Electronic Supplementary Information

Enhanced performance of tin halide perovskite solar cell by addition of lead thiocyanate

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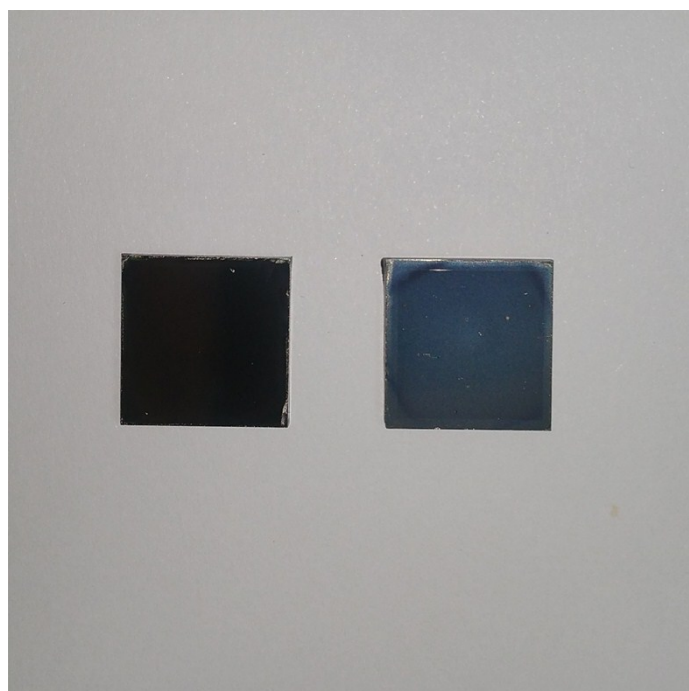
Figure S1. Images of 10% Pb(SCN)$_2$ films with the vacuum assisted annealing (VAA) (left) and without VAA(right)
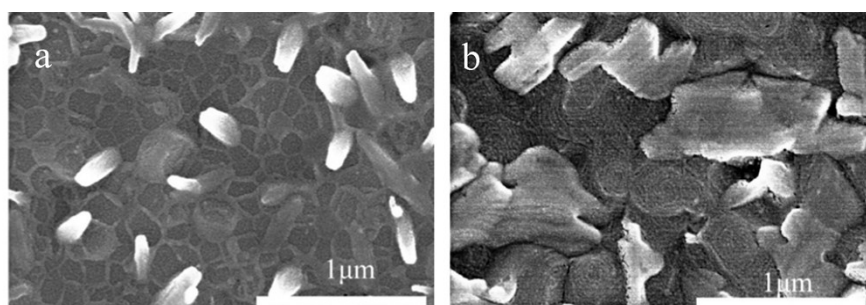

Figure S2.SEM images of 10% Pb(SCN)$_2$ film with VAA (a)and without VAA(b)
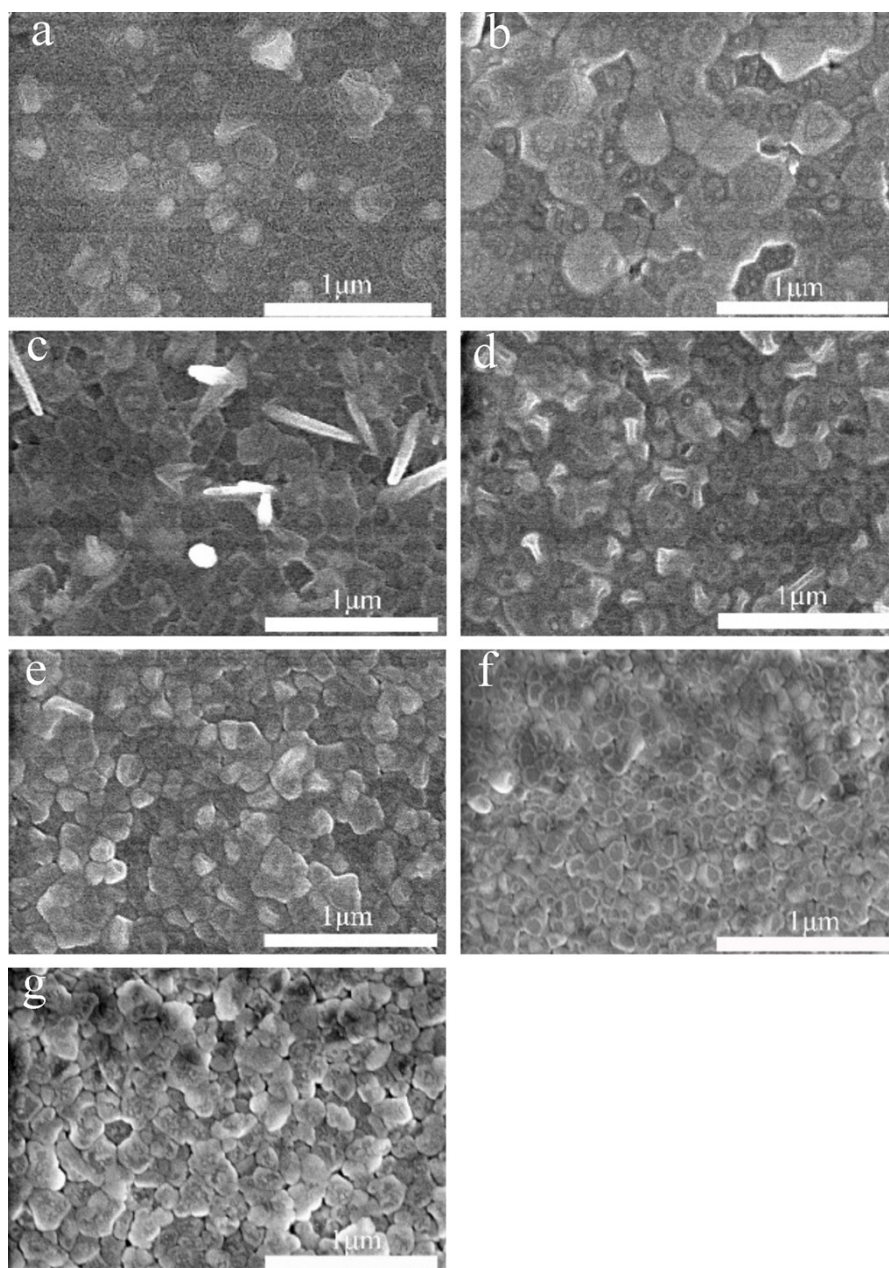
Figure S3. Top view SEM images of MASnI$_3$ films with (a) 0%, (b) 5%, (c) 10%, (d) 15%,(e) 20%, (f) 25% and (g)30% Pb(SCN)$_2$ in the precursors deposited on PEDOT:PSS HTLs at different magnifications.
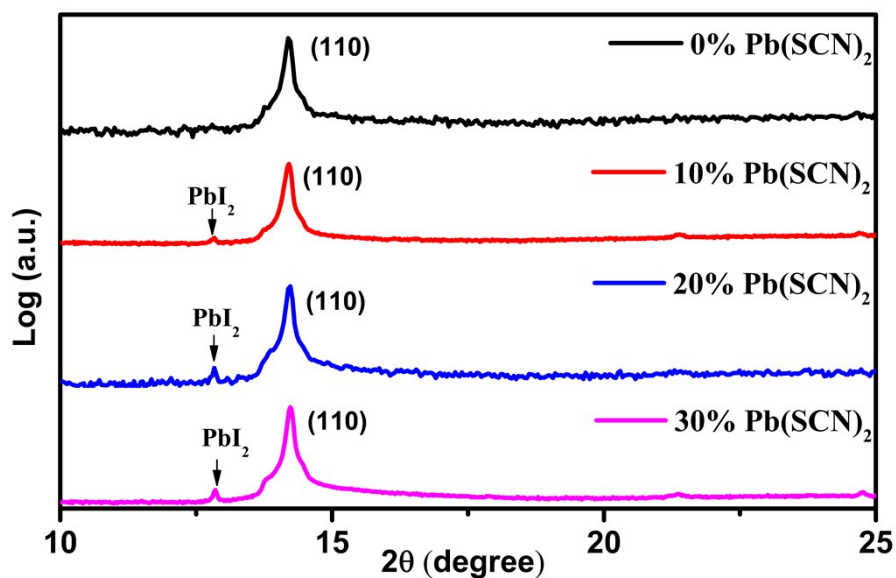
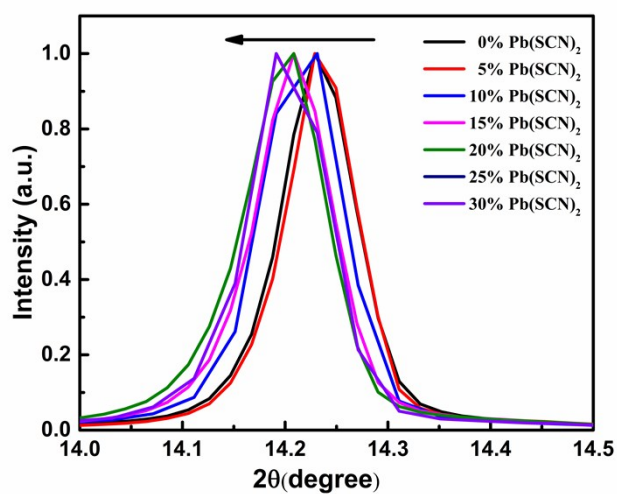**Figure S4.** Intensity of PbI_2 peak at 12.8° with various amounts of $Pb(SCN)_2$ additives in the precursors.

Figure S5. the peak positions at the (110) planes of $MASnI_3$ with various amounts of $Pb(SCN)_2$ additives in the precursors.
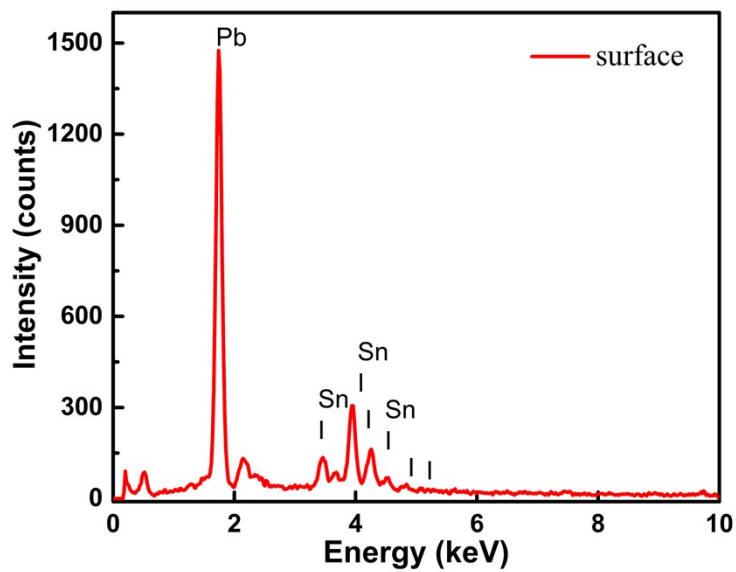
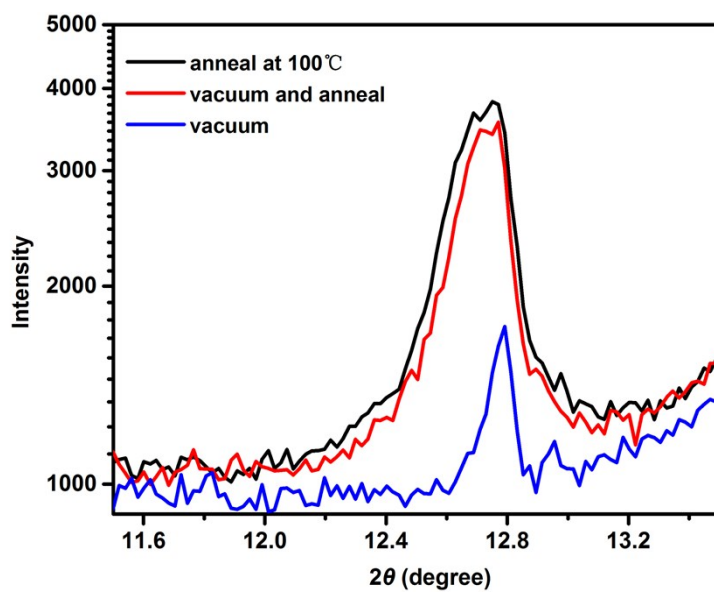**Figure S6.** SEM-EDS spectra taken from the surface of perovskite film

Figure S7. Intensity of PbI$_2$ peak at 12.8° with various treatment condition coated on ITO substrates.
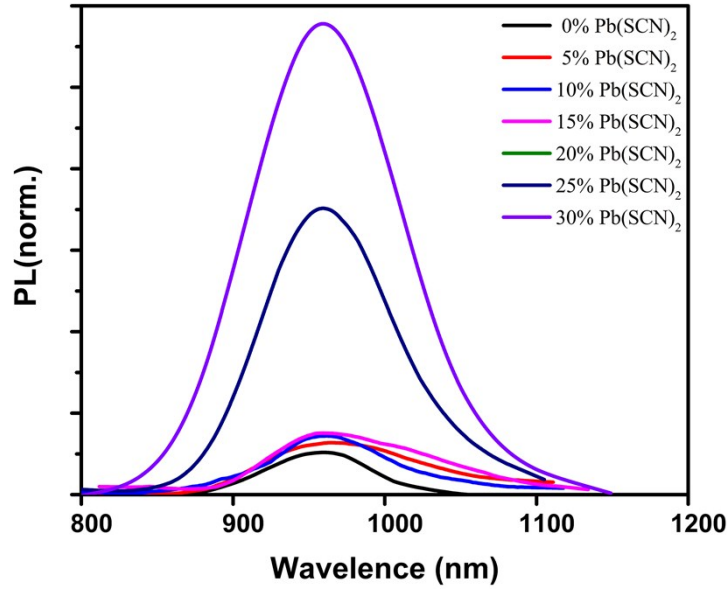
Figure S8. Photoluminescence spectra of MASnI₃ films with various amounts of Pb(SCN)₂ additives in the precursors.

Table S1. Summary of typical photovoltaic parameters for the solar cells prepared using MASnI₃ with various amounts of Pb(SCN)₂ additives in the precursor and measured under reverse and forward voltage scanning

|	J_{sc} $[mA\,cm^{-2}]$	V_{OC} [V]	FF [%]	PCE [%]
0% Pb(SCN)₂ (forward)	5.37	0.30	54	0.87
0% Pb(SCN)₂ (reverse)	5.40	0.32	48	0.83
5% Pb(SCN)₂ (forward)	6.28	0.42	59	1.54
5% Pb(SCN)₂ (reverse)	6.50	0.39	59	1.50
10% Pb(SCN)₂ (forward)	6.46	0.46	65	2.00
10% Pb(SCN)₂ (reverse)	4.88	0.47	65	1.53
15% Pb(SCN)₂ (forward)	10.48	0.48	64	3.22
15% Pb(SCN)₂ (reverse)	9.77	0.48	62	2.89
20% Pb(SCN)₂ (forward)	17.69	0.50	64	5.69
20% Pb(SCN)₂ (reverse)	16.89	0.51	61	5.10
25% Pb(SCN)₂ (forward)	13.55	0.52	63	4.46
25% Pb(SCN)₂ (reverse)	13.68	0.51	62	4.47
30% Pb(SCN)₂ (forward)	10.81	0.64	64	4.30
30% Pb(SCN)₂ (reverse)	11.13	0.63	65	4.53
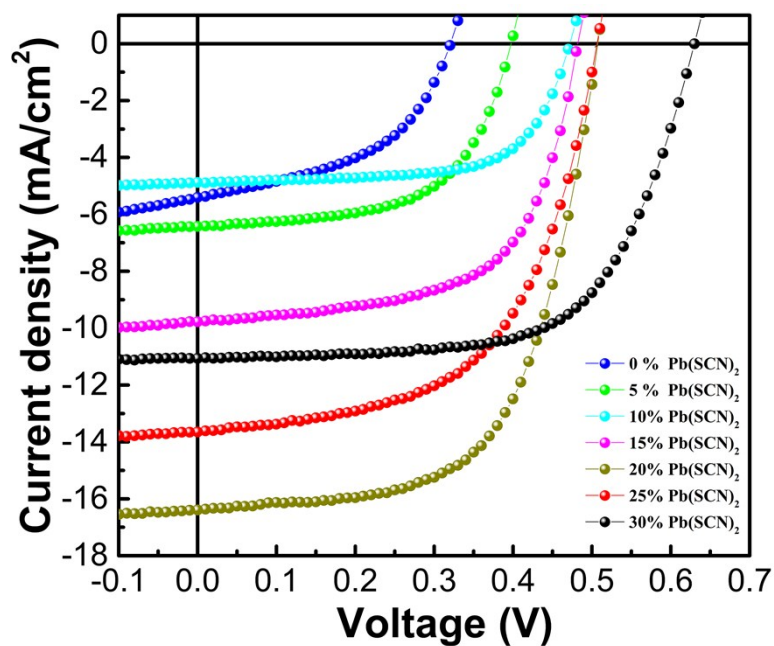
Figure S9. J-V curves of the perovskite solar cells, prepared using MASnI$_3$ with various amounts of Pb(SCN)$_2$ additives in the precursors, measured under reverse voltage scanning

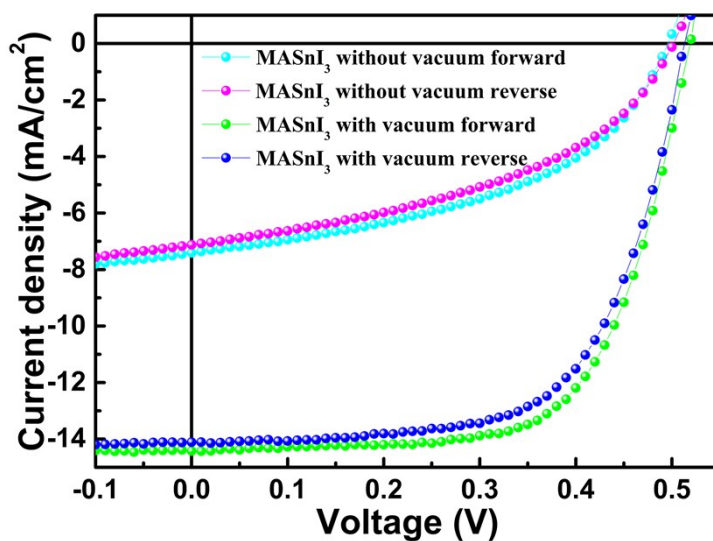**Figure S10.** J–V curves of the perovskite solar cells using MASnI$_3$ with VAA and without VAA and add 20% Pb(SCN)$_2$ in the perovskite precursor , under reverse and forward voltage scanning.
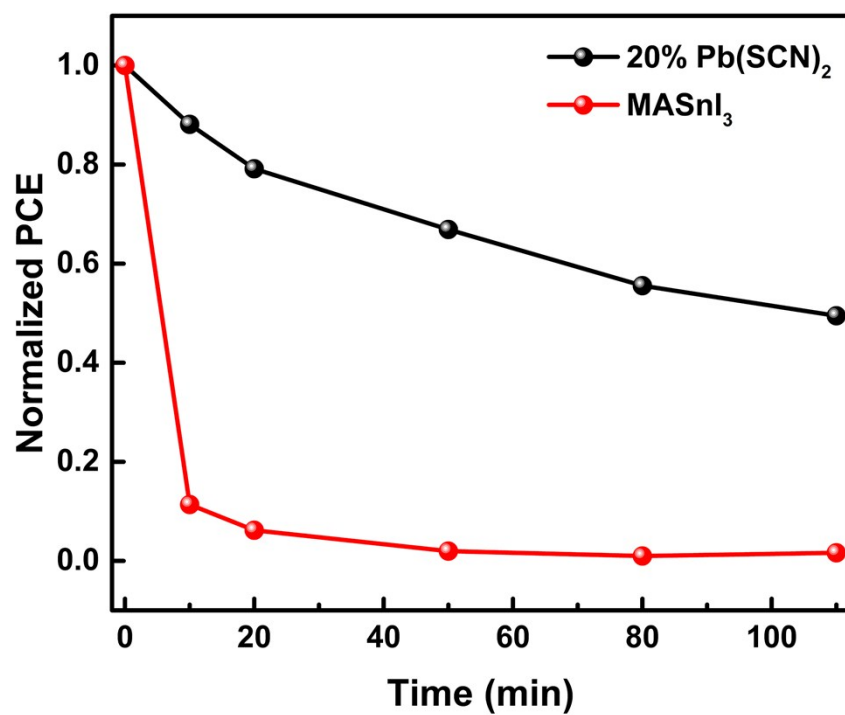
Figure S11. Normalized PCE of the unencapsulated device based on MASnI$_3$ and 20% Pb(SCN)$_2$-doped perovskite film stored in the air for over 110 min.
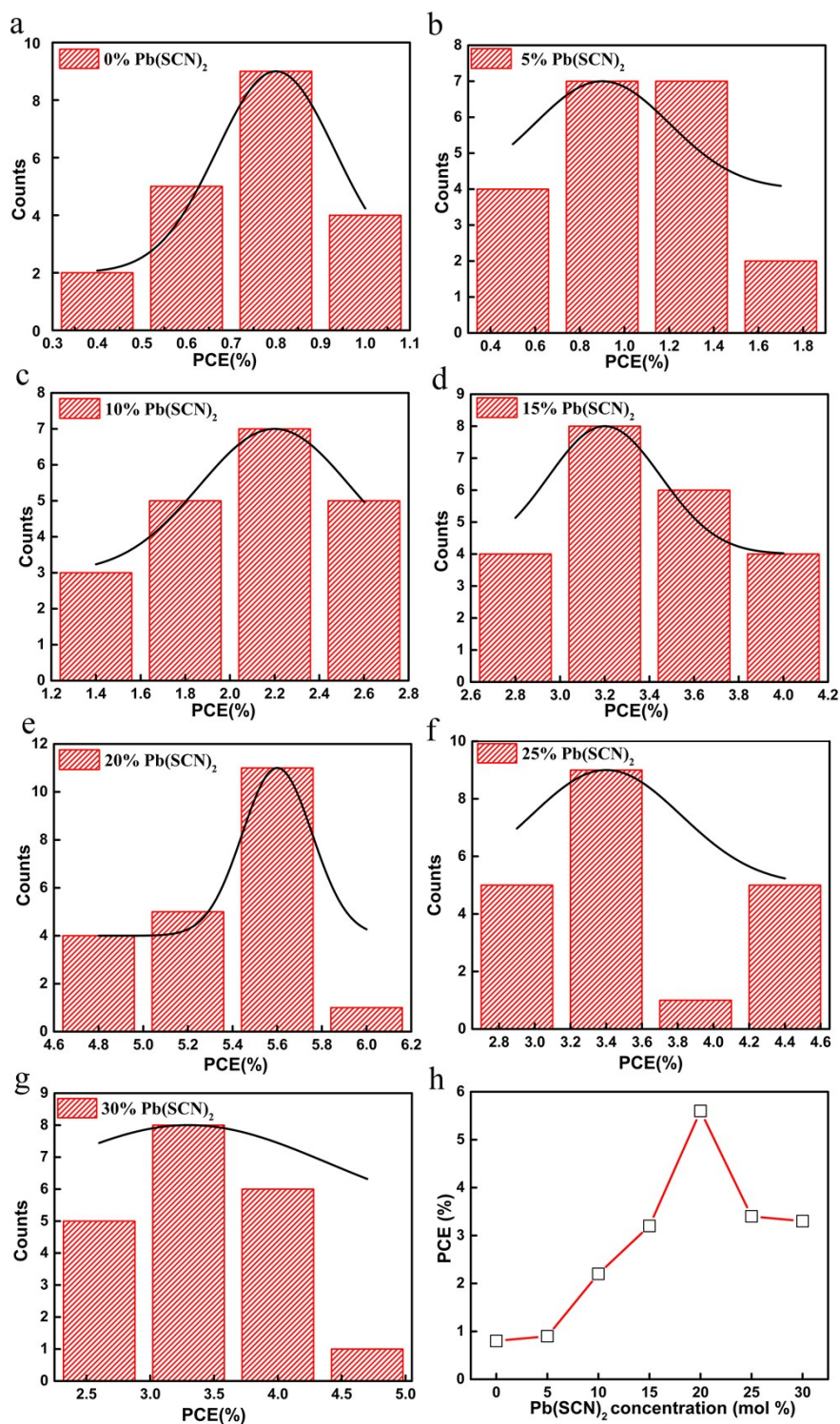
Figure S12. Statistics of the PCE distribution when the MASnI₃ films is doped with (a) 0%, (b) 5%, (c) 10%, (d) 15%,(e) 20%, (f) 25% and (g)30% Pb(SCN)₂ in the precursors. Black solid line denotes the Gaussian distribution fitting. (h) the best PCE distribution of MASnI₃ films for various Pb(SCN)₂ concentrations.
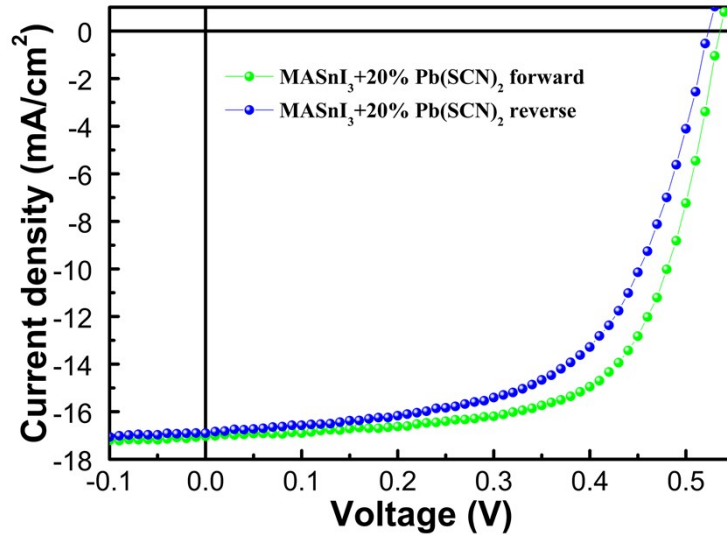
Figure S13. J-V curves of the best performance cell with 20% Pb(SCN)$_2$ in the precursor measured under forward and reverse voltage scanning

Table S2. The photovoltaic parameters of the best solar cells prepared with 20% Pb(SCN)$_2$ additives in the precursor and measured under reverse and forward voltage scanning

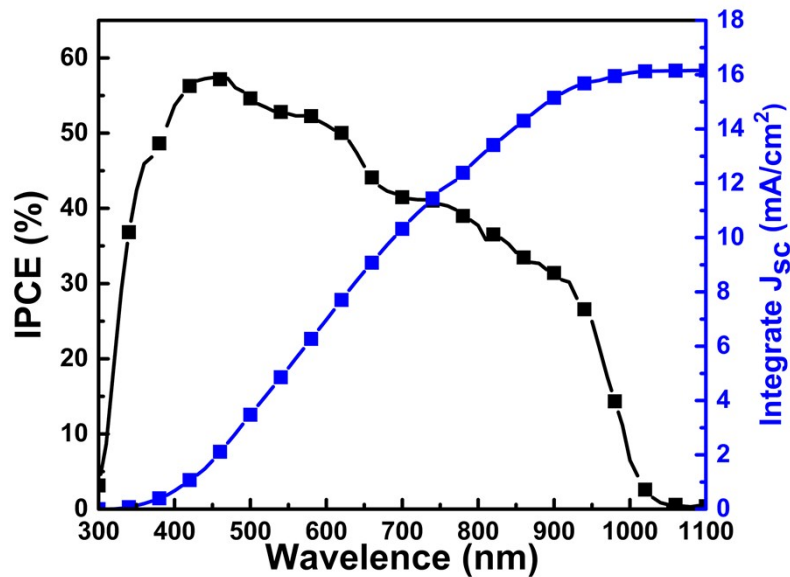|	J_{sc} [$mA\ cm^{-2}$]	V_{OC} [V]	FF [%]	PCE [%]
forward	17.03	0.54	66	6.03
reverse	16.90	0.52	60	5.31

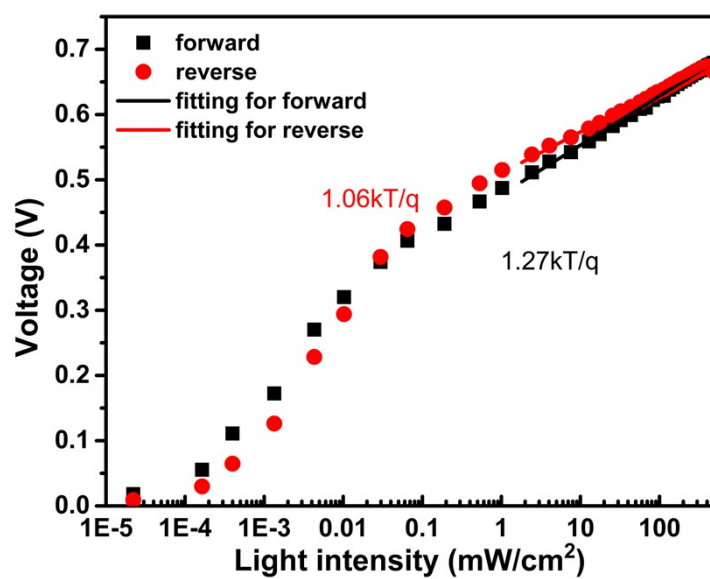**Figure S14.** EQE spectra of the solar cells using MASnI$_3$ with 20% Pb(SCN)$_2$ additives in the precursors

Figure S15. Open circuit voltage (V_{OC}) of perovskite PV device with 20% Pb(SCN)$_2$ additive plotted against incident light intensity.