



Supplementary information

Reducing Defects in Organic-Lead Halide Perovskite Film by Delayed Thermal Annealing Combined with KI/I₂ for Efficient Perovskite Solar Cells

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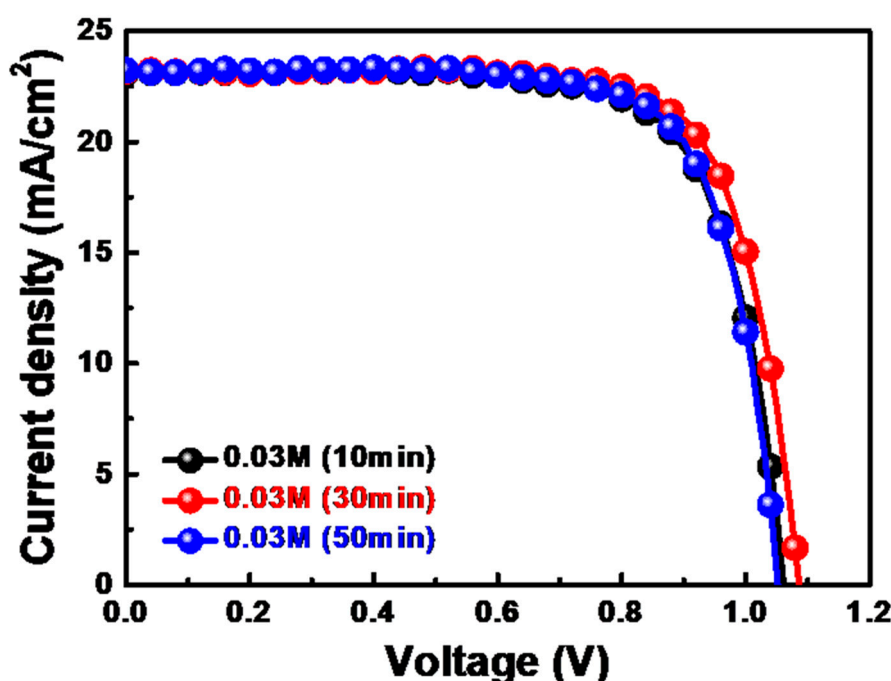


Figure S1. The J-V curves of PSCs with 30 mM KI under various thermal baking time.

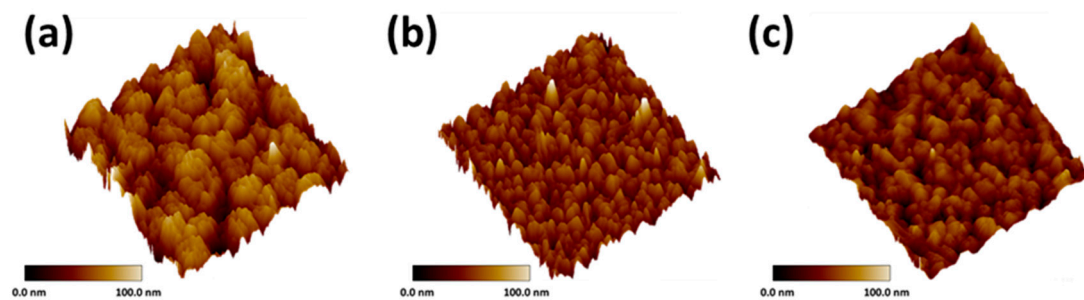


Figure S2. The AFM images of perovskite film with 30 mM KI at different delay-annealing times. (a) 0 min, (b) 30 min and (c) 60 min.

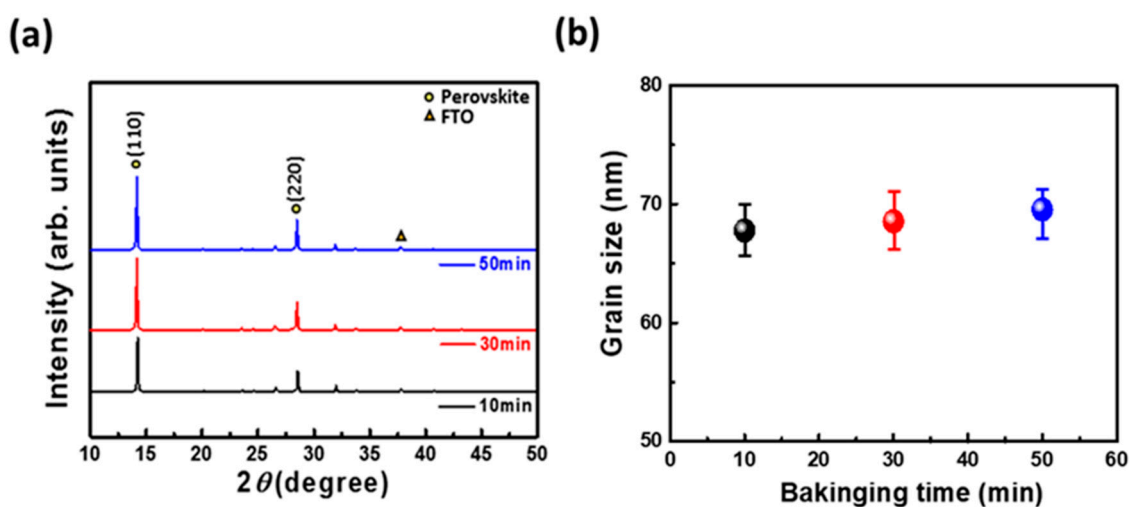


Figure S3. (a) XRD analysis of perovskite films with 0.03M KI under various thermal baking times. (b) Crystal size in perovskite films with 0.03M KI under various thermal baking times.

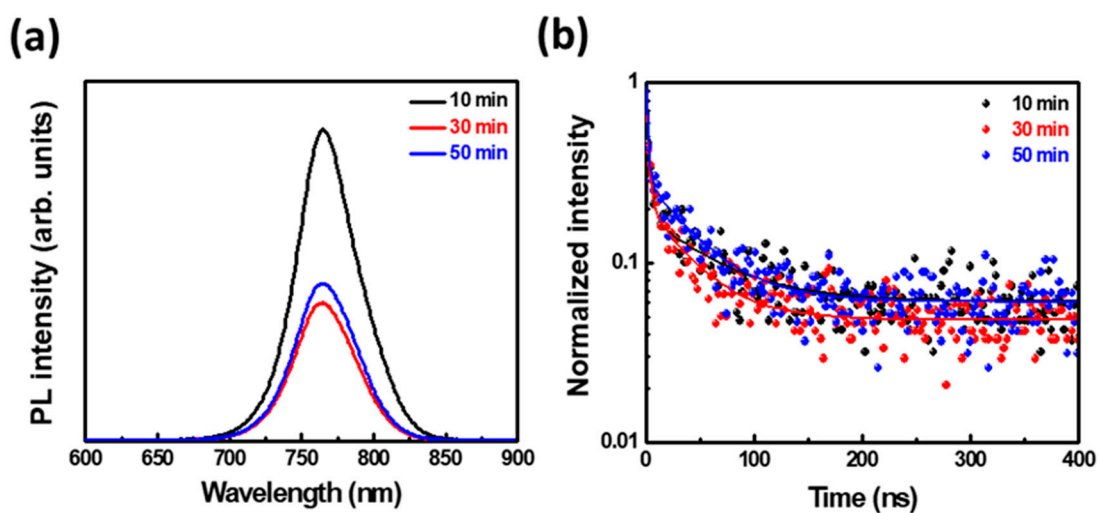


Figure S4. (a) PL and (b) TRPL of perovskite films with 0.03M KI on TiO₂/FTO glass under various thermal baking times.

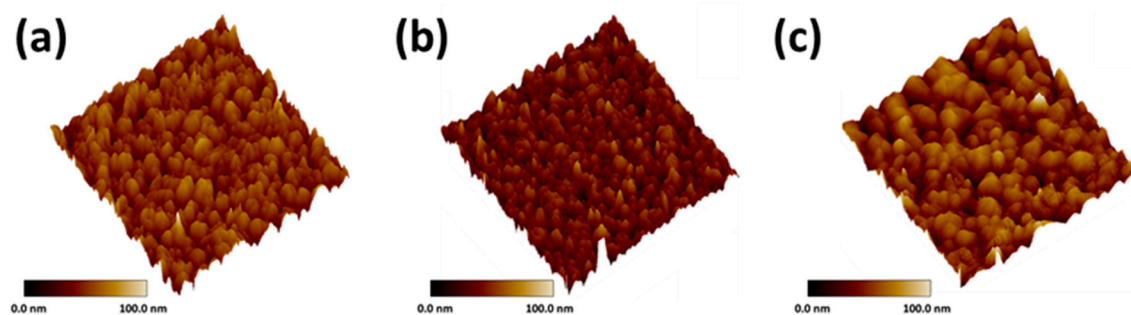


Figure S5. AFM of perovskite films with 0.03M KI/I₂ on TiO₂/FTO glass at different delayed annealing times. (a) 10 min, (b) 30 min and (c) 60 min.

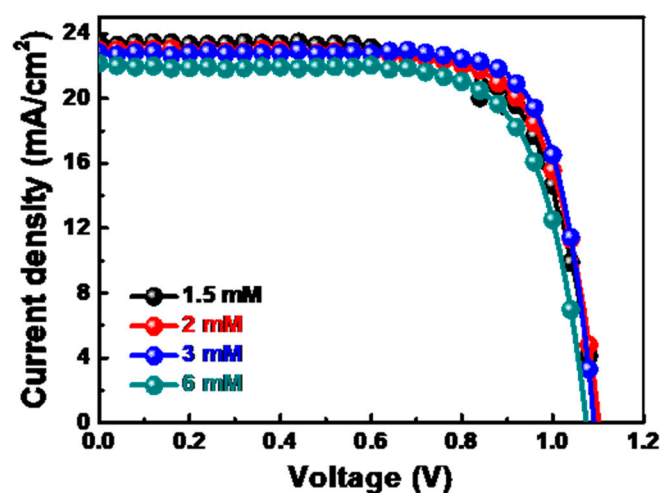


Figure S6. The J-V curves of PSCs with 30 mM KI and various concentrations of I₂.

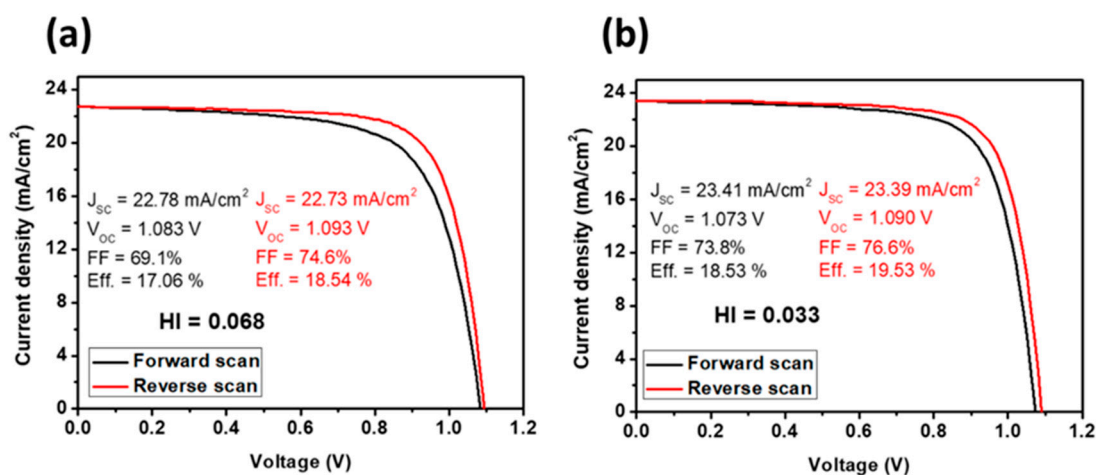


Figure S7. The J-V curves of PSCs by forward (Black) and reverse scan (Red). (a) Pristine and (b) KI (30 mM) + I₂ (3 mM).

Table S1. The R_{max} and RMS of perovskite films with 30 mM KI prepared at different delayed annealing times.

Time (min)	0	30	60
R_{max} (nm)	482	429	154
RMS (nm)	53	36	19

Table S2. Photovoltaic characteristics of PSCs with 30 mM KI at different thermal baking times.

Time (min)		V_{oc} (V)	J_{sc} (mA/cm ²)	FF (%)	PCE (%)
10	Maximum	1.061	23.09	73.8	18.10
	Mean deviation	1.060 ± 0.014	22.65 ± 0.41	71.6 ± 1.4	17.22 ± 0.58
30	Maximum	1.086	23.19	75.1	18.93
	Mean deviation	1.069 ± 0.014	22.73 ± 0.30	75.5 ± 1.9	18.21 ± 0.39
50	Maximum	1.052	23.22	74.7	18.26
	Mean deviation	1.061 ± 0.010	22.88 ± 0.29	73.2 ± 1.4	17.77 ± 0.42

Table S3. The carrier lifetimes of perovskite with 30 mM KI fitting from TRPL analysis at different thermal baking times.

Thermal Baking Time (min)	A_1 (%)	τ_1 (ns)	A_2 (%)	τ_2 (ns)	τ_{avg} (ns)
10	86	2.7	14	58.7	10.5
30	79	2.3	21	39.8	10.2
50	73	1.9	27	44.1	13.3

Table S4. R_{max} and RMS of perovskite films with KI (30 mM)/I₂ (3 mM) at various delayed thermal annealing times.

Time (min)	0	30	60
R_{max} (nm)	366	366	225
RMS (nm)	34	28	26