

Supplementary Material

Improving Two-Step Prepared $\text{CH}_3\text{NH}_3\text{PbI}_3$ Perovskite Solar Cells by Co-Doping Potassium Halide and Water in PbI_2 Layer

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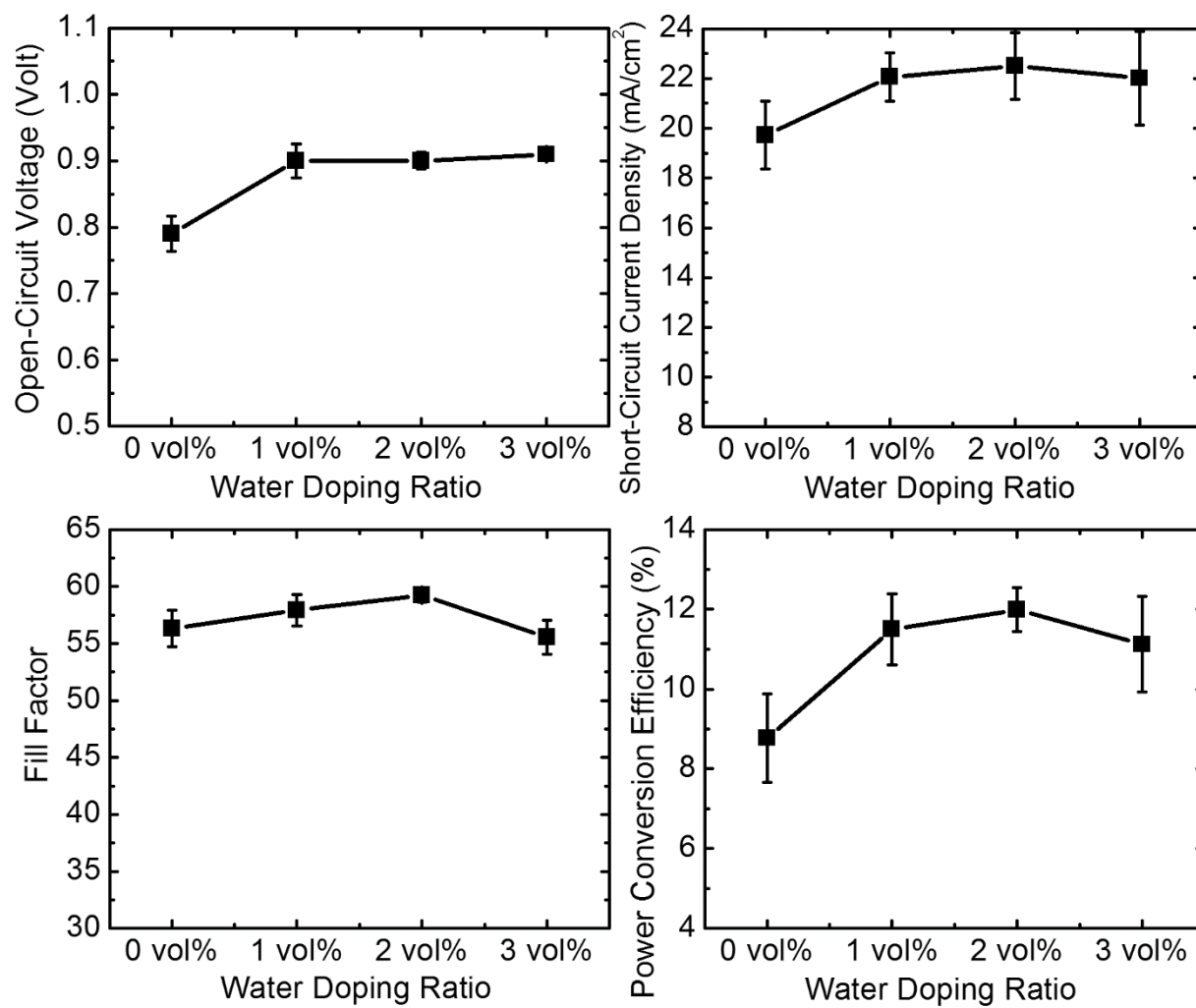


Figure S1. The tendency of photovoltaic performance of the water-doped devices as a function of water amount.

Table S1. The corresponding photovoltaic parameters of devices in Figure S1.

Samples	V _{oc} (Volt)	J _{sc} (mA/cm ²)	FF	PCE (%)	R _{SH} ($\Omega \cdot \text{cm}^2$)	R _s ($\Omega \cdot \text{cm}^2$)
Ref	0.79 ± 0.03	19.7 ± 1.4	56.3 ± 1.6	8.8 ± 1.1	340 ± 99	7.2 ± 0.7
Ref + 1 vol% water	0.90 ± 0.03	22.1 ± 1.0	57.9 ± 1.4	11.5 ± 0.9	206 ± 53	4.6 ± 0.3
Ref + 2 vol% water	0.90 ± 0.01	22.5 ± 1.3	59.2 ± 0.6	12.0 ± 0.6	168 ± 40	3.6 ± 0.1
Ref + 3 vol% water	0.91 ± 0.01	22.0 ± 1.9	55.6 ± 1.5	11.2 ± 1.2	192 ± 55	4.9 ± 0.8

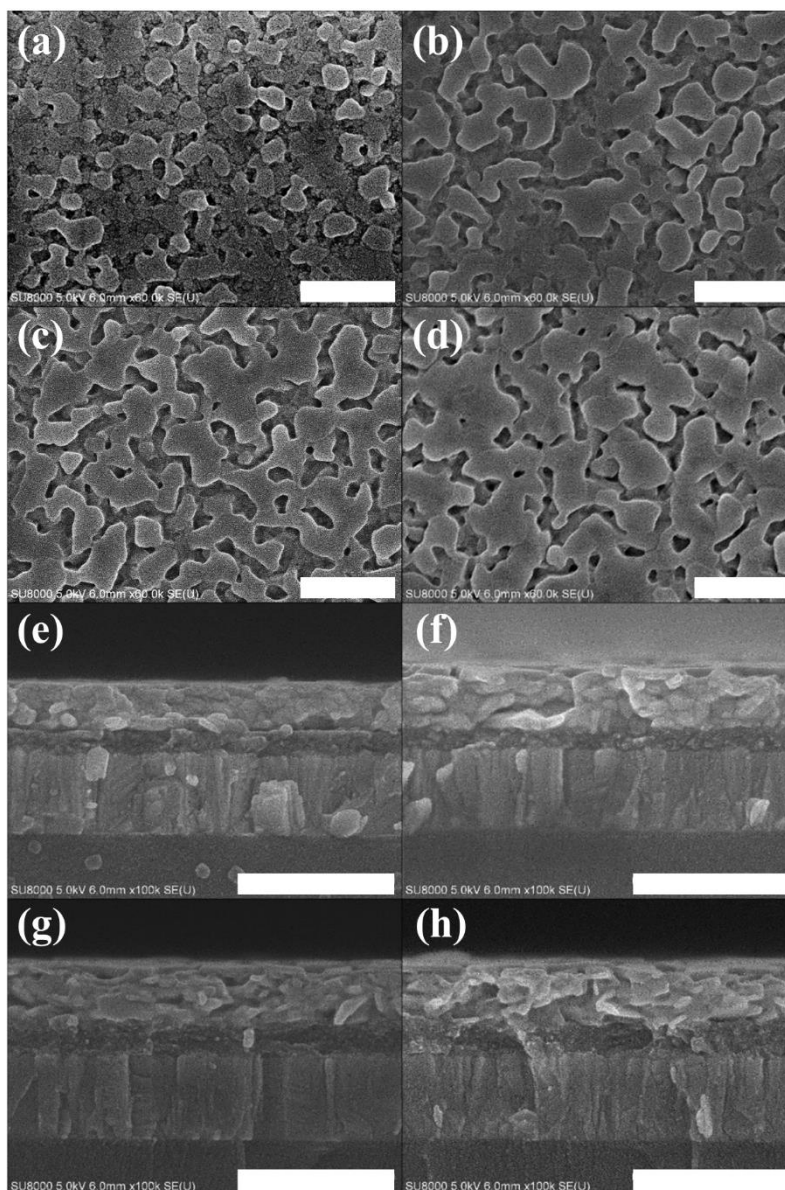


Figure S2. SEM morphology and cross-section of PbI₂ films with (a,e) 0%, (b,f) 1%, (c,g) 2% and (d,h) 3% water (scale bar = 500 nm).

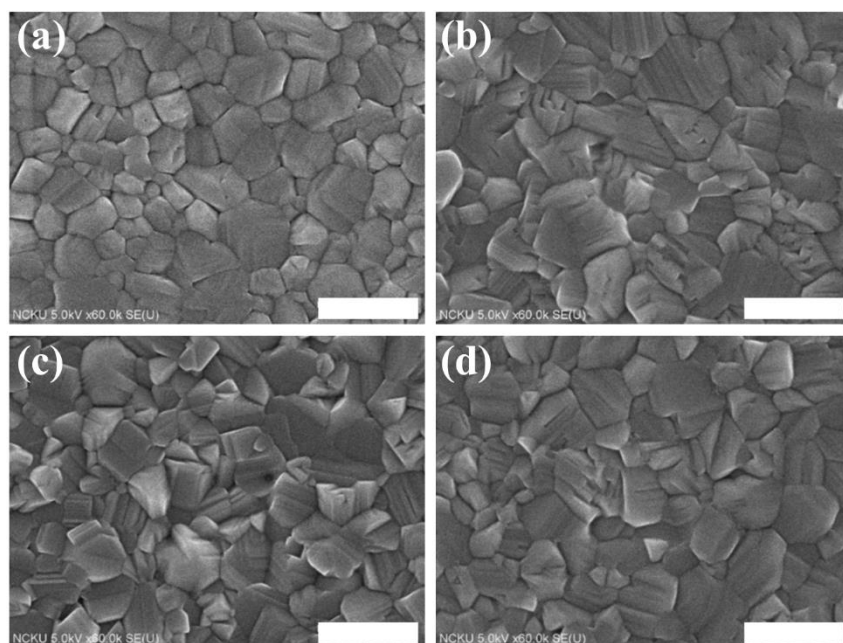


Figure S3. SEM morphology of perovskite films prepared by PbI₂ with (a) 0%, (b) 1%, (c) 2% and (d) 3% water (scale bar = 500 nm).

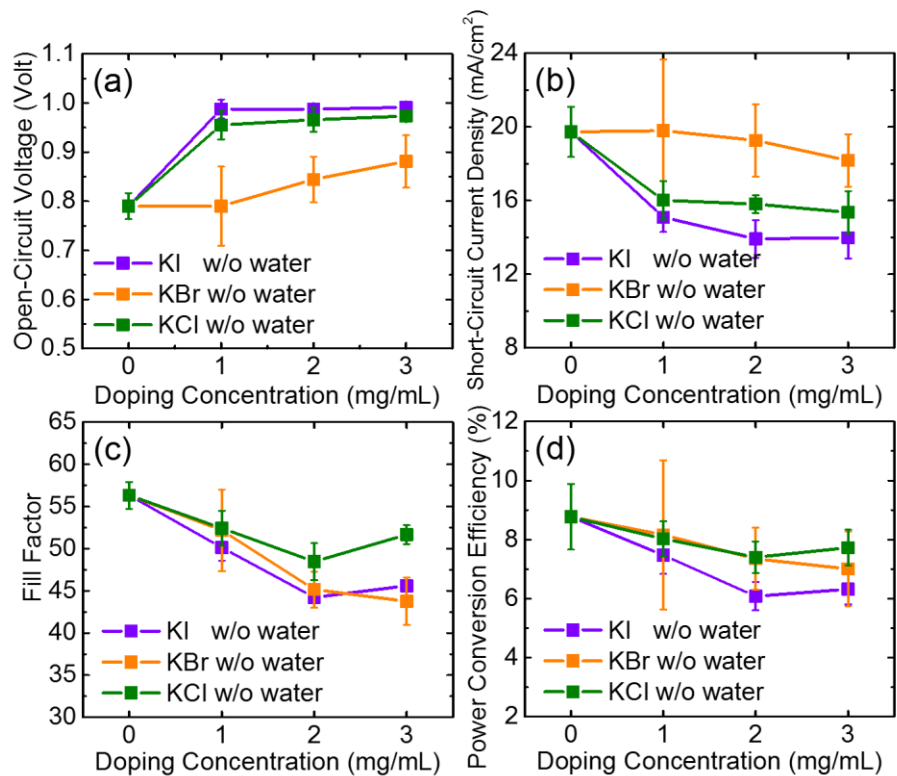


Figure S4. The (a) V_{oc} ; (b) J_{sc} ; (c) FF; (d) PCE of the potassium halide-doped devices as a function of doping amounts of KI, KBr and KCl.

Table S2. The corresponding photovoltaic parameters of devices in Figure S4 and Figure 2.

Samples	V _{OC} (Volt)	J _{SC} (mA/cm ²)	FF	PCE (%)	R _{SH} (Ω·cm ²)	R _S (Ω·cm ²)
Ref	0.79 ± 0.027	19.7 ± 1.4	56.3 ± 1.6	8.8 ± 1.1	340 ± 99	7.2 ± 0.7
KI (1 mg/mL)	0.99 ± 0.019	15.1 ± 0.8	50.1 ± 1.5	7.5 ± 0.6	262 ± 40	8.8 ± 1.6
KI (2 mg/mL)	0.99 ± 0.004	13.9 ± 1.0	44.2 ± 0.6	6.1 ± 0.5	165 ± 30	13.5 ± 1.1
KI (3 mg/mL)	0.99 ± 0.010	14.0 ± 1.1	52.2 ± 4.8	6.3 ± 0.5	203 ± 30	13.2 ± 0.8
KBr (1 mg/mL)	0.79 ± 0.080	19.8 ± 3.9	52.2 ± 4.8	8.2 ± 2.5	220 ± 70	11.7 ± 3.3
KBr (2 mg/mL)	0.84 ± 0.046	19.3 ± 2.0	45.2 ± 2.1	7.3 ± 1.1	162 ± 28	13.7 ± 3.7
KBr (3 mg/mL)	0.88 ± 0.053	18.2 ± 1.4	43.8 ± 2.8	7.0 ± 1.3	217 ± 45	15.2 ± 2.1
KCl (1 mg/mL)	0.96 ± 0.030	16.0 ± 1.0	52.4 ± 2.1	8.0 ± 0.6	337 ± 137	12.5 ± 1.8
KCl (2 mg/mL)	0.97 ± 0.024	15.8 ± 0.5	48.5 ± 2.2	7.4 ± 0.5	269 ± 86	10.4 ± 2.1
KCl 3 mg/mL)	0.97 ± 0.009	15.4 ± 1.2	51.7 ± 1.1	7.7 ± 0.6	209 ± 37	12.7 ± 1.4
Ref + 2 vol% water	0.90 ± 0.013	22.5 ± 1.3	59.2 ± 0.6	12.0 ± 0.6	168 ± 40	3.6 ± 0.1
KI (4 mg/mL) + 2 vol% water	0.97 ± 0.008	21.3 ± 1.2	67.0 ± 2.2	13.9 ± 0.7	555 ± 39	5.5 ± 0.7
KI (8 mg/mL) + 2 vol% water	0.97 ± 0.014	22.1 ± 1.3	59.8 ± 2.9	12.8 ± 0.7	878 ± 337	6.6 ± 0.6
KI (12 mg/mL) + 2 vol% water	1.01 ± 0.008	21.3 ± 1.3	56.7 ± 2.3	12.2 ± 1.0	498 ± 176	7.8 ± 1.2
KBr (1 mg/mL) + 2 vol% water	0.85 ± 0.035	22.1 ± 1.0	63.4 ± 1.9	11.9 ± 1.2	264 ± 46	3.8 ± 0.3
KBr (2 mg/mL) + 2 vol% water	0.89 ± 0.029	19.9 ± 1.4	58.2 ± 3.6	10.3 ± 1.8	310 ± 70	5.1 ± 0.6
KBr (3 mg/mL) + 2 vol% water	1.00 ± 0.006	19.1 ± 1.4	58.4 ± 2.1	11.2 ± 1.2	405 ± 66	5.9 ± 0.7
KCl (1 mg/mL) + 2 vol% water	0.92 ± 0.010	21.7 ± 1.3	62.8 ± 1.3	12.5 ± 1.2	809 ± 485	4.4 ± 0.3
KCl (2 mg/mL) + 2 vol% water	0.97 ± 0.007	21.0 ± 1.6	62.8 ± 0.8	12.8 ± 1.2	1217 ± 106	4.7 ± 0.3
KCl (3 mg/mL) + 2 vol% water	0.94 ± 0.006	21.1 ± 1.8	60.8 ± 1.8	12.1 ± 1.3	551 ± 207	5.6 ± 0.7

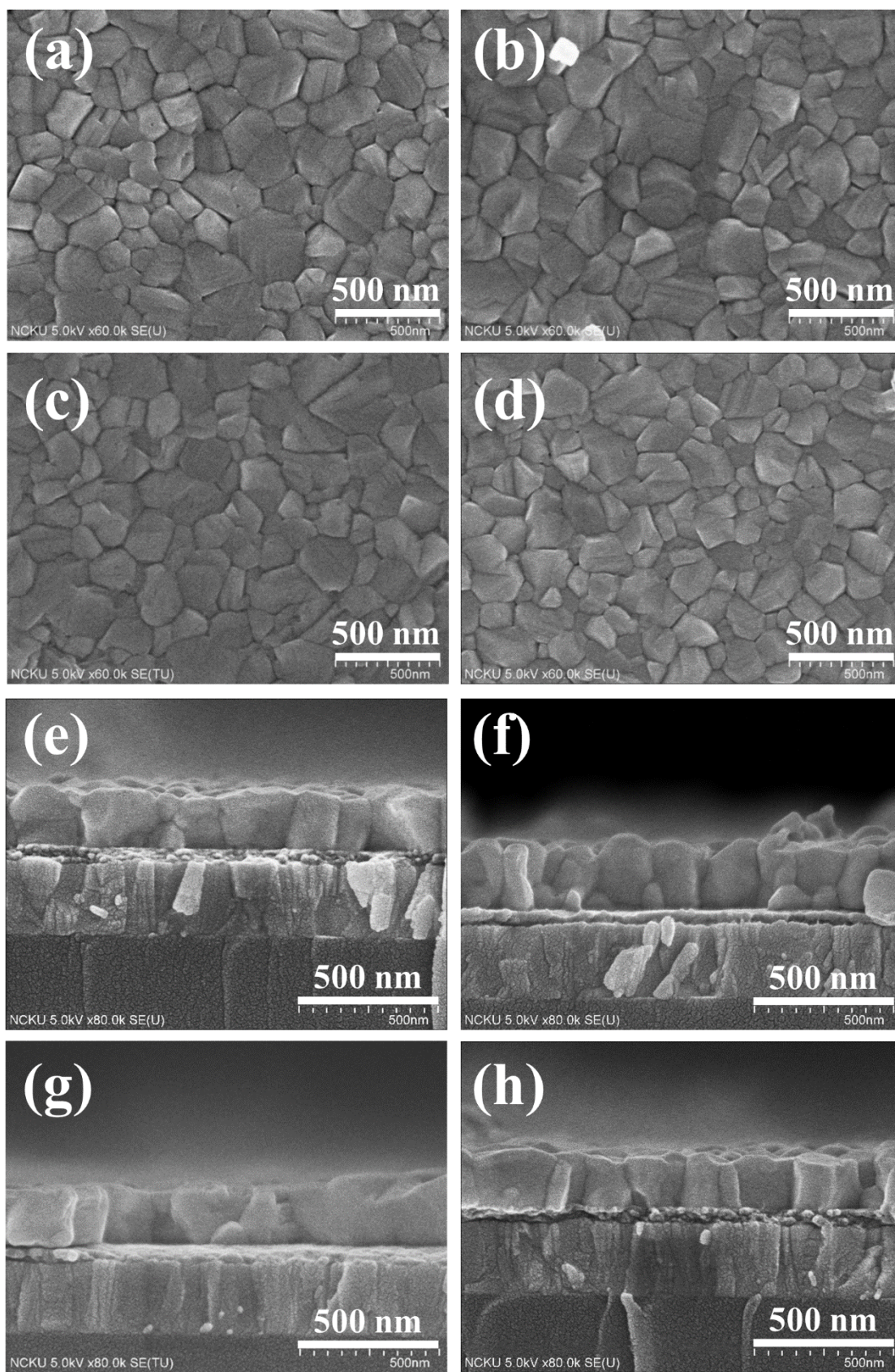


Figure S5. The SEM cross sectional images of the potassium halide-doped MAPbI₃ films (without water additive). (a) ref, (b) 1 mg/mL KI, (c) 1 mg/mL KBr, and (d) 1 mg/mL KCl.

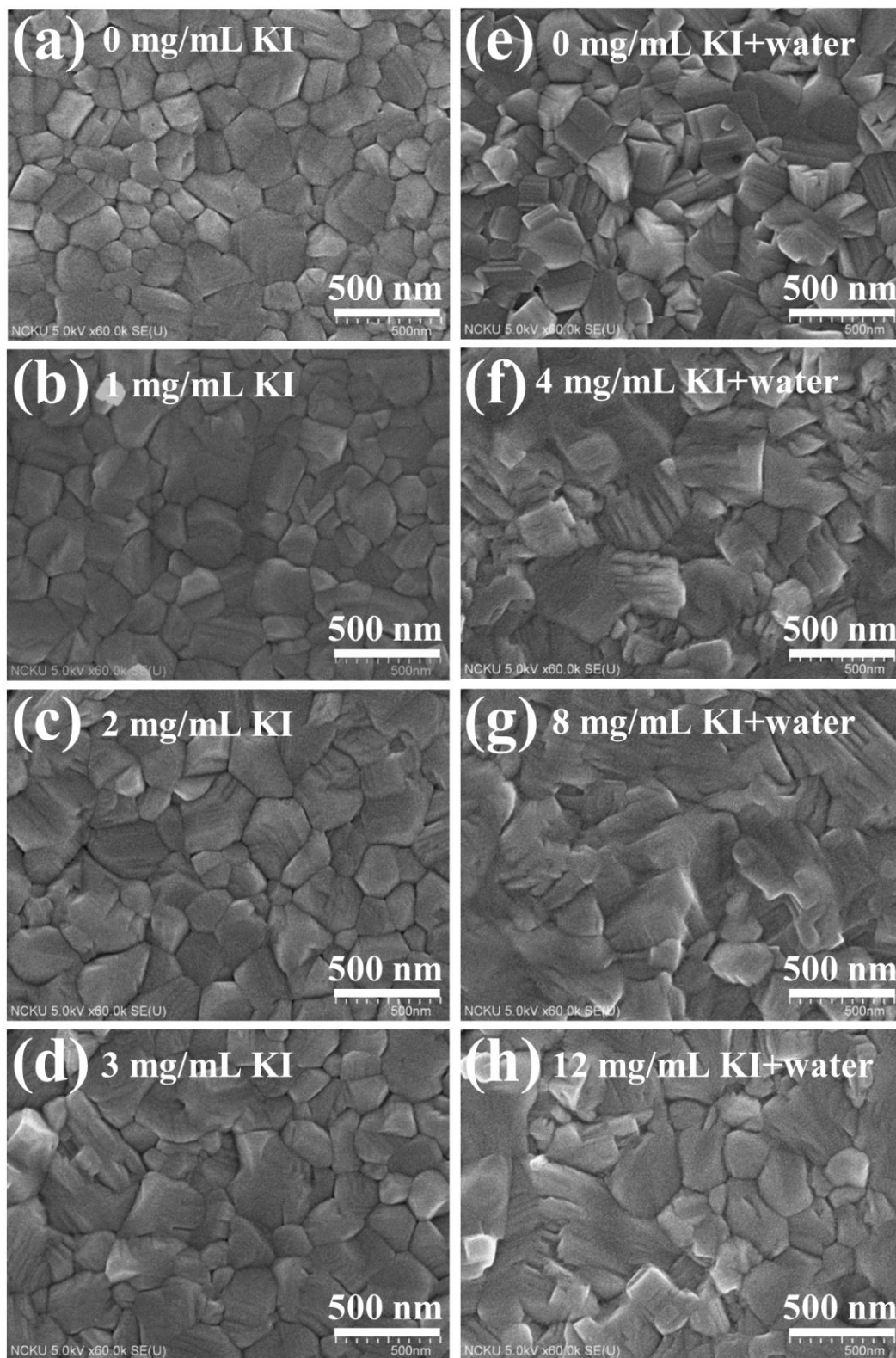


Figure S6. SEM surface morphology of the perovskite films with different KI and water additives in PbI_2 layer.

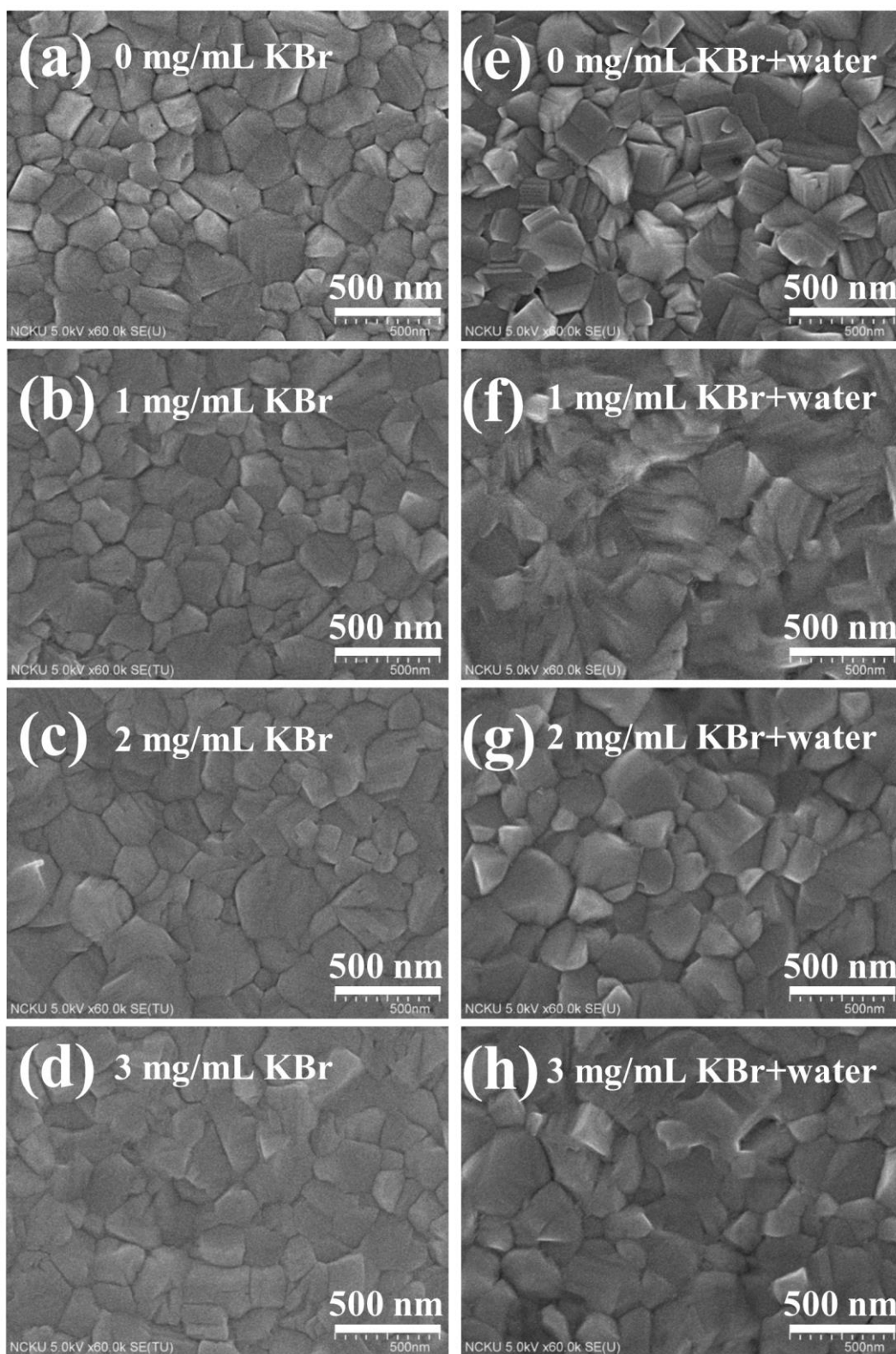


Figure S7. SEM surface morphology of the perovskite films with different KBr and water additives in PbI_2 layer.

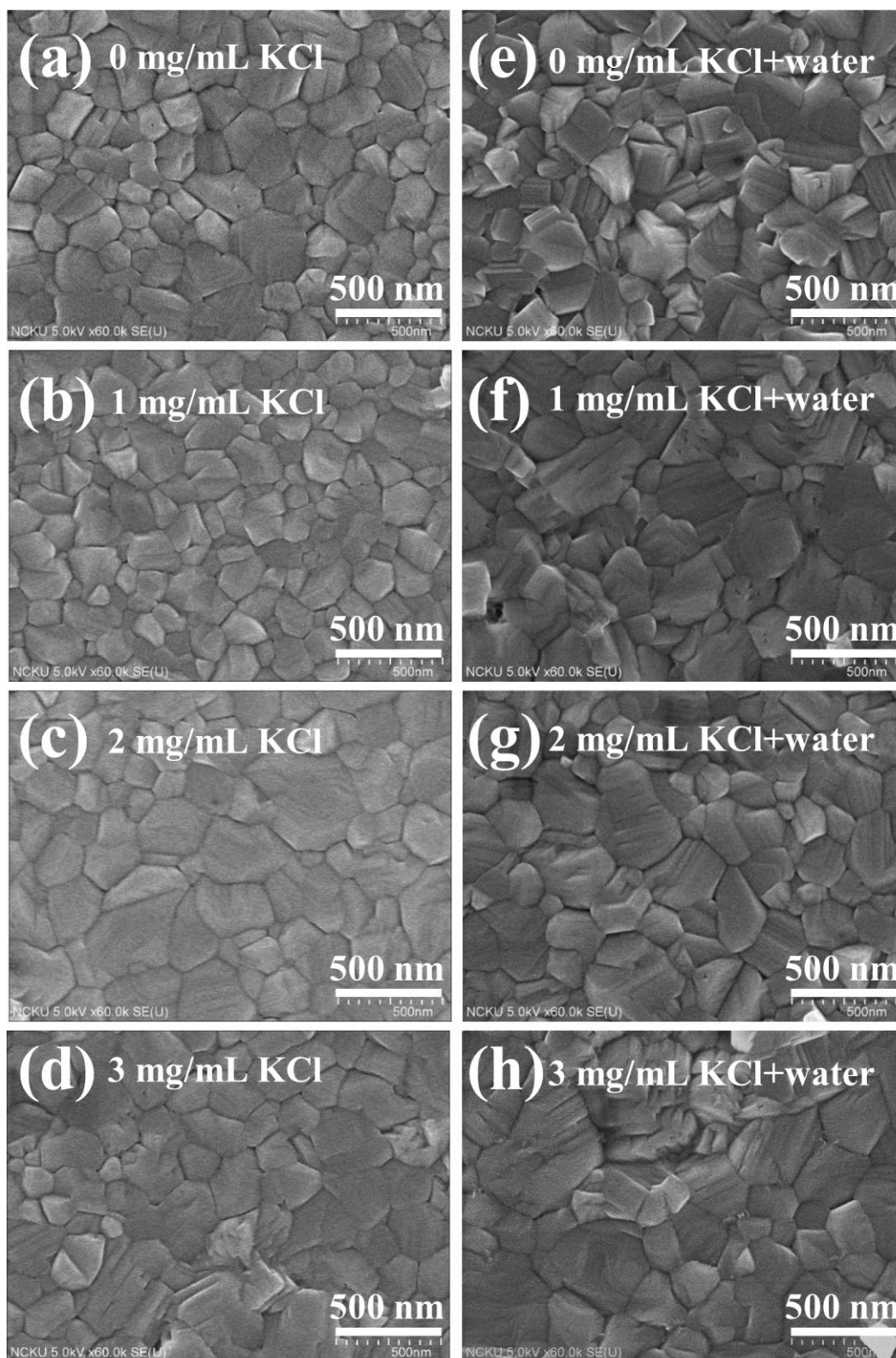


Figure S8. SEM surface morphology of the perovskite films with different KCl and water additives in PbI_2 layer.