Supplementary information

The properties, photovoltaic performance and stability of Visible to Near-IR all inorganic perovskite

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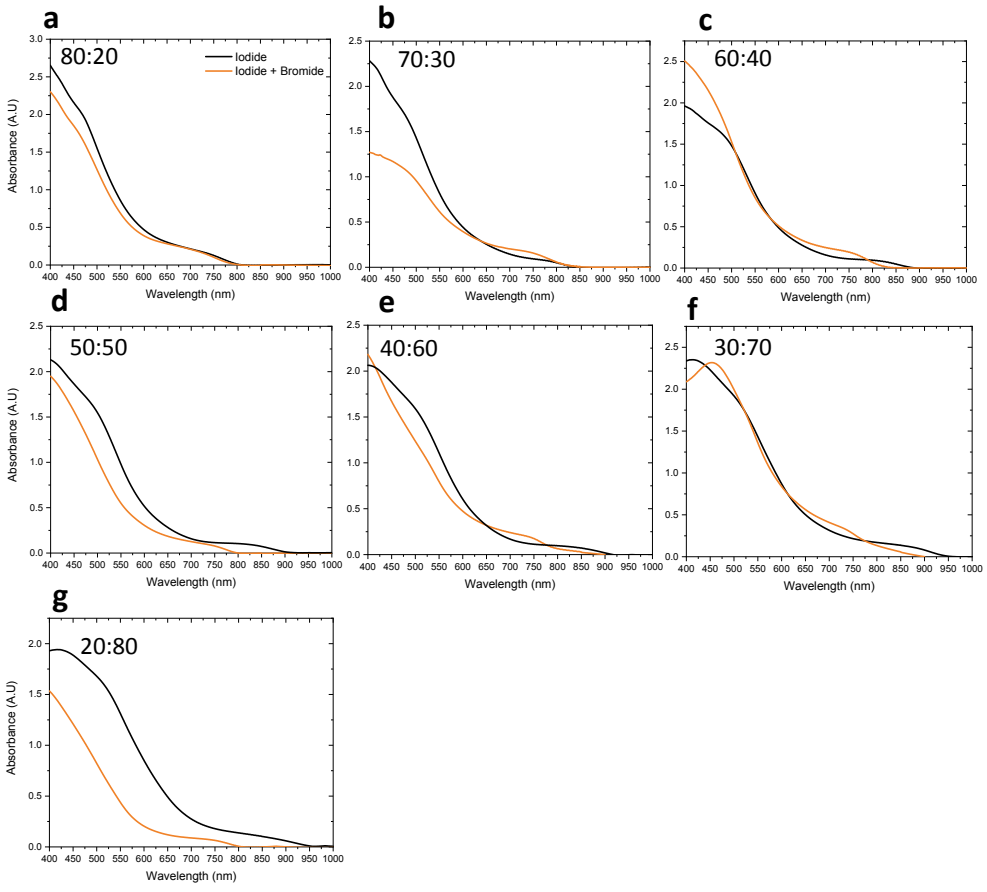

Fig. S1 Comparison of the absorbance spectra between films with only iodide $CsSn_yPb_{1-y}I_3$ ($0<y<1$) and films with mixture of bromide and iodide ($0<y<1$, $0<x<3$). The films are without encapsulation at different ratios of Pb:Sn in room conditions (37% humidity, 18^0C).

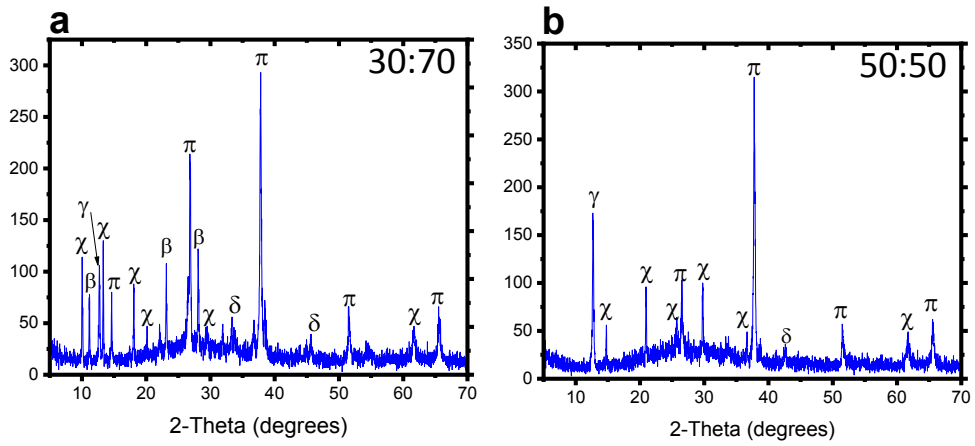

Fig. S2 XRD patterns of different ratio of Pb:Sn after degradation (a) 30:70 $CsSn_{0.7}Pb_{0.3}I_{2.44}Br_{0.56}$ (b) 50:50 $CsSn_{0.5}Pb_{0.5}I_{2.6}Br_{0.4}$.The measurements after degradation were taken after leaving the samples for 48 hours at room environment conditions. (π-$CsPbI_3$ cubic phase, χ-$CsPbI_3$ orthorombic phase, α-$CsSnI_3$, δ-SnO_2, β-SnI_2,γ-PbI_2,τ -CsI).

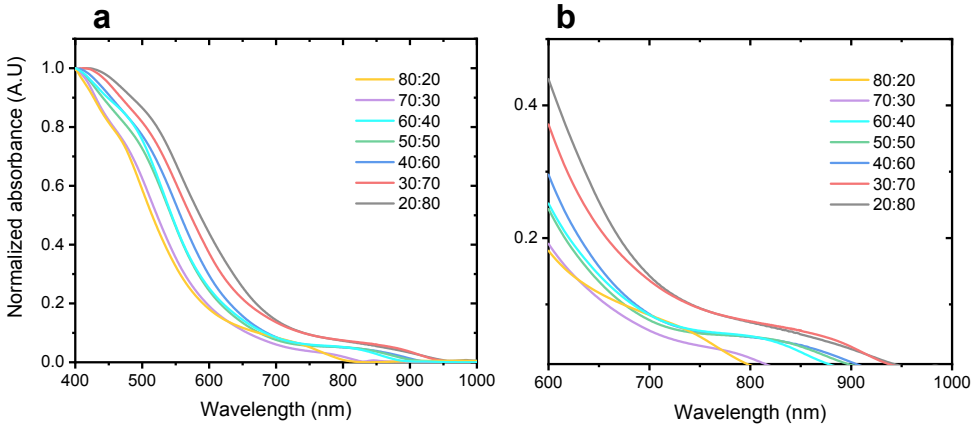

Fig. S3 (a) Absorbance spectra of $CsSn_yPb_{1-y}I_3$ (0<y<1) films encapsulated at different ratio of Pb:Sn. (b) Magnification of the absorbance spectra in the range 600-1000 nm.

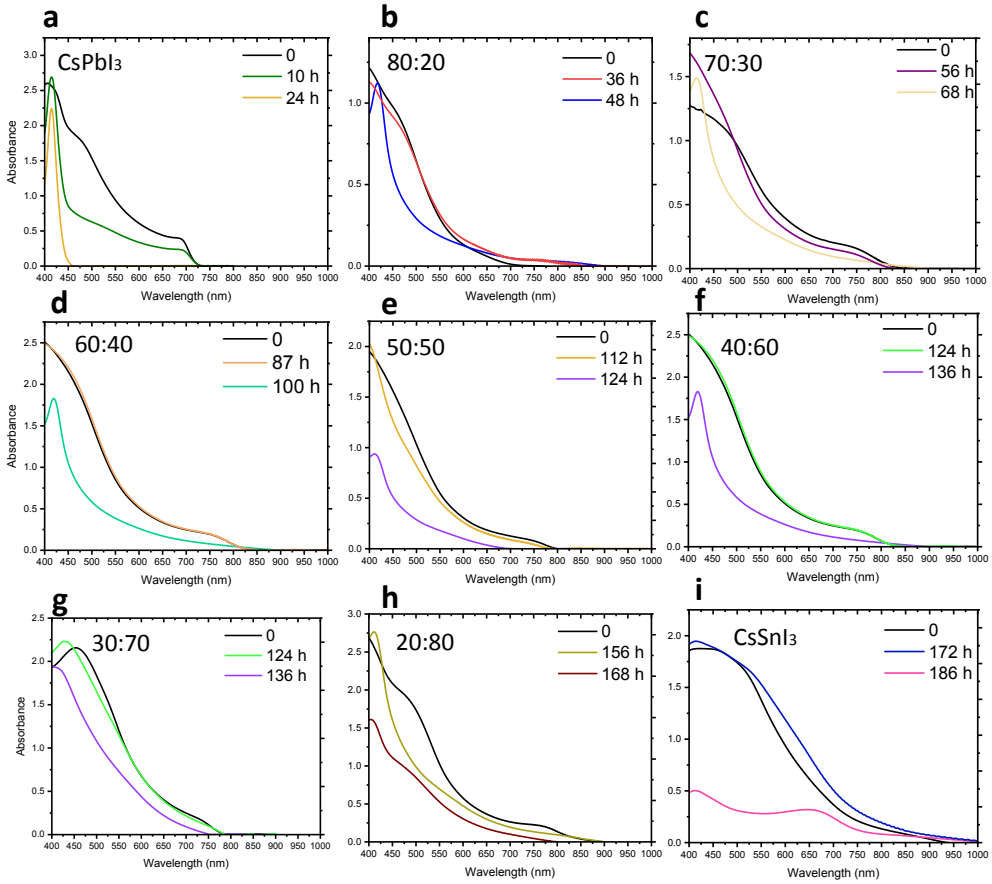

Fig. S4 Absorbance spectra of $CsSn_yPb_{1-y}Br_xI_{3-x}$ (0<y<1, 0<x<3) films encapsulated for different ratio of Pb:Sn under continuous 1 sun illumination, 18 °C and 27% humidity. (a) $CsPbI_3$ (b) 80:20 - $CsSn_{0.2}Pb_{0.8}I_{2.6}Br_{0.4}$ (c) 70:30 - $CsSn_{0.3}Pb_{0.7}I_{2.4}Br_{0.6}$ (d) 60:40 - $CsSn_{0.4}Pb_{0.6}I_{2.2}Br_{0.8}$, (e) 50:50 - $CsSn_{0.5}Pb_{0.5}I_2Br_1$ (f) 40:60 - $CsSn_{0.6}Pb_{0.4}I_{1.8}Br_{1.2}$ (g) 30:70 - $CsSn_{0.7}Pb_{0.3}I_{1.6}Br_{1.4}$ (h) 20:80 - $CsSn_{0.8}Pb_{0.2}I_{1.4}Br_{1.6}$ (i) $CsSnI_3$.

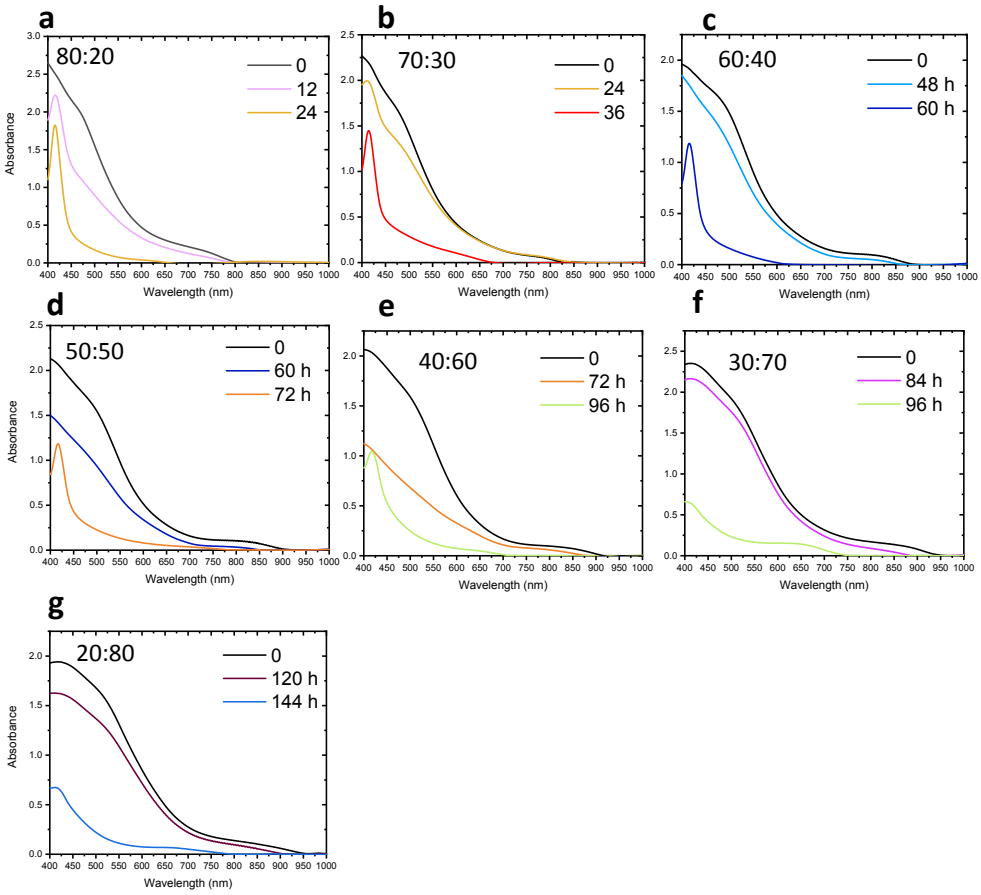

Fig. S5 Absorbance spectra of $CsSn_yPb_{1-y}I_3$ (0<y<1) films encapsulated at different ratio of Pb:Sn under continuous 1 sun illumination, 26 °C and 16% humidity. (a) 80:20 - $CsSn_{0.2}Pb_{0.8}I_3$ (b)70:30 - $CsSn_{0.3}Pb_{0.7}I_3$ (c) 60:40 - $CsSn_{0.4}Pb_{0.6}I_3$, (d) 50:50 - $CsSn_{0.5}Pb_{0.5}I_3$ (e) 40:60 - $CsSn_{0.6}Pb_{0.4}I_3$ (f) 30:70 - $CsSn_{0.7}Pb_{0.3}I_3$ (g) 20:80 - $CsSn_{0.8}Pb_{0.2}I_3$

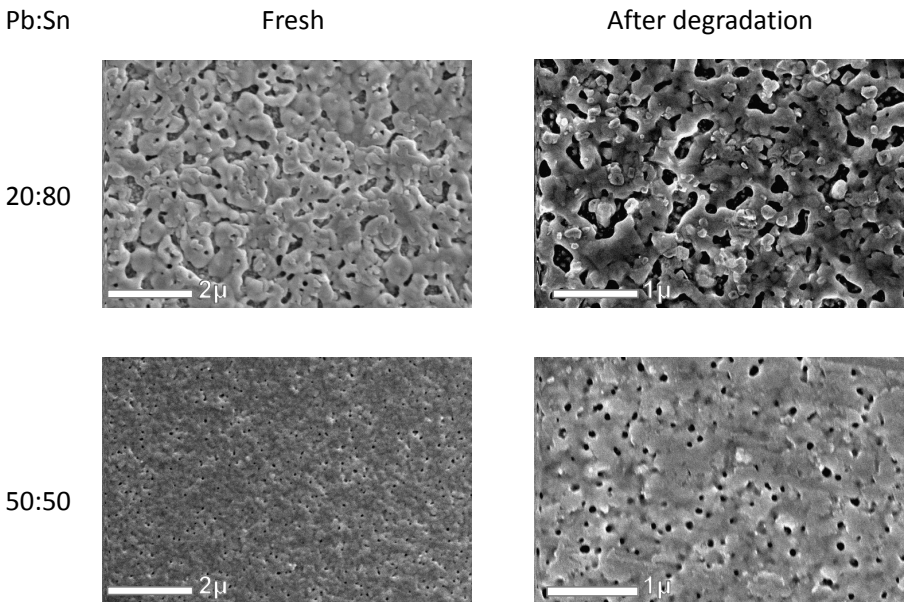

Fig. S6. SEM micrographs of fresh films, and films after degradation (48 h) for 20:80 ($CsSn_{08}Pb_{0.2}I_{1.4}Br_{1.6}$), 50:50 ($CsSn_{0.5}Pb_{0.5}I_2Br_1$) Pb:Sn ratios.

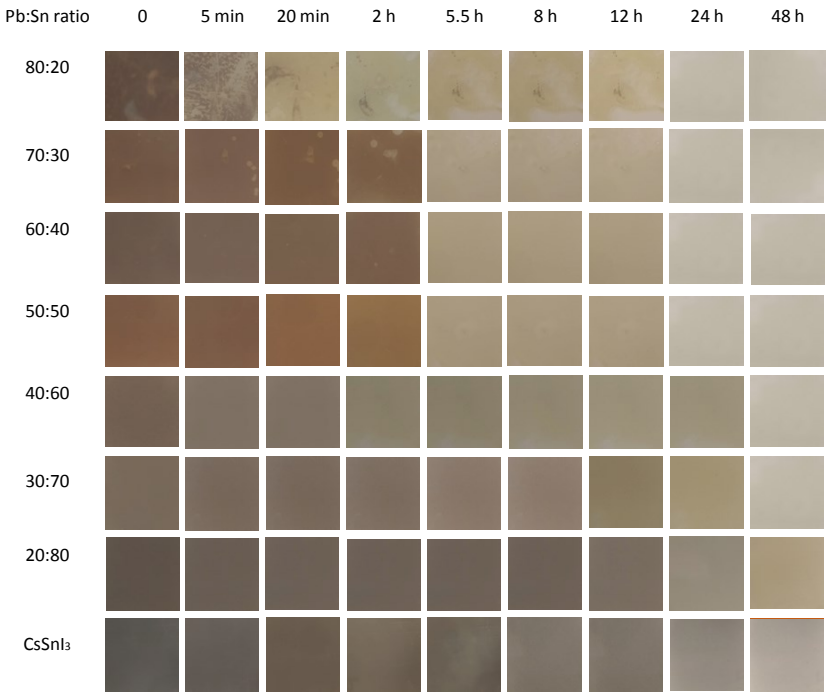

Fig. S7 Photos of $CsSn_yPb_{1-y}Br_xI_{3-x}$ ($0<y<1$, $0<x<3$) films without encapsulation at different ratios of Pb:Sn in room conditions (37% humidity, 18^0C). The change in the color of the film can be observed with time.

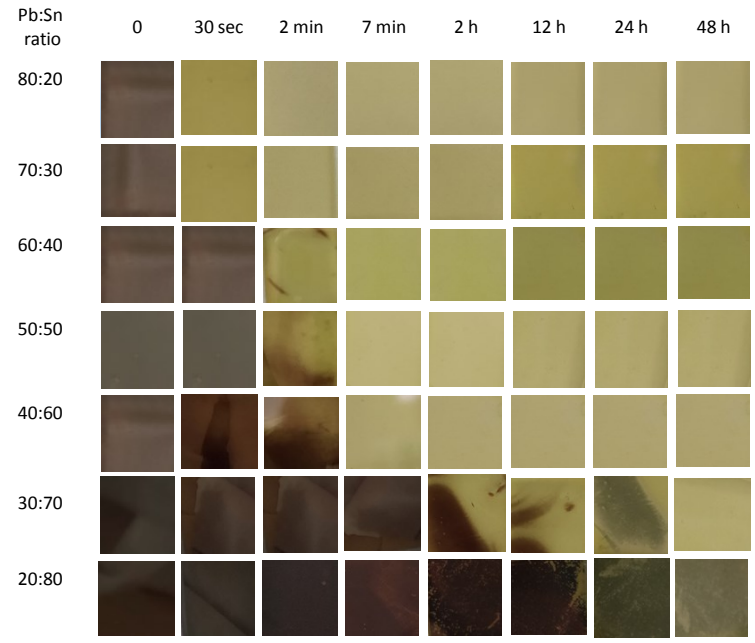

Fig. S8 Photos of $CsSn_yPb_{1-y}I_3$ ($0<y<1$) films without encapsulation at different ratios of Pb:Sn in room conditions (37% humidity, 18^0C). The change in the color of the film can be observed with time

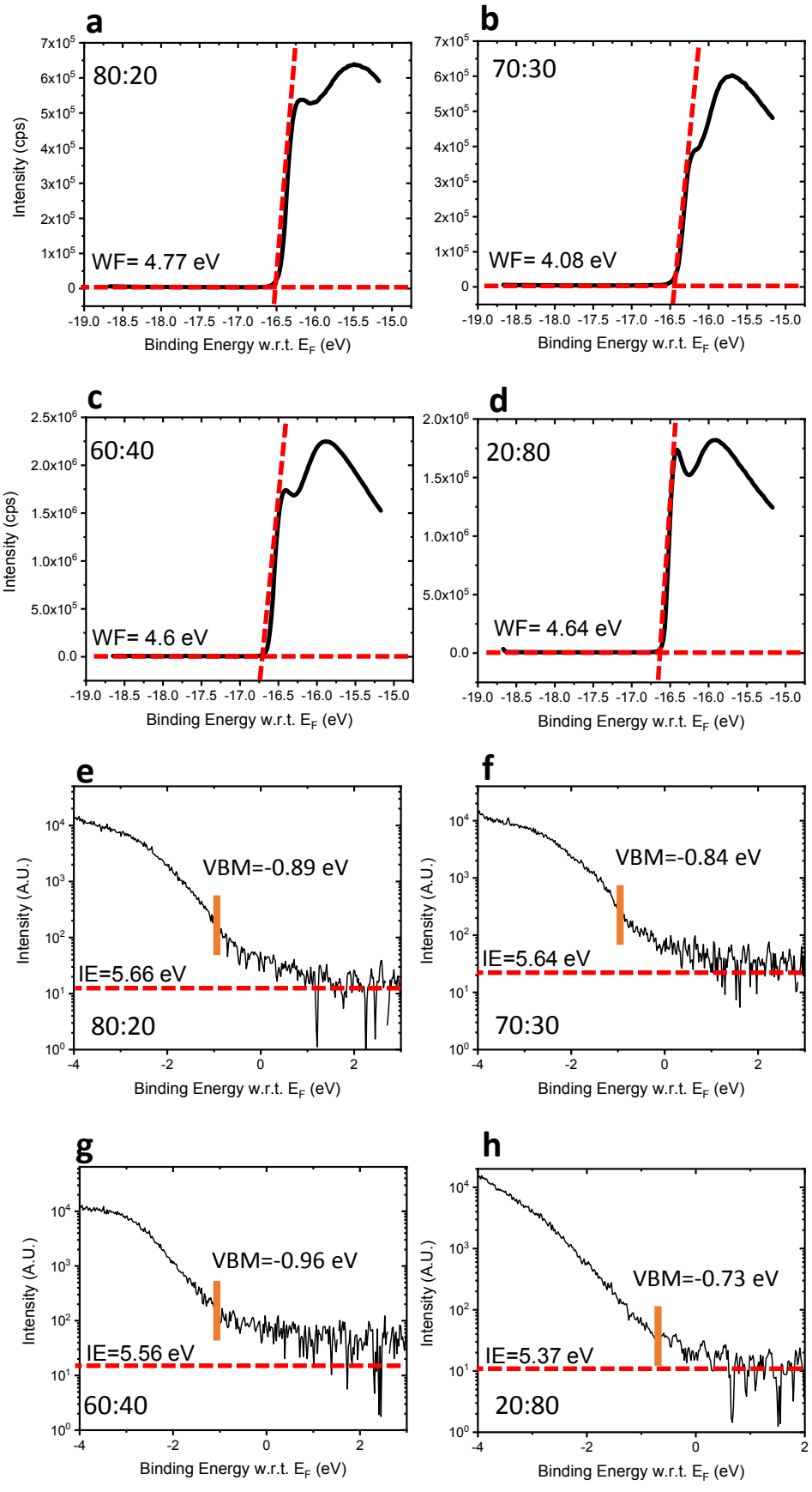
a
80:20
WF= 4.77 eV
Intensity (cps)
Binding Energy w.r.t. E_F (eV)
b
70:30
WF= 4.08 eV
Binding Energy w.r.t. E_F (eV)
c
60:40
WF= 4.6 eV
Intensity (cps)
Binding Energy w.r.t. E_F (eV)
d
20:80
WF= 4.64 eV
Binding Energy w.r.t. E_F (eV)
e
VBM=-0.89 eV
IE=5.66 eV
80:20
Intensity (A.U.)
Binding Energy w.r.t. E_F (eV)
f
VBM=-0.84 eV
IE=5.64 eV
70:30
Intensity (A.U.)
Binding Energy w.r.t. E_F (eV)
g
VBM=-0.96 eV
IE=5.56 eV
60:40
Intensity (A.U.)
Binding Energy w.r.t. E_F (eV)
h
VBM=-0.73 eV
IE=5.37 eV
20:80
Intensity (A.U.)
Binding Energy w.r.t. E_F (eV)

Fig. S9 Ultraviolet photoemission spectroscopy (UPS) measurement of the ratios: 80:20 ($CsSn_{0.2}Pb_{0.8}I_{2.6}Br_{0.4}$), 70:30 ($CsSn_{0.3}Pb_{0.7}I_{2.4}Br_{0.6}$), 60:40 ($CsSn_{0.4}Pb_{0.6}I_{2.2}Br_{0.8}$), 20:80 ($CsSn_{0.8}Pb_{0.2}I_{1.4}Br_{1.6}$).

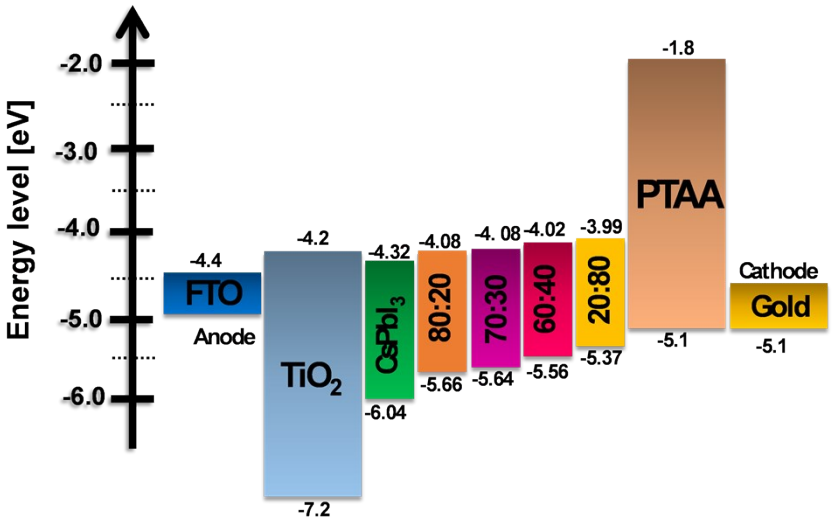

Fig. S10 Energy diagram of complete device (energy level of PTAA was taken from references 1), the perovskite composition is $CsSn_yPb_{1-y}Br_xI_{3-x}$ ($0<y<1$, $0<x<3$)

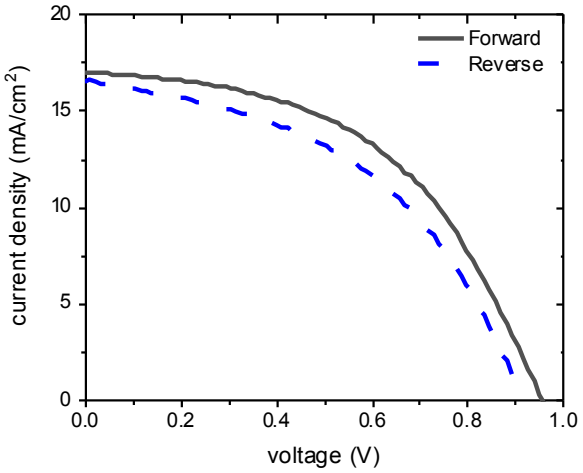

Fig. S11: Hysteresis curves (forward and reverse scan) of $CsSn_yPb_{1-y}Br_xI_{3-x}$ with 80:20 Pb:Sn ratio.

Table S1: The Delta in the PV parameters of the cells before and after illumination.

Pb:Sn ratio	ΔV_{oc}	ΔJ_{sc}	ΔFF	ΔPCE
80:20	0.170	6.95	22.51	5.48
70:30	0.100	4.91	15.66	2.48

60:40	0.087	0.33	8.86	1.77

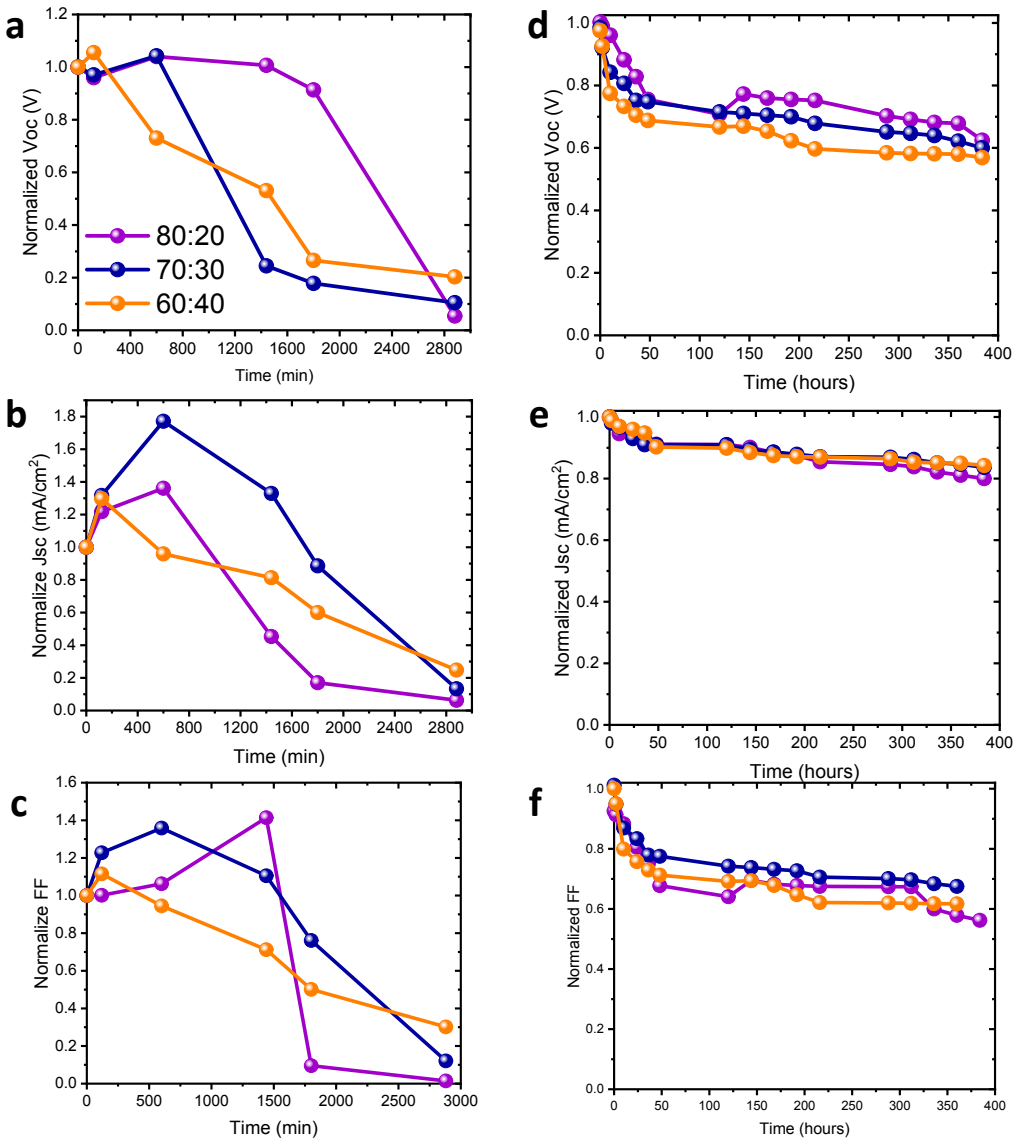

Fig: S12: Stability of full devices. (A),(B),(C) under continuous 1 illumination. (D),(E),(F) shelf life stability , the cells were stored in the glove box between measurements.

1 S. Ryu, J. Seo, S. S. Shin, Y. C. Kim, N. J. Jeon, J. H. Noh and S. Il Seok, *J. Mater. Chem. A*, 2015, **3**, 3271–3275.