Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supporting Information

Understanding the stability origins of ambient stable $CsPbI_2Br$ inorganic halide perovskites

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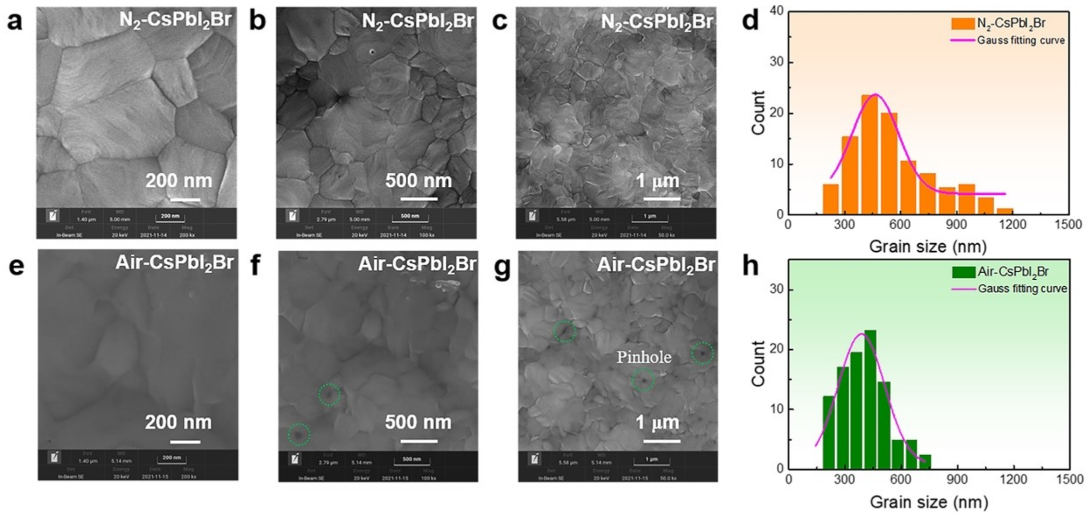

Figure S1. Surface SEM images and particle size statistics. The top SEM morphology images and particle size statistics of $CsPbI_2Br$ films prepared in (**a-d**) N_2 and (**e-h**) air.

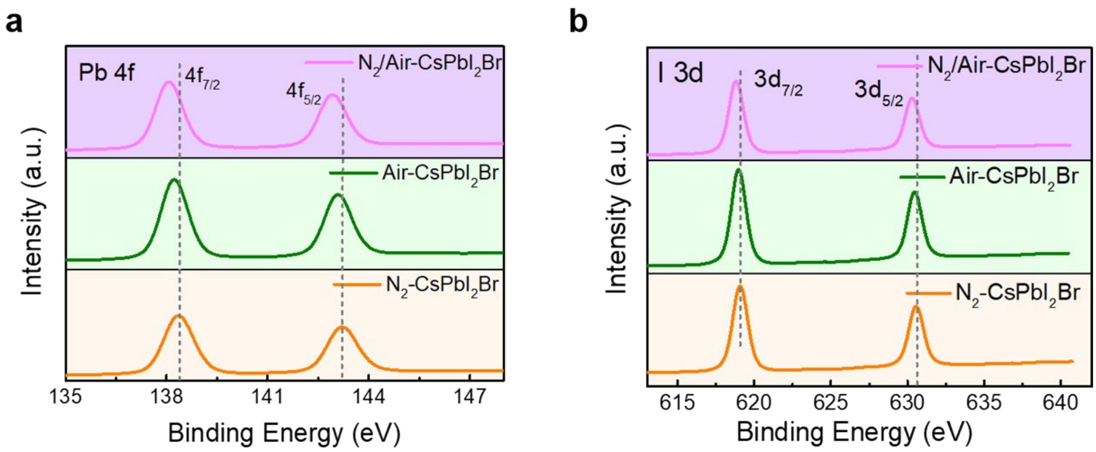

Figure S2. The XPS spectra of Pb 4f and I 3d of $CsPbI_2Br$ films in different atmospheres. The XPS signal of (**a**) Pb 4f and (**b**) the core-level I 3d spectra of $CsPbI_2Br$ precursor film in different atmospheres (N_2, Air and N_2/Air).

Table S1. The binding energy by the XPS signal of Pb 4f, I 3d and O 1s of $CsPbI_2Br$ film prepared in N_2 and Air

Atmospheres	Pb (eV)		I (eV)		O 1s (eV)
	4 $f_{7/2}$	4 $f_{5/2}$	3 $d_{7/2}$	3 $d_{5/2}$	
N_2-$CsPbI_2Br$	138.3	143.2	619.1	630.5	531.3
Air-$CsPbI_2Br$	138.2	143.1	619.0	630.4	529.8, 531.1
N_2/air-$CsPbI_2Br$	138.1	142.9	618.8	630.3	531.5

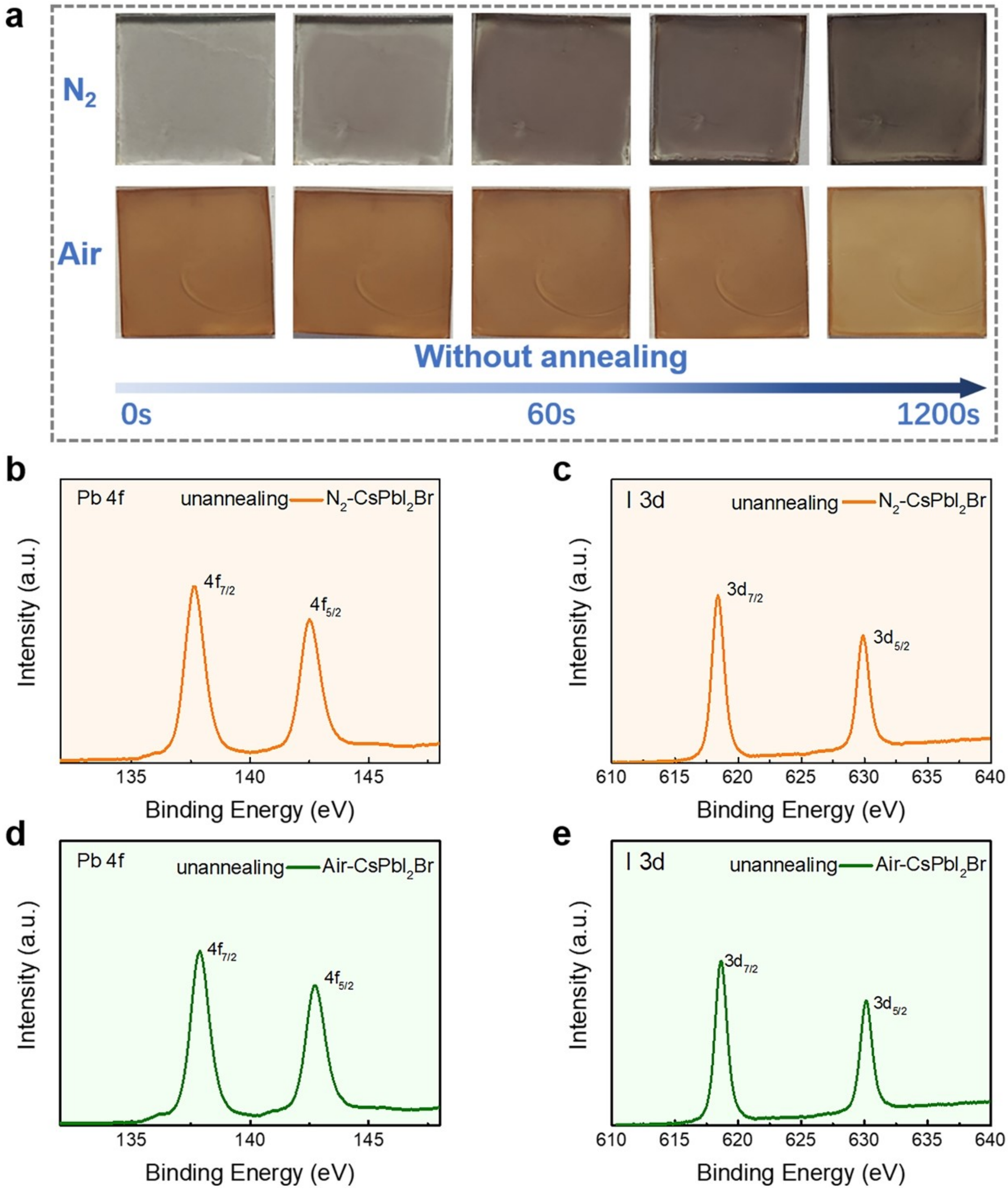

Figure S3. Photographs changes and XPS spectra of Pb 4f and I 3d of $CsPbI_2Br$ precursor film before the anneal in different atmospheres. a, Photographs changes. **b-e,** the binding energy by the XPS signal of Pb 4f and I 3d of $CsPbI_2Br$ precursor film before the anneal in different atmospheres (N_2 and air)

Table S2. The binding energy by the XPS signal of Pb 4f, I 3d and O 1s of $CsPbI_2Br$ precursor film before the anneal in N_2 and Air

Atmospheres	Pb (eV)		I (eV)		O 1s (eV)	
	4 $f_{7/2}$	4 $f_{5/2}$	3 $d_{7/2}$	3 $d_{5/2}$		
N_2-$CsPbI_2Br$	137.8	142.7	618.6	630.1	529.8	531.5
Air-$CsPbI_2Br$	137.9	142.7	618.7	630.1	529.8	531.5

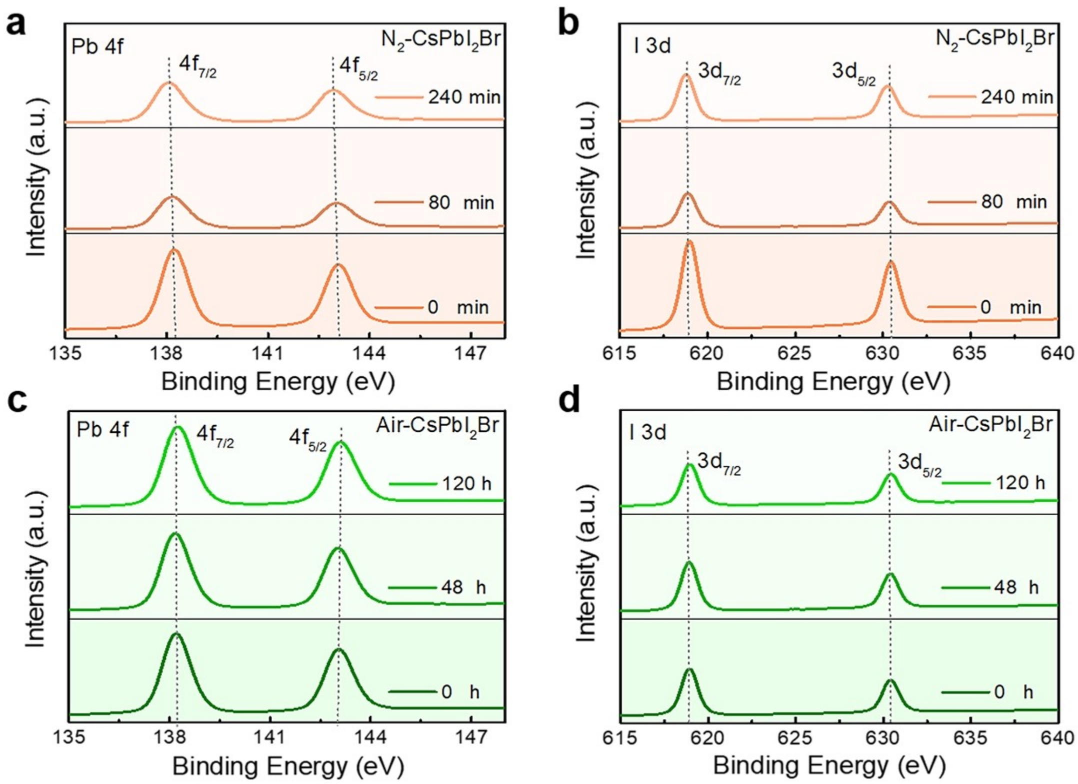

Figure S4. XPS spectra of Pb 4f and I 3d for $CsPbI_2Br$ films prepared in different atmospheres. a,b, Pb 4f and I 3d core level for $CsPbI_2Br$ films prepared in N_2 after ageing in ambient conditions. **c,d**, Pb 4f and I 3d core level for $CsPbI_2Br$ films prepared in air after ageing in ambient conditions.

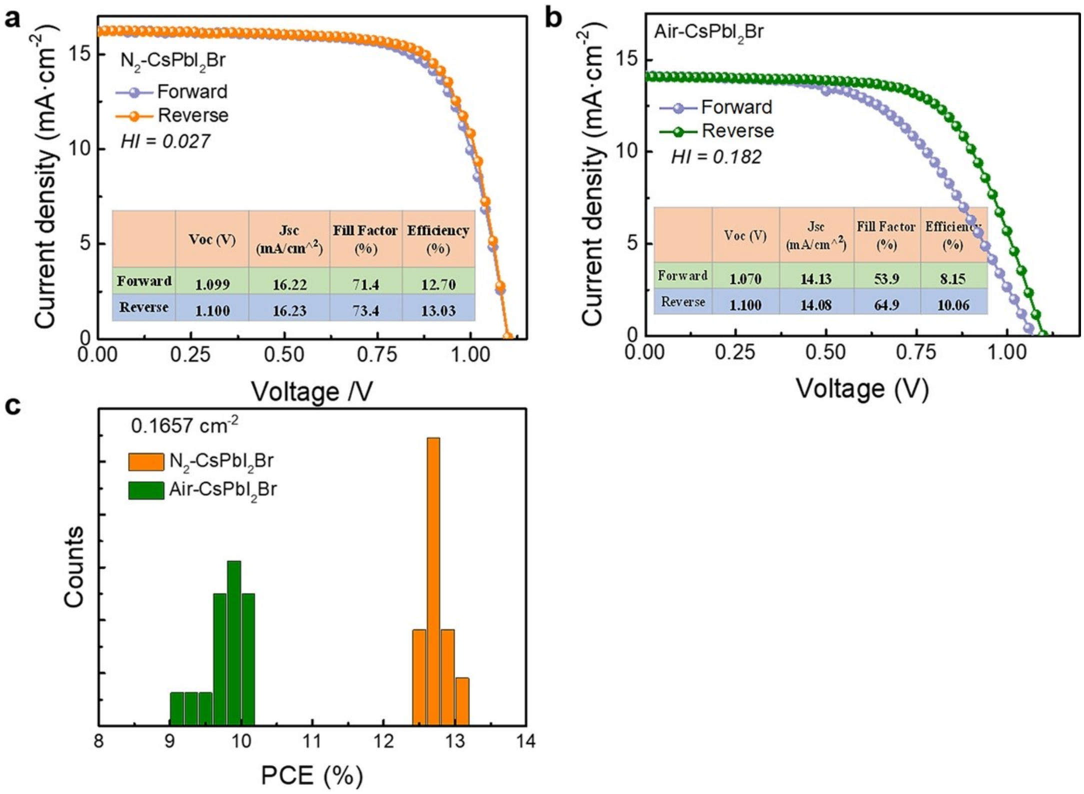

Figure S5. Photovoltaic performance of $CsPbI_2Br$ PSCs prepared in different atmospheres. a,b, *J-V* curves and (**c**) histograms of PCE values for 16 devices of $CsPbI_2Br$ PSCs prepared in different atmospheres (N_2 and air) and only based on the dense TiO_2.

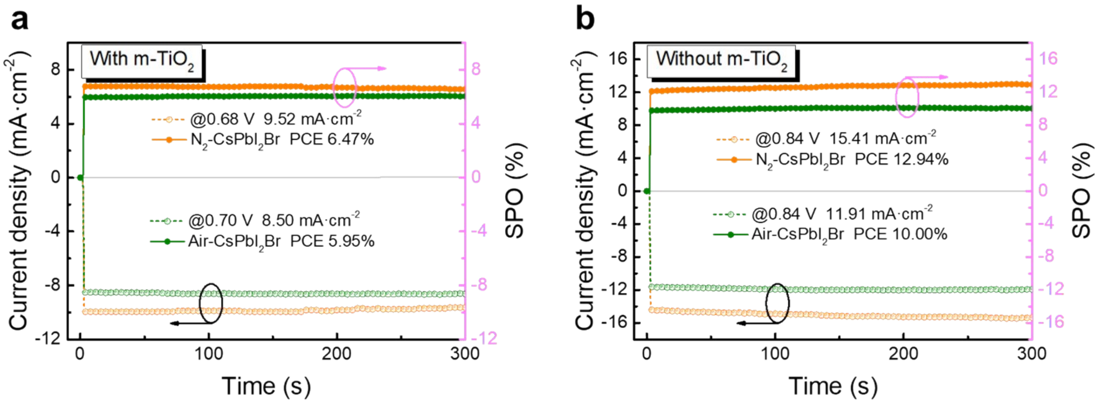

Figure S6. Steady-state output current density under maximum power point of $CsPbI_2Br$ PSCs prepared in different atmospheres (N_2 and air). (a) Based on the dense TiO_2, (b) Based on the dense TiO_2 and mesoporous-TiO_2 (m-TiO_2)

Table S3. The photovoltaic parameters of $CsPbI_2Br$ PSCs prepared in different atmospheres (N_2 and Air) and only based on the dense TiO_2

Preparation atmosphere	*Scan type*	V_{oc} (V)	J_{sc} ($mA \cdot cm^{-2}$)	*FF* (%)	*PCE* (%)	*Hysteresis of PCE (%)*
N_2 (without m-TiO_2)	Forward	1.10	16.22	71	12.67	2.7
	Reverse	1.10	16.23	73	13.03	
Air (without m-TiO_2)	Forward	1.07	14.13	54	8.16	18.2
	Reverse	1.10	14.08	65	10.07	

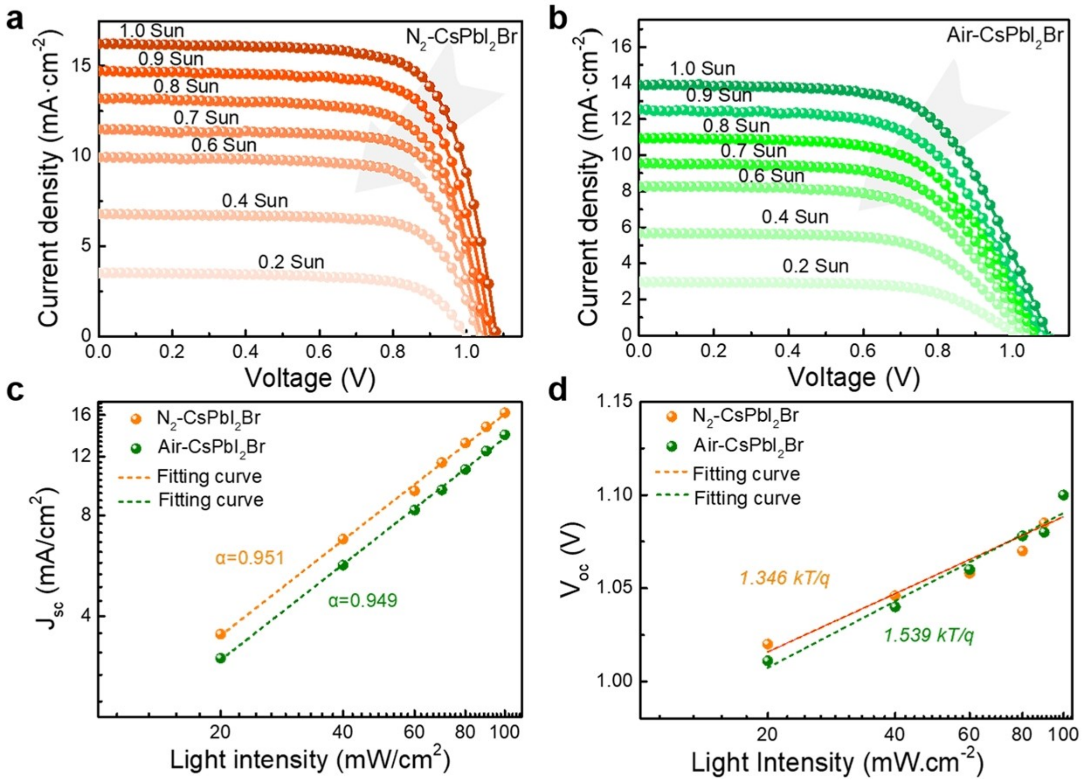

Figure S7. Get an ideal factor using the *J-V* under variable light intensity. a,b, *J-V* curves with variable light intensity, **c**, J_{sc} and **d,** V_{oc} dependency on light intensity of $CsPbI_2Br$ PSCs prepared in different atmospheres (N_2 and air) and only based on the dense TiO_2.

Table S4. The EIS parameters of of $CsPbI_2Br$ PSCs prepared in different atmospheres

Preparation atmosphere	R_s (Ω)	R_{trans} (Ω)	C_{trans} (F)
N_2	60.01	54.62	1.3×10^{-6}
Air	59.99	71.71	1.9×10^{-7}

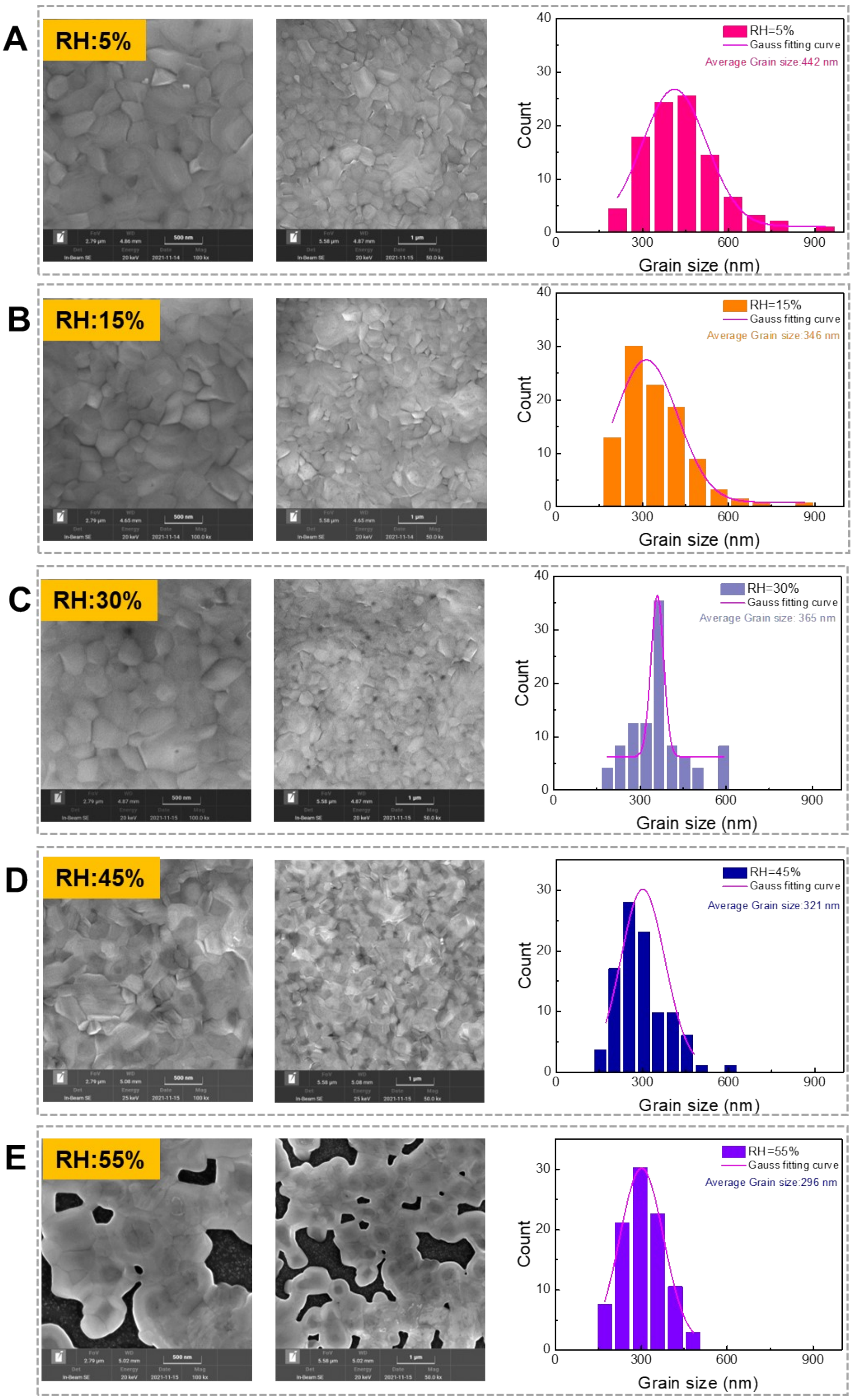

Figure S8. The top and cross-sectional SEM morphology images and particle size statistics of $CsPbI_2Br$ films prepared in ambient humidity (RH=5%/15%/30%/45%/55%)

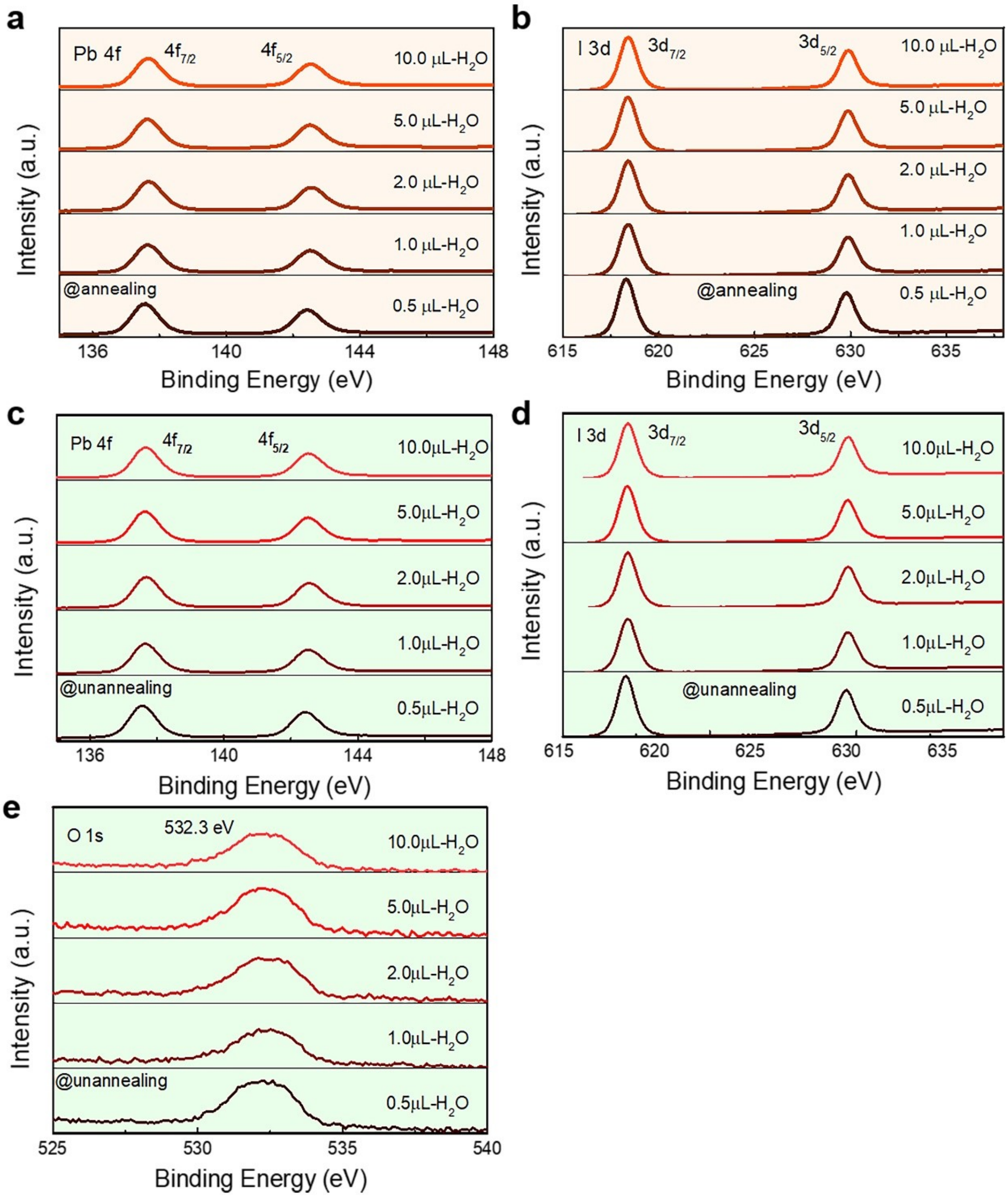

Figure S9. a,b, XPS spectra of Pb 4f and I 3d for annealing $CsPbI_2Br$ films prepared in N_2 with water as additives. **c-e**, XPS spectra of Pb 4f, I 3d and O 1s for unannealing $CsPbI_2Br$ films prepared in N_2 with water as additives (The volume ratio of water to perovskite precursor solution is 1:400, 1:200,1:100, 1:40 and 1:20).

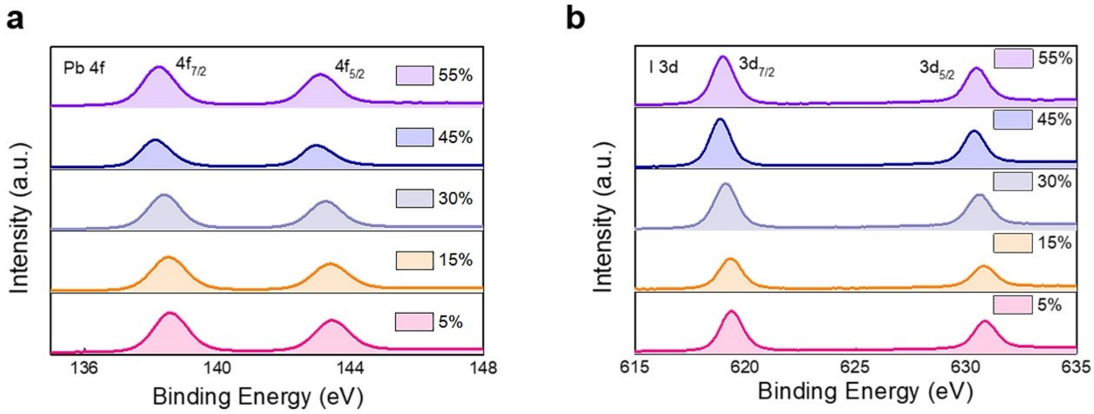

Figure S10. XPS spectra of (**a**) Pb 4f and (**b**) I 3d for $CsPbI_2Br$ films prepared at different humidity (5%~55%).

Table S5. EIS and photoelectric parameters of $CsPbI_2Br$ inorganic PSCs with mesoporous TiO_2 under different ambient humidity.

RH /%	R_{trans} (Ω)	V_{oc} (V)	J_{sc} ($mA \cdot cm^{-2}$)	FF (%)	PCE (%)
5	57.99	0.95	12.72	58	7.01
15	62.48	0.97	10.51	60	6.12
30	71.71	0.94	9.20	59	5.10
45	143.3	1.02	8.72	55	4.89
55	516.6	0.92	8.07	60	4.45

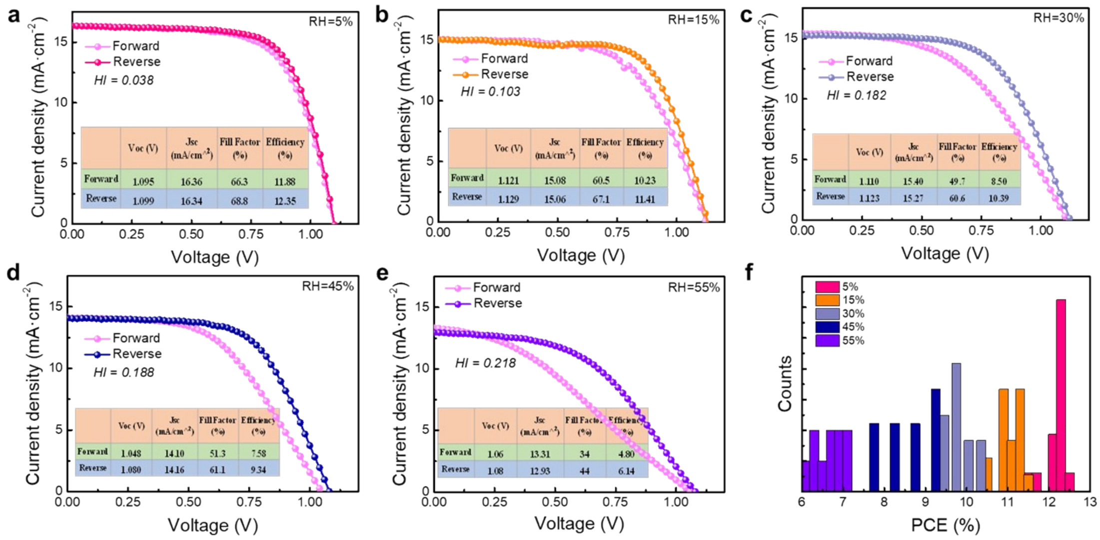

Figure S11. a-e, *J-V* curves and **f**, histograms of PCE values of $CsPbI_2Br$ PSCs prepared under different ambient humidity without mesoporous TiO_2.

Table S6. The photoelectric parameters of $CsPbI_2Br$ inorganic PSCs prepared under different ambient humidity and only based on the dense TiO_2

RH /%	*Scan type*	V_{oc} (V)	J_{sc} (mA·cm^{-2})	*FF* (%)	*PCE* (%)	*Hysteresis of PCE (%)*
5	Forward	1.10	16.36	66	11.93	3.6
	Reverse	1.10	16.34	69	12.40	
15	Forward	1.12	15.08	61	10.30	10.3
	Reverse	1.13	15.06	67	11.40	
30	Forward	1.11	15.40	50	8.55	18.2
	Reverse	1.12	15.27	61	10.43	
45	Forward	1.05	14.10	51	7.55	18.8
	Reverse	1.08	14.16	61	9.33	
55	Forward	1.06	13.31	34	4.80	21.8
	Reverse	1.08	12.93	44	6.14	

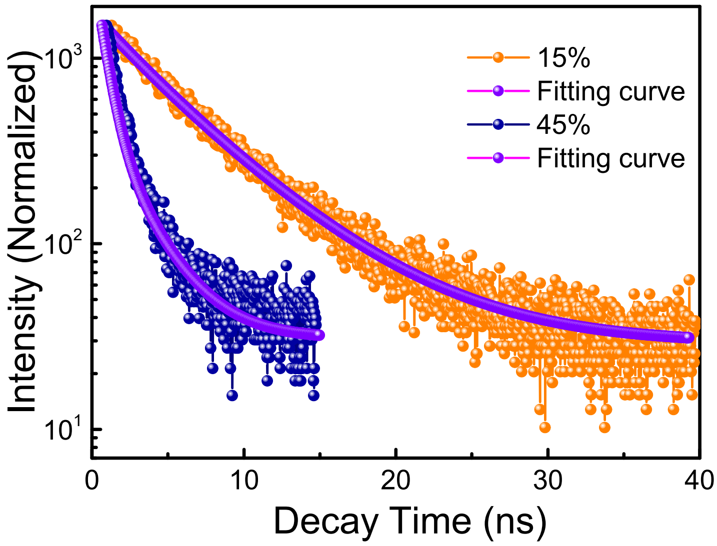

Figure S12. TRPL of $CsPbI_2Br$ PSCs prepared in ambient with different humidity.

Table S7. The TRPL parameters of $CsPbI_2Br$ films prepared under different ambient humidity

RH (%)	τ_1 (ns)	τ_2 (ns)	A_1 (ns)	A_2 (ns)	B	$\tau_{average}$ (ns)
15	3.31	6.29	225.40	415.90	10.74	5.23
45	0.66	2.51	980.00	157.10	10.00	0.92