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

Supporting Information

Enhanced performance of tin-based perovskite solar cells induced by ammonium hypophosphite additive

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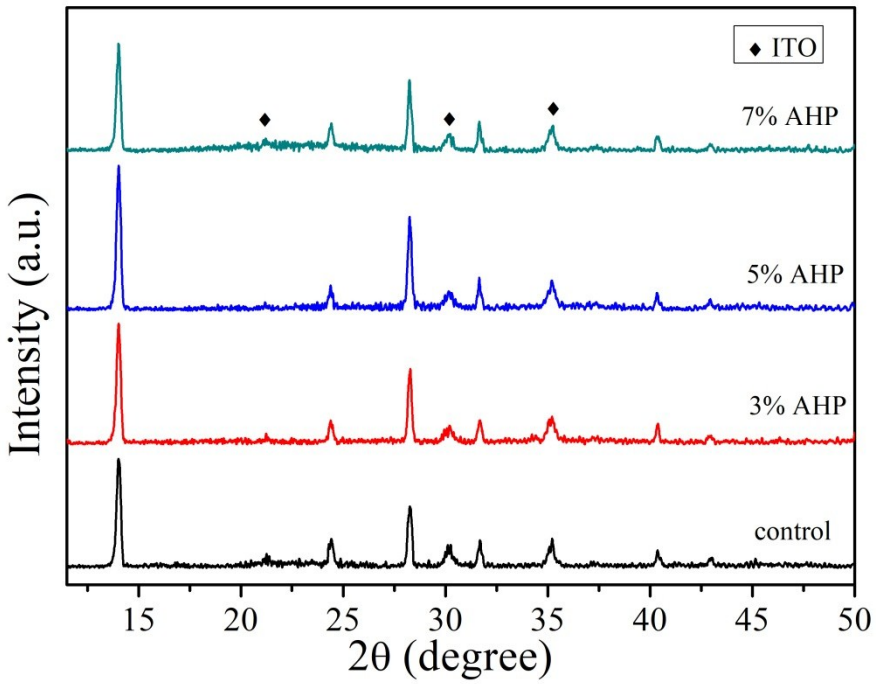

Figure S1. XRD pattern of $FASnI_3$ films with various amounts of AHP.

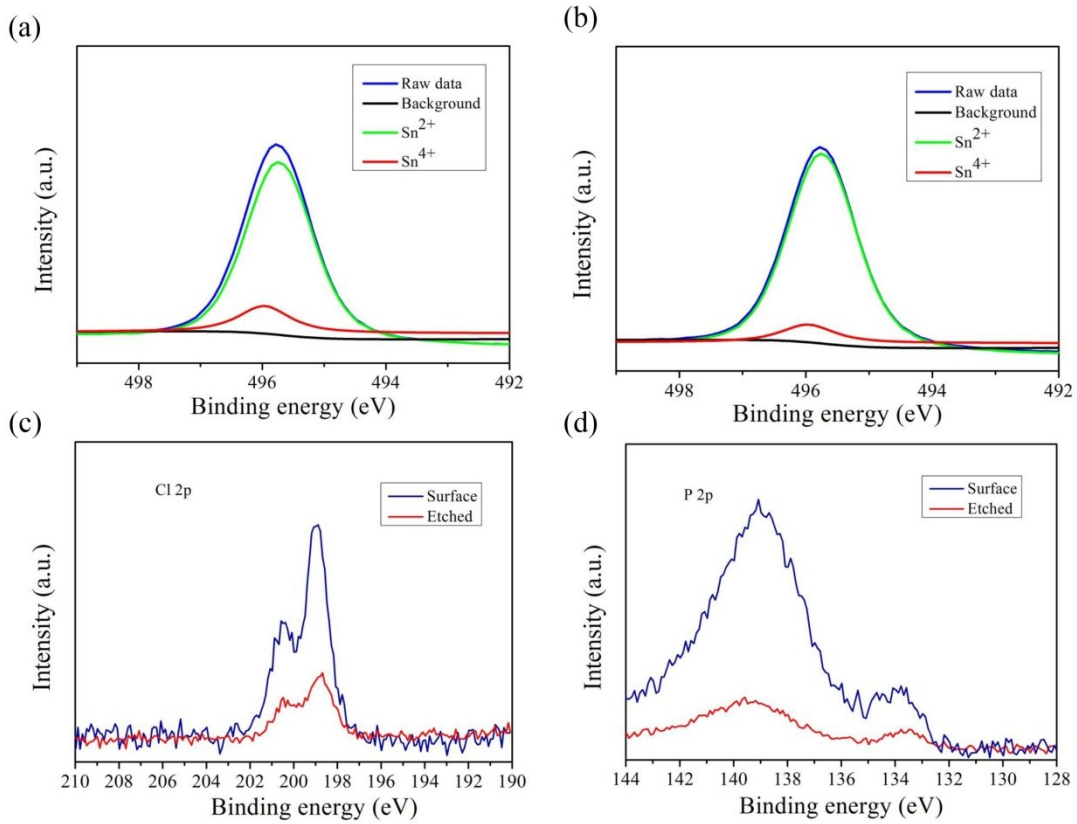

Figure S2. XPS spectra (Sn 3d) of (a) $FASnI_3$perovskitefilm and (b)5mol% AHP included $FASnI_3$perovskite film. XPS profile of (c) Cl peaks and (d) P peaks before and after Argon etching.

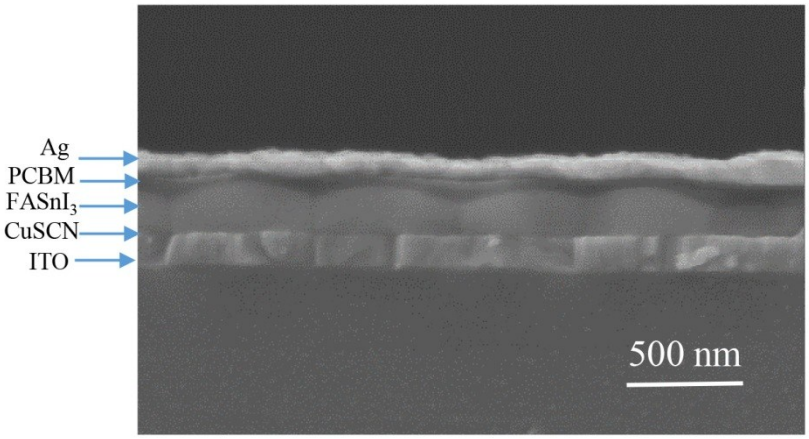

Figure S3. Cross-sectional SEM image of the $FASnI_3$ solar cells.

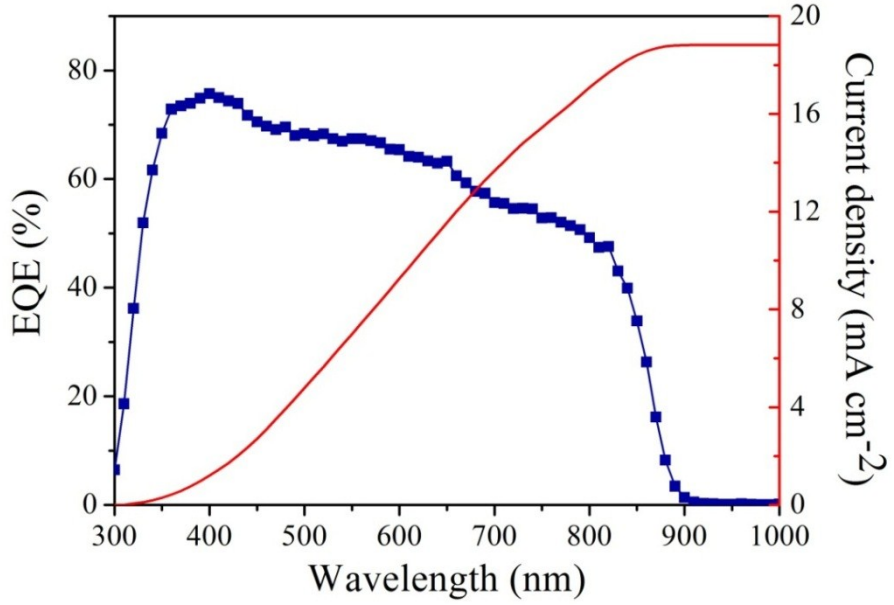

Figure S4. External quantum efficiency (EQE) of the champion $FASnI_3$ solar cell and corresponding integrated current density.

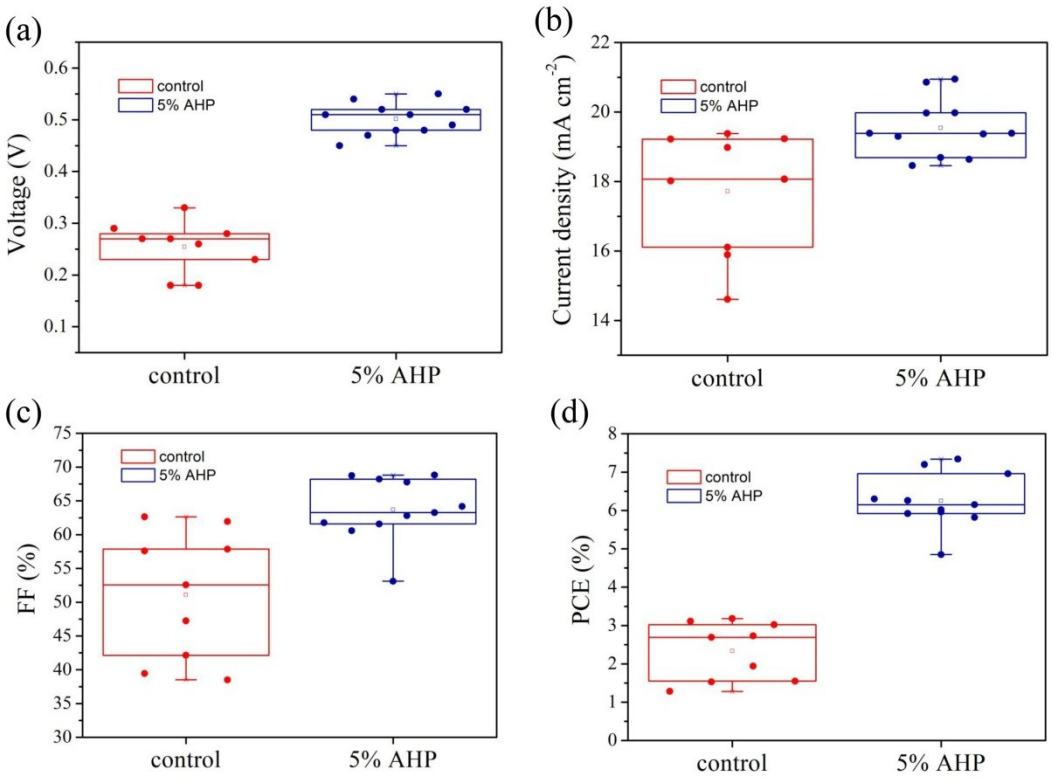

Figure S5. Distribution of photovoltaic parameters of plain $FASnI_3$ solar cells and 5 mol% AHP included $FASnI_3$solar cells.

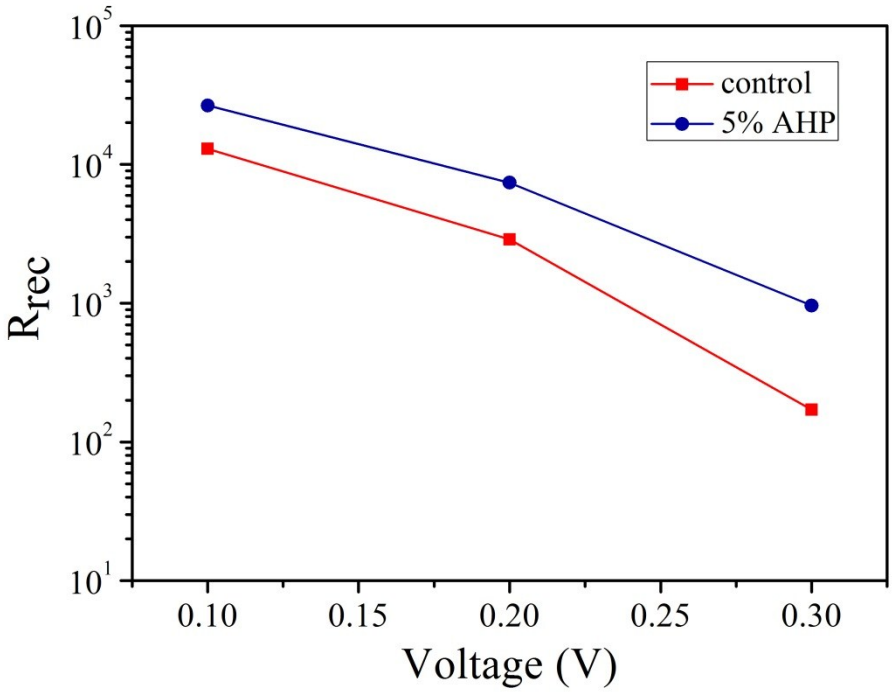

Figure S6. The fitted values of R_{rec} measured at different bias voltages.

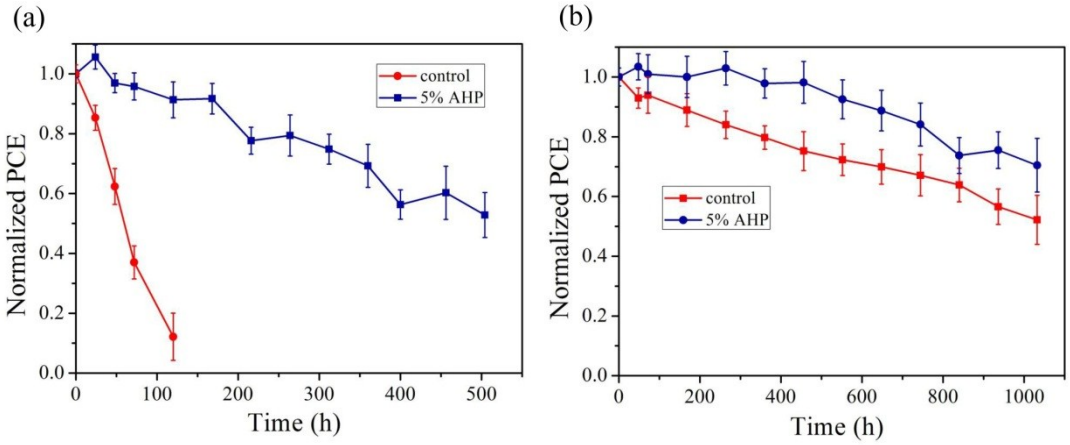

Figure S7. (a) Normalized PCE of $FASnI_3$ solar cells as a function of storage time in ambient air with~20% humidity. (b) Normalized PCE of $FASnI_3$ solar cells as a function of storage time in N_2 without encapsulation.

Table S1. Fitted parameters of time-resolved PL curves of the perovskite films.

Sample	A_1	τ_1(ns)	A_2	τ_2 (ns)
control	0.22	0.23	0.78	0.85
5% AHP	0.19	0.25	0.81	2.23

Table S2. Photovoltaic performance of $FASnI_3$ solar cells with different amounts of AHP.

AHP concentration	V_{OC} (V)	J_{SC} (mA cm^{-2})	FF (%)	PCE (%)
Control	0.25±0.05	17.72±1.65	51.11±9.01	2.34±0.71
3%	0.35±0.03	18.54±1.82	59.89±2.67	3.93±0.72
5%	0.50±0.03	19.55±0.79	63.71±4.47	6.25±0.67
7%	0.33±0.04	19.18±0.98	57.91±2.43	3.71±0.56

The average values for each condition are calculated from 8 separate devices.

Table S3. Summary of photovoltaic performance of $FASnI_3$ solar cells.

Composition	Device structure	V_{oc}(V)	PCE (%)	Ref
$FASnI_3$ (SnF_2)	FTO/c-TiO_2/mp-TiO_2/perovskite/spiro-OMeTAD/Au	0.24	2.1	[1]
$FASnI_3$ (SnF_2, N_2H_5Cl)	ITO/PEDOT:PSS/perovskite/PCBM/BCP/Ag	0.46	5.4	[2]
$FASnI_3$(SnF_2, pyrazine)	FTO/c-TiO_2/mp-TiO_2/perovskite/spiro-OMeTAD/Au	0.32	4.8	[3]
$FASnI_3$ (SnF_2, TMA)	ITO/PEDOT:PSS/perovskite/C_{60}/Ag	0.47	7.09	[4]
{en}$FASnI_3$ (SnF_2)	FTO/c-TiO_2/mp-TiO_2/perovskite/PTAA/Au	0.48	7.14	[5]
{PN}$FASnI_3$ (SnF_2)	FTO/c-TiO_2/mp-TiO_2/perovskite/PTAA/Au	0.44	5.85	[6]
$FASn(Br_{0.25}I_{0.75})_3$ (SnF_2)	FTO/c-TiO_2/mp-TiO_2/perovskite/spiro-OMeTAD/Au	0.41	5.5	[7]
$FASnI_3$ (SnF_2, PMMA)	ITO/PEDOT:PSS/perovskite/PCBM/Ag	0.48	3.62	[8]
$FASnI_3$ ($SnCl_2$,HQSA)	ITO/NiO_x/perovskite/PCBM/Ag	0.55	6.76	[9]
$FASnI_3$ ($SnCl_2$, AHP)	ITO/CuSCN/perovskite/PCBM/Ag	0.55	7.34	This work

Table S4. The recombination resistances of plain $FASnI_3$ solar cells and 5 mol% AHP included $FASnI_3$ solar cells fitted from the Nyquist plots.

Bias (V)	Control (Ω)	5% AHP (Ω)
0.1	13000	26600
0.2	2890	7430
0.3	171	962

Table S5. Summary of lifetime of $FASnI_3$ solar cells stored in air without encapsulation.

Composition	Device structure	RH (%)	Lifetime	Ref
$FASnI_3$ (SnF_2, TMA)	ITO/PEDOT:PSS/perovskite/C_{60}/Ag	50	20 h	4
$FASnI_3$ (SnF_2, TMA)	FTO/SnO_2/C_{60}/perovskite/spiro-OMeTAD/Ag	50	10 h	4
$FASnI_3$ (SnF_2)	FTO/PEDOT:PSS/perovskite/PCBM/BCP/Ag	40	8 h	10
$FA_{0.75}MA_{0.25}SnI_3$ (SnF_2)	ITO/PEDOT:PSS/perovskite/C_{60}/BCP/Ag	-	1 h	11
$FASnI_3$ (SnF_2)	ITO/PEDOT:PSS/perovskite/C_{60}/BCP/Al	20	50 h	12
$FASnI_3$ (SnF_2, PEAI)	ITO/PEDOT:PSS/perovskite/C_{60}/BCP/Al	20	80 h	12
$FASnI_3$ (SnF_2, $EDAI_2$, GAI)	ITO/PEDOT:PSS/perovskite/C_{60}/BCP/Ag	20	180 h	13
$FASnI_3$ ($SnCl_2$, KHQSA)	ITO/NiO_x/perovskite/PCBM/Ag	20	500 h	9
$FASnI_3$ ($SnCl_2$, KHQSA)	ITO/NiO_x/perovskite/PCBM/Ag	45	168 h	9
$FASnI_3$ ($SnCl_2$, AHP)	ITO/CuSCN/perovskite/PCBM/Ag	20	500 h	This work

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