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

Supporting Information

This file includes Figure S1-S11 and table S1-S2.

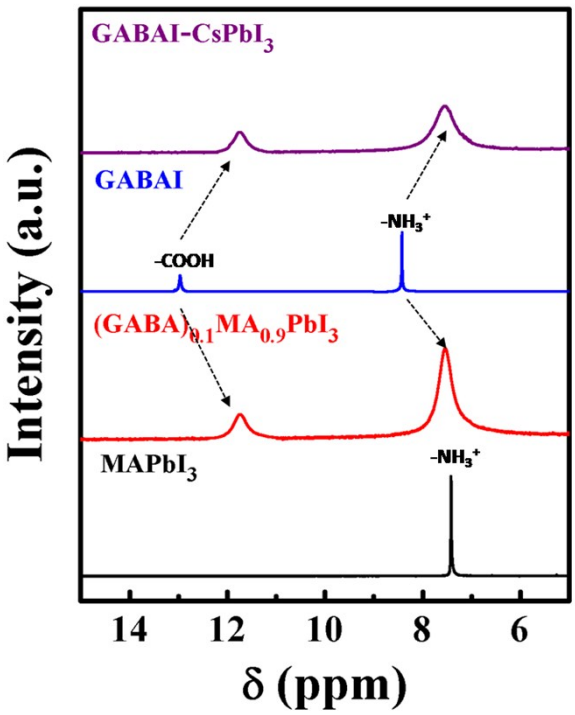

Figure S1. ^{1}H NMR spectra of $MAPbI_3$, GABAI, $(GABA)_{0.1}MA_{0.9}PbI_3$, and GABAI-$CsPbI_3$ in deuterated Dimethyl sulphoxide–d6 (DMSO-d6).

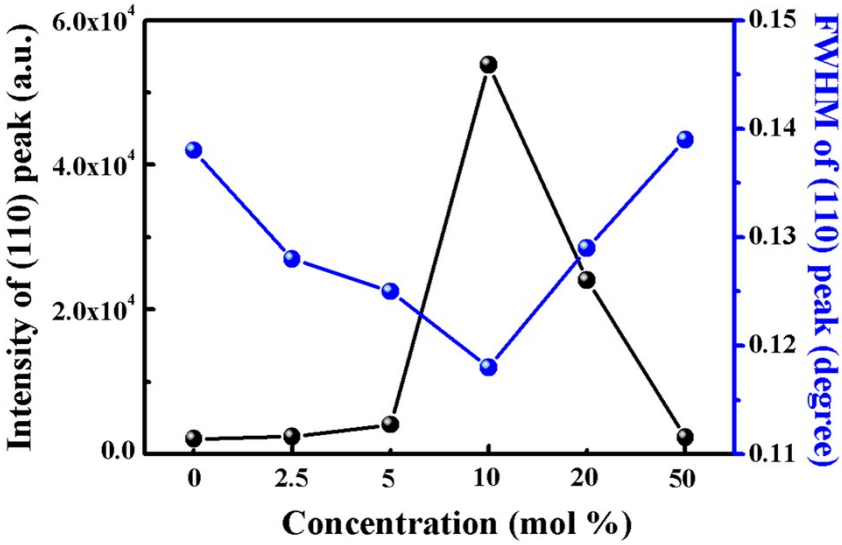

Figure S2. Intensity and FWHM variations of (110) peak of the controlled $MAPbI_3$ films (0 mol%) and $(GABA)_xMA_{1-x}PbI_3$ films with different GABA-incorporation concentrations: 2.5 mol% (x=0.025), 5 mol% (x=0.05), 10 mol% (x=0.1), 20 mol% (x=0.2), and 50 mol% (x=0.5).

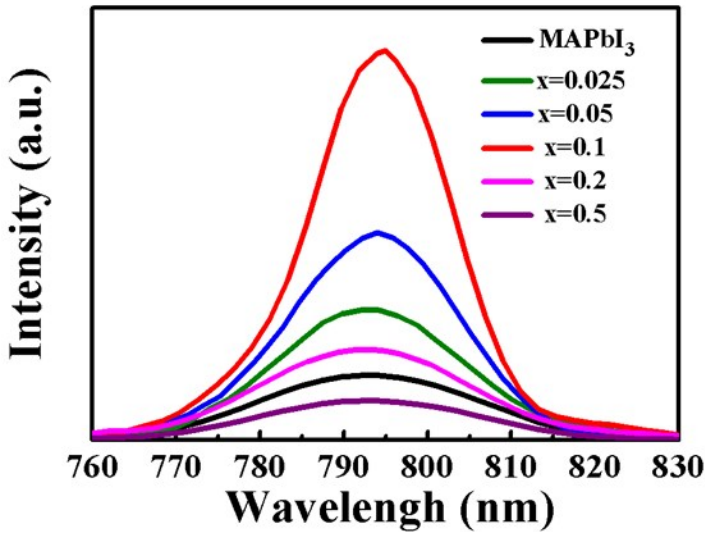

Figure S3. PL spectra of controlled $MAPbI_3$, $(GABA)_{0.025}MA_{0.975}PbI_3$, $(GABA)_{0.05}MA_{0.95}PbI_3$, $(GABA)_{0.1}MA_{0.9}PbI_3$, $(GABA)_{0.2}MA_{0.8}PbI_3$, and $(GABA)_{0.5}MA_{0.5}PbI_3$ perovskite films.

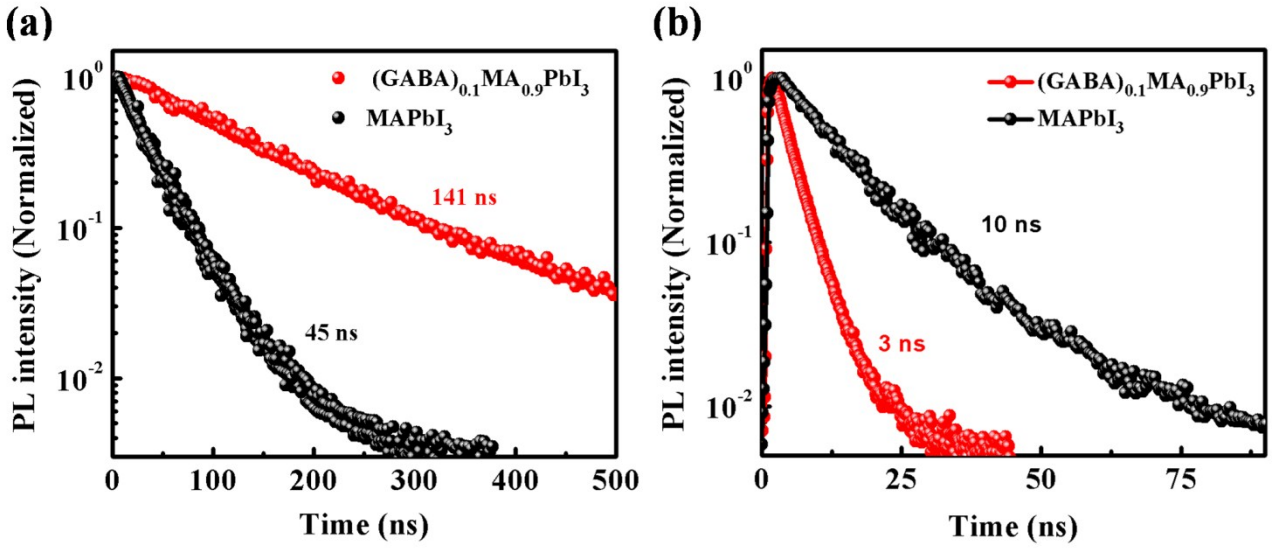

Figure S4. Time-resolved photoluminescence (TRPL) spectra of $MAPbI_3$ and $(GABA)_{0.1}MA_{0.9}PbI_3$ perovskite films on (a) bare glass substrates. (b) glass/TiO_2 substrates.

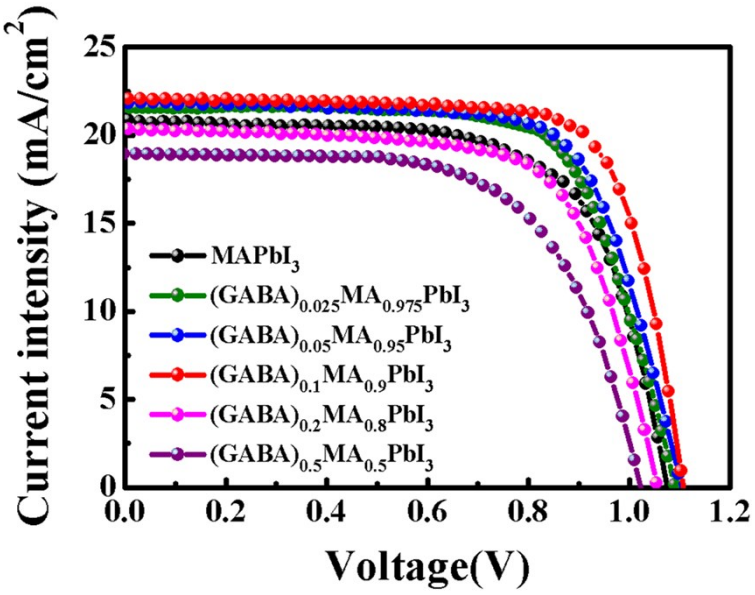

Figure S5. Representative *J-V* curves of solar cells based on the $MAPbI_3$, $(GABA)_{0.025}MA_{0.975}PbI_3$, $(GABA)_{0.05}MA_{0.95}PbI_3$, $(GABA)_{0.1}MA_{0.9}PbI_3$, $(GABA)_{0.2}MA_{0.8}PbI_3$, and $(GABA)_{0.5}MA_{0.5}PbI_3$ perovskite films.

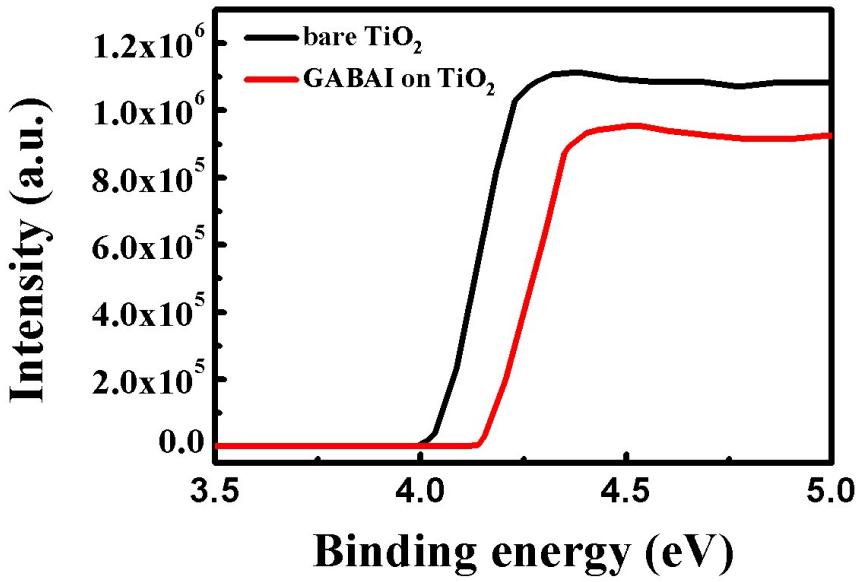

Figure S6. The UPS spectrum of GABAI solution soaked TiO_2 film. The work function of bare TiO_2 was ~4.03 eV. With $GABA^+$, the work function of the TiO_2 shifted to ~4.13 eV.

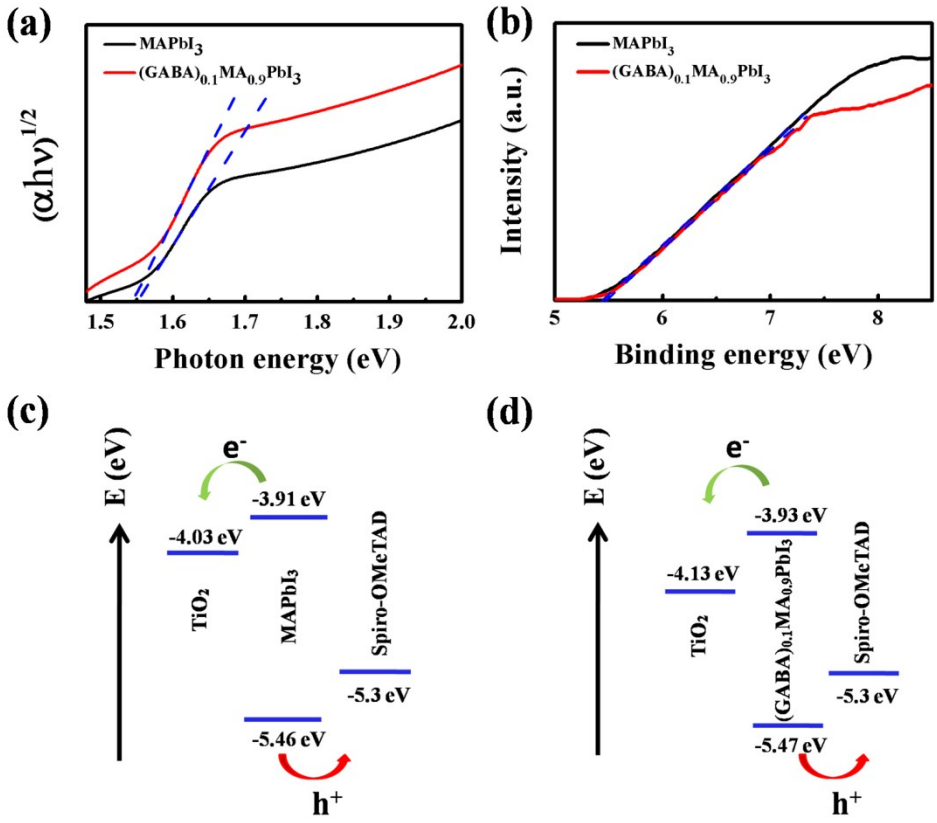

Figure S7. (a) Tauc plot of $MAPbI_3$ and $(GABA)_{0.1}MA_{0.9}PbI_3$ films from UV-vis spectra. $(\alpha h\nu)^{1/2}$ as a function of photon energy. Eg is obtained by linear fit of the data at absorption onset region. (b)The UPS spectrum of $MAPbI_3$ and $(GABA)_{0.1}MA_{0.9}PbI_3$ films. Schematic energy level diagrams of (c) TiO_2, $MAPbI_3$, and Spiro-OMeTAD and (d) TiO_2 with $GABA^+$, $(GABA)_{0.1}MA_{0.9}PbI_3$, and Spiro-OMeTAD in PSCs.

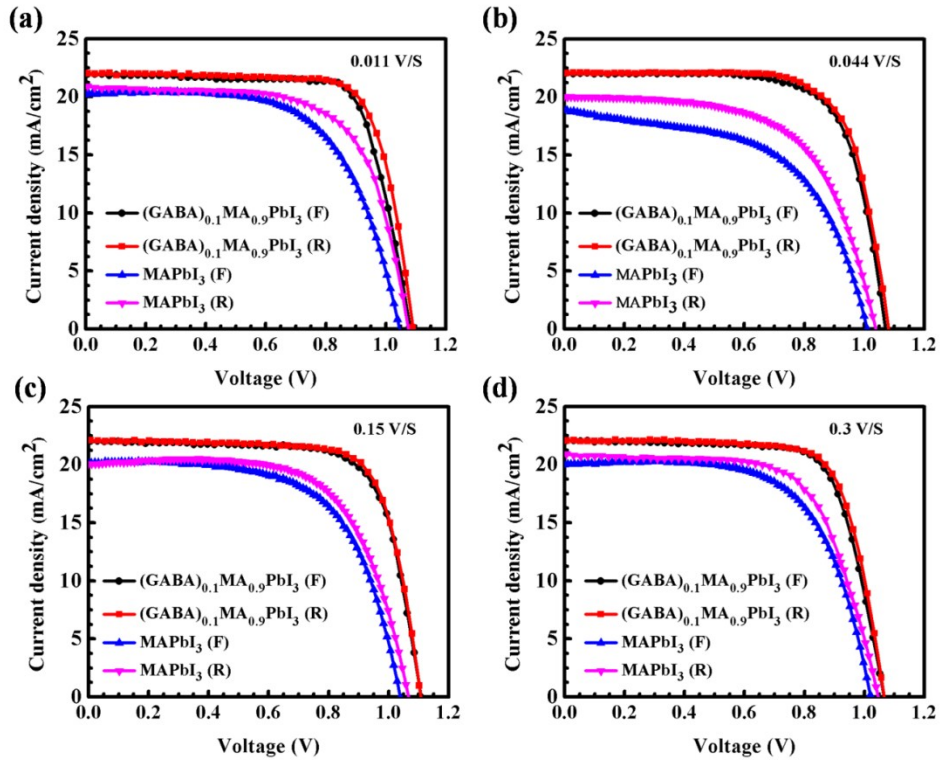

Figure S8. *J-V* characteristics of the best-performing device achieved with $MAPbI_3$ and $(GABA)_{0.1}MA_{0.9}PbI_3$ films obtained by both forward (F) and reverse (R) scanning direction with scanning rate of (a)0.011 V/S (a) 0.044 V/S(a) 0.15 V/S (a) 0.3 V/S.

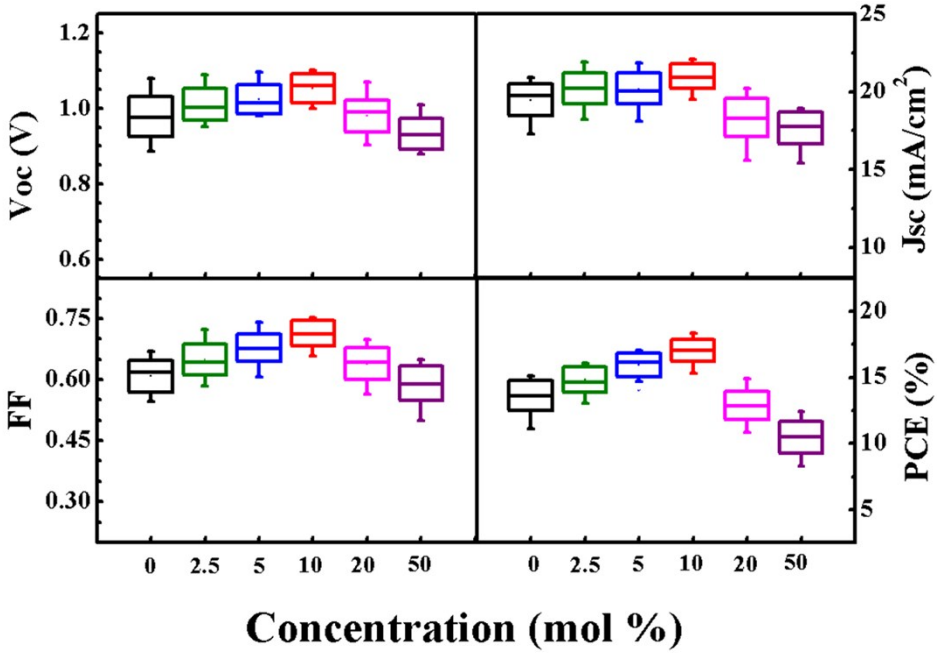

Figure S9. Photovoltaic parameter statistics of the solar cells based on controlled $MAPbI_3$ films (0 mol%) and $(GABA)_xMA_{1-x}PbI_3$ films with different GABA-incorporation concentrations: 2.5 mol% (x=0.025), 5 mol% (x=0.05), 10 mol% (x=0.1), 20 mol% (x=0.2), and 50 mol% (x=0.5).

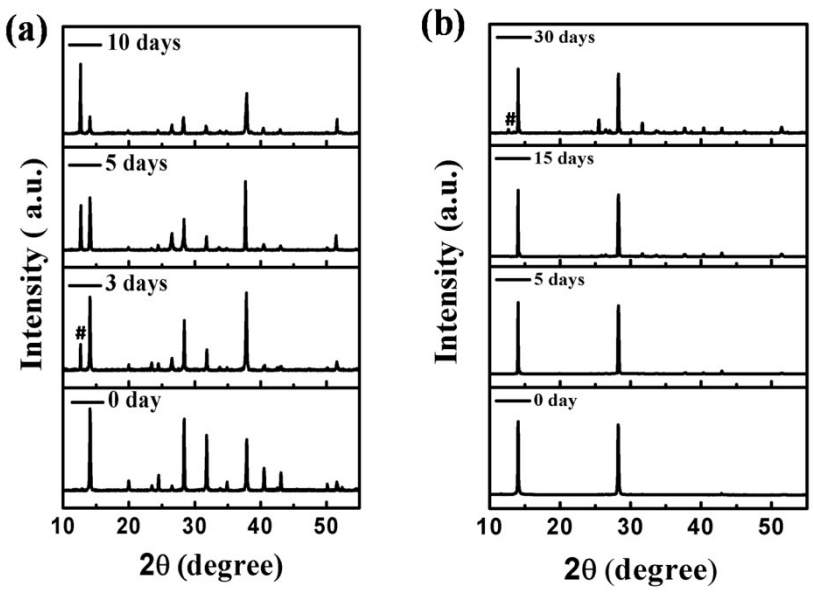

Figure S10. XRD patterns of (a) controlled $MAPbI_3$ films and (b) $(GABA)_{0.1}MA_{0.9}PbI_3$ films stored at room temperature in a 60% relative humidity for different days. The pound sign (#) represent the diffraction peak of PbI_2 indexed to the (001) plane.

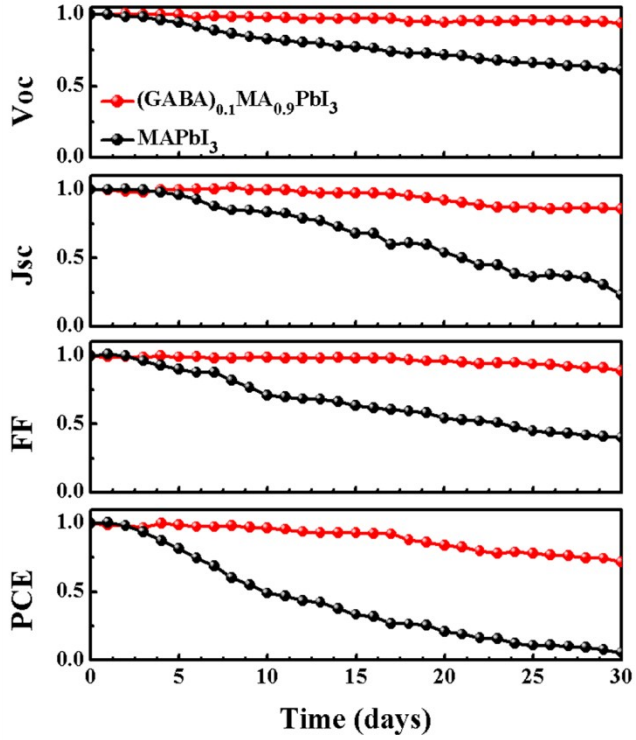

Figure S11. Comparison of ambient air stability of high-performance solar cell devices based on $MAPbI_3$ and $(GABA)_{0.1}MA_{0.9}PbI_3$ perovskite films.

Table S1. The extracted equivalent circuit element parameters of series of the devices with the $MAPbI_3$ and $(GABA)_xMA_{1-x}PbI_3$ films with different GABA-incorporation concentrations: 2.5 mol% (x=0.025), 5 mol% (x=0.05), 10 mol% (x=0.1), 20 mol% (x=0.2), and 50 mol% (x=0.5).

	$MAPbI_3$	x=0.025	x=0.05	x=0.1	x=0.2	x=0.5
R_{sh} (KΩ)	0.202	0.228	0.226	0.225	0.218	0.217
R_{ct} (KΩ)	1.762	1.197	0.892	0.712	3.232	5.013

Table S2. Photovoltaic parameters of the best-performance solar cell based on $(GABA)_{0.1}MA_{0.9}PbI_3$ and $MAPbI_3$ film measured with forward and reverse scan at scan rate of 0.011 V/S, 0.044 V/S, 0.15 V/S, 0.3 V/S, respectively.

Scan rate (V/S)	Sample	Scan direction	*V*oc (V)	*J*sc (mA/cm^2)	*FF* (%)	PCE (%)
0.011	$(GABA)_{0.1}MA_{0.9}PbI_3$	Forward	1.08	21.95	75.71	17.94
		Reverse	1.09	22.03	75.72	18.18
	$MAPbI_3$	Forward	1.05	20.21	63.02	13.37
		Reverse	1.08	20.86	63.14	14.22
0.044	$(GABA)_{0.1}MA_{0.9}PbI_3$	Forward	1.08	22.06	73.33	17.47
		Reverse	1.08	22.07	73.38	17.49
	$MAPbI_3$	Forward	1.01	19.85	55.69	11.17
		Reverse	1.04	20.03	60.79	12.66
0.15	$(GABA)_{0.1}MA_{0.9}PbI_3$	Forward	1.09	22.00	74.08	17.76
		Reverse	1.10	22.08	75.03	18.22
	$MAPbI_3$	Forward	1.04	20.15	62.99	13.20
		Reverse	1.06	20.37	67.10	14.48
0.3	$(GABA)_{0.1}MA_{0.9}PbI_3$	Forward	1.06	22.05	73.59	17.20
		Reverse	1.07	22.06	74.01	17.46
	$MAPbI_3$	Forward	1.02	20.00	64.72	13.20
		Reverse	1.05	20.89	65.82	14.45