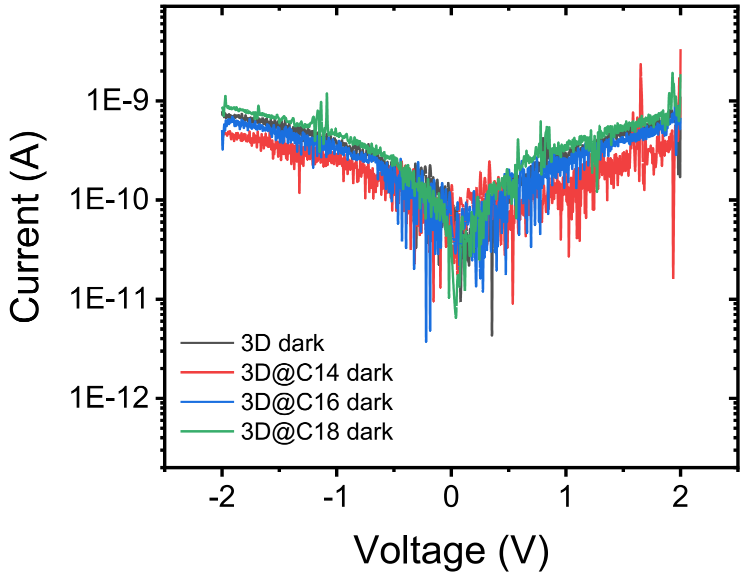
Supplementary Figure 7. J-V curves of 3D only and C18 perovskite coated devices measured at different scan speeds in both forward and reverse directions.



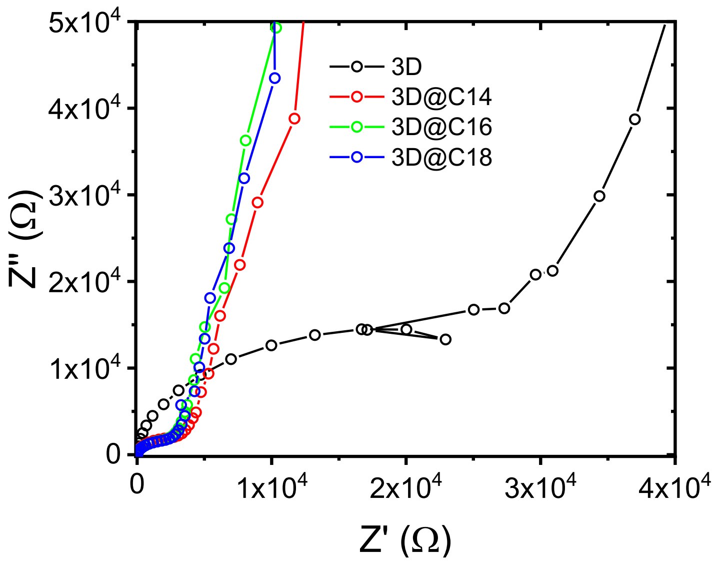
Supplementary Figure 8. Absorption spectra of 3D only and 2D perovskite coated perovskite thin films measured from the perovskite side (front) and from the glass side (back).

Supplementary Table 1. The decay parameters obtained from fitting the time-resolved PL decay curves of 3D only and 2D perovskite coated thin films with bi-exponential decay function.

Samples	τ_1 (ns)	τ_2 (ns)	A_1 (Relative %)	A_2 (Relative %)
3D only	18	92	129 (93%)	2 (7%)
3D@C14	36	134	120 (87%)	5 (13%)
3D@C16	36	144	121 (86%)	5 (14%)
3D@C18	32	121	132 (85%)	6 (15%)



Supplementary Figure 9. Dark current-voltage curves of 3D only and 2D perovskite coated PSC devices measured at room temperature. The IV plots are smoothened in origin to have a better clarity.



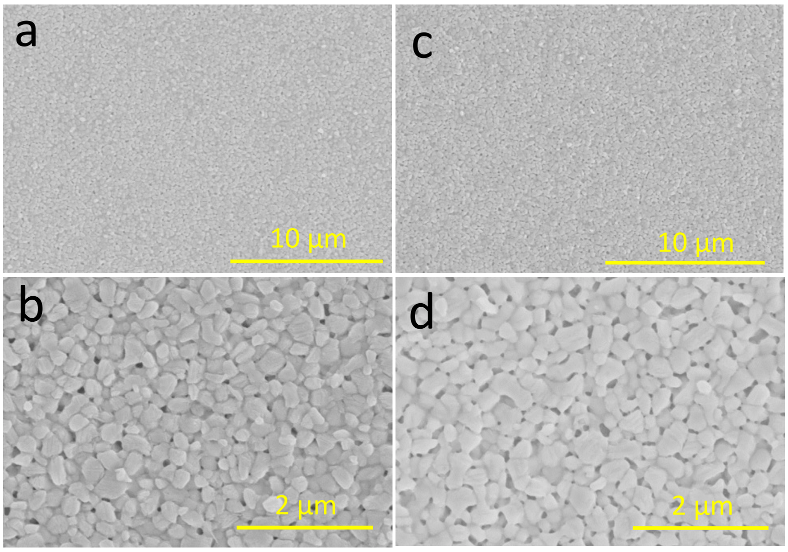
Supplementary Figure 10. Nyquist plots of 3D only and 2D perovskite coated PSC devices in low resistance region, measured at a bias of 0.8 V under dark conditions

Supplementary Table 2**.** Conductivities of 3D only and 2D perovskite coated thin films obtained by using the equation (1), J-V curves were measured in both dark and under 1 sun illumination.

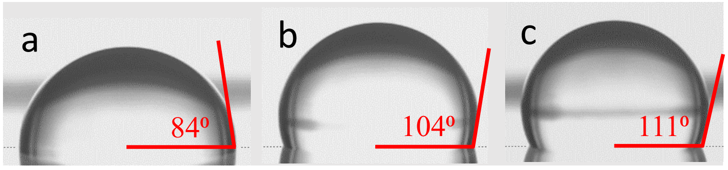
Sample	Measurement condition (Dark/ Light)	Conductivity $S\cdot cm^{-1}$ (Average of 6 devices)
3D only	Dark	1.75×10^{-6}
3D only	Light	1.62×10^{-4}
3D@C14	Dark	1.06×10^{-6}
3D@C14	Light	1.28×10^{-5}
3D@C16	Dark	1.52×10^{-6}
3D@C16	Light	4.38×10^{-6}
3D@C18	Dark	1.98×10^{-6}
3D@C18	Light	4.17×10^{-5}

Supplementary Table 3. The EIS parameters obtained from fitting the EIS spectra of 3D only and 2D perovskite coated PSC devices using CPE model.

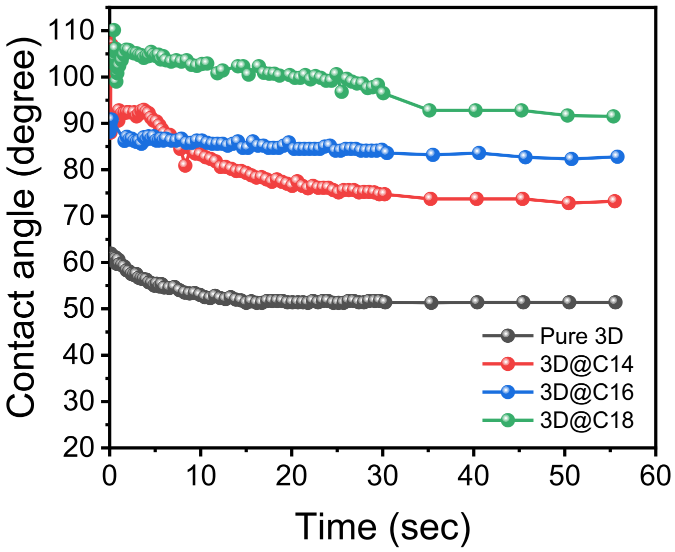
Samples	R_s (Ω)	R_{ct} (Ω)	CPE_{ct} (Mho)	R_{rec} (Ω)	CPE_{rec} (Mho)
3D only	12 (18%)	27696 (14%)	2.17×10^{-8} (32%)	7.53×10^{5} (28%)	1.24×10^{-6} (18%)
3D@C14	10 (17%)	2794 (15%)	2.6×10^{-8} (50%)	2.23×10^{6} (44%)	1.11×10^{-7} (12%)
3D@C16	10.8 (16%)	2242 (15%)	2.75×10^{-8} (51%)	3.80×10^{6} (51%)	8.47×10^{-7} (11%)
3D@C18	10.8 (16%)	2242 (15%)	2.72×10^{-8} (51%)	4.65×10^{6} (71%)	9.99×10^{-7} (11%)



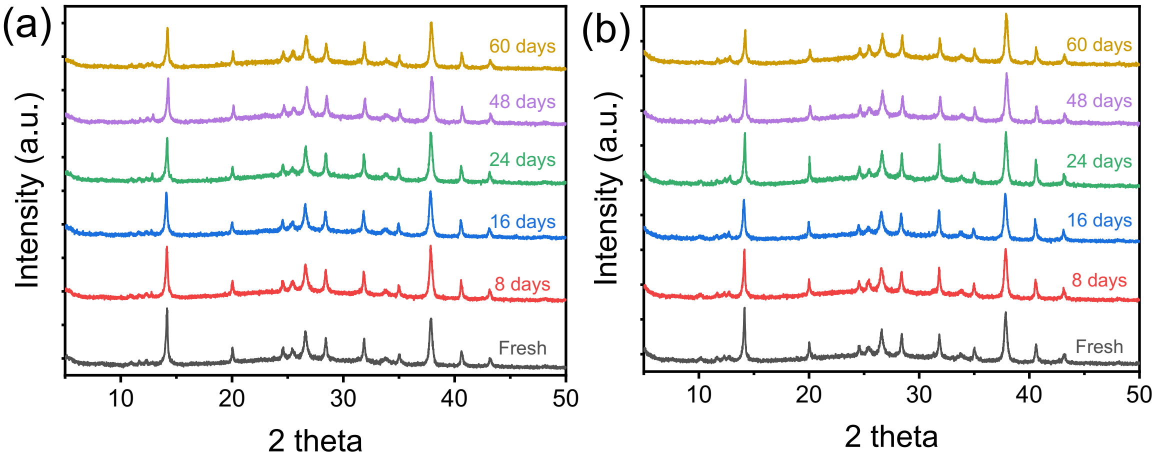
Supplementary Figure 11. Top view SEM of the surface of (a,b) C14 coated 3D and (c,d) C16 coated FAMA 3D perovskite thin films.



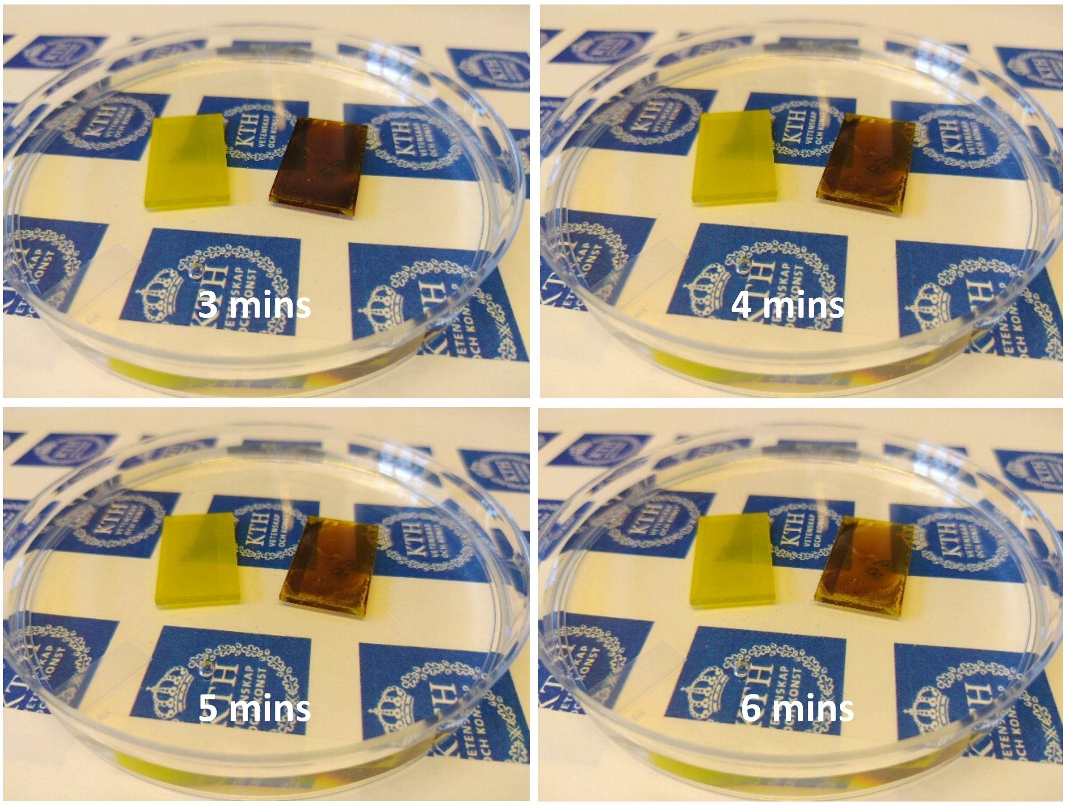
Supplementary Figure 12. Contact angle measured on the surface of pure 2D (a) C14, (b) C16, and (c) C18 perovskite thin films.



Supplementary Figure 13. Dynamic contact angle measurements on the surface of pure 3D and C14, C16, C18 2D perovskite coated 3D perovskite thin films.



Supplementary Figure 14. (a) XRD patterns of the (a) 3D@C14 only and (b) 3D@C16 thin films illustrating how 2D perovskite helps in preventing the degradation of 3D perovskite when monitored over a period of 2 months and stored under an ambient atmosphere with a relative humidity of 25-80%.



Supplementary Figure 15. Water stability test on pure 3D and C18 coated 3D perovskite thin films. The photos were taken after immersing both the films in water.