

Supporting information

Semi-transparent perovskite solar cells: Unveiling the trade-off between transparency and efficiency

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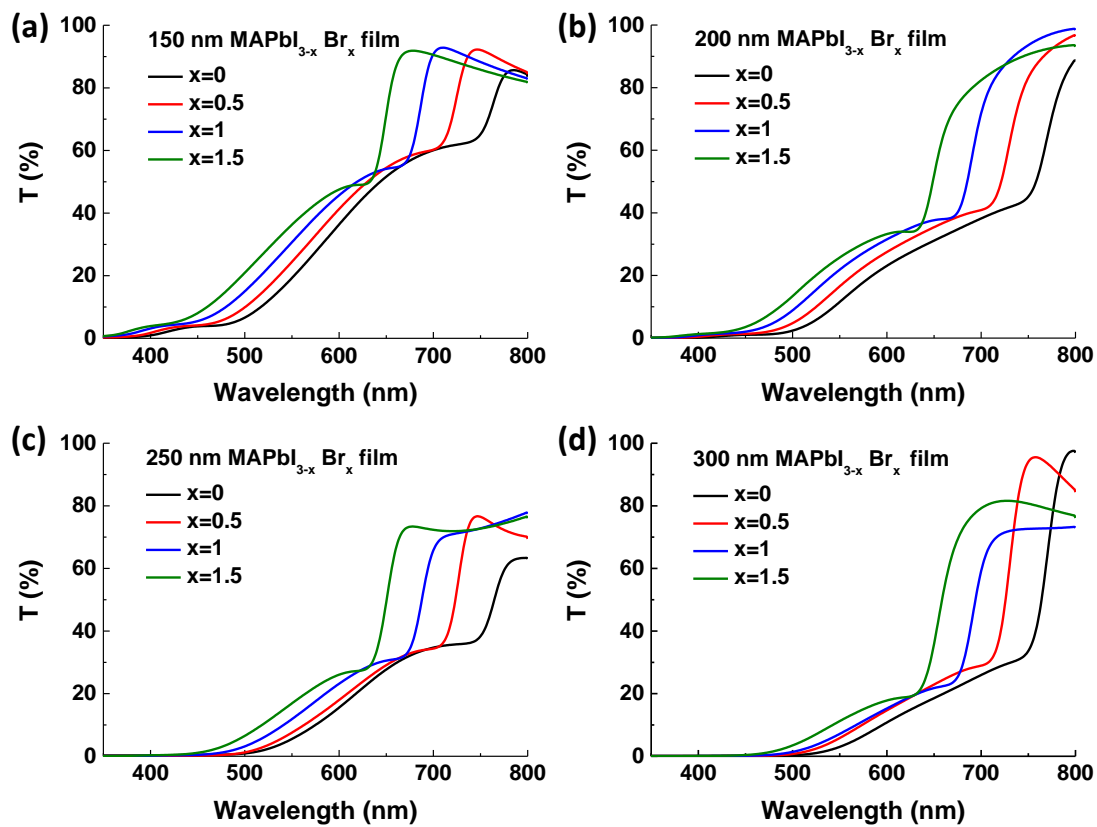


Figure S1. The transmittance spectra of MAPbI_{3-x}Br_x ($x=0, 0.5, 1$ and 1.5) films with different thicknesses, (a) 150 nm, (b) 200 nm, (c) 250 nm and (d) 300 nm.

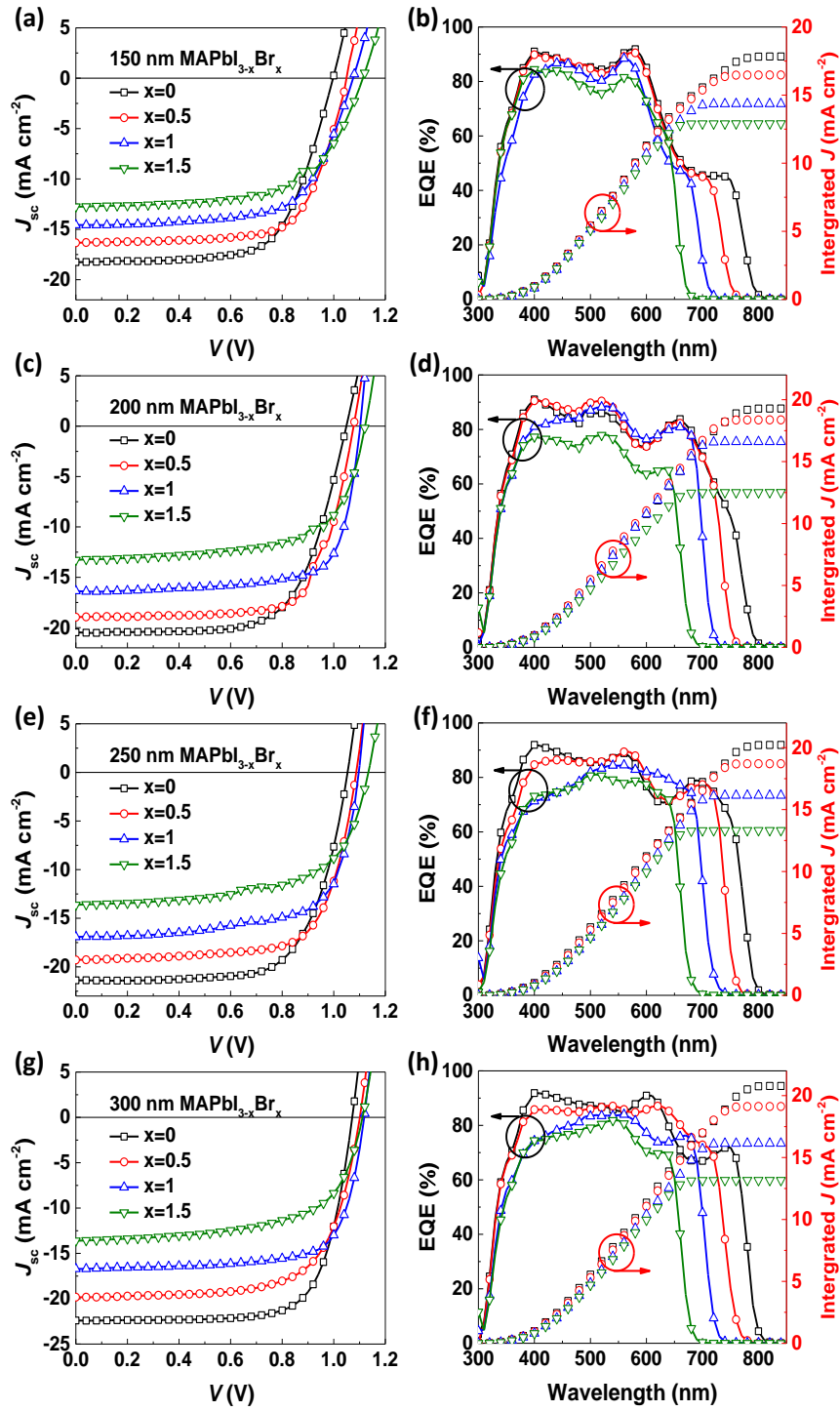


Figure S2. The J - V and EQE curves of opaque Pero-SCs with different thicknesses of $\text{MAPbI}_{3-x}\text{Br}_x$ ($x=0, 0.5, 1$ and 1.5) films, (a),(b) 150 nm, (c), (d) 200 nm, (e),(f) 250 nm and (g),(h) 300 nm.

Table S1. Photovoltaic parameters of opaque Pero-SCs with different thicknesses of MAPbI_{3-x}Br_x (x=0, 0.5, 1 and 1.5).
150 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	1.00	18.25	66.4	12.08
x=0.5	1.05	16.33	69.4	11.90
x=1	1.08	14.58	65.8	10.30
x=1.5	1.11	12.75	62.2	8.80

200 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	1.05	20.47	67.0	14.39
x=0.5	1.07	18.56	71.7	14.23
x=1	1.10	16.36	74.3	13.30
x=1.5	1.12	13.23	65.2	9.71

250 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	1.05	21.38	68.5	15.43
x=0.5	1.07	19.35	69.0	14.34
x=1	1.09	16.59	70.8	12.70
x=1.5	1.13	13.62	62.0	9.58

300 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	1.07	22.40	73.0	17.53
x=0.5	1.10	19.83	68.1	14.88
x=1	1.12	16.70	73.5	13.72
x=1.5	1.11	13.60	62.1	9.39

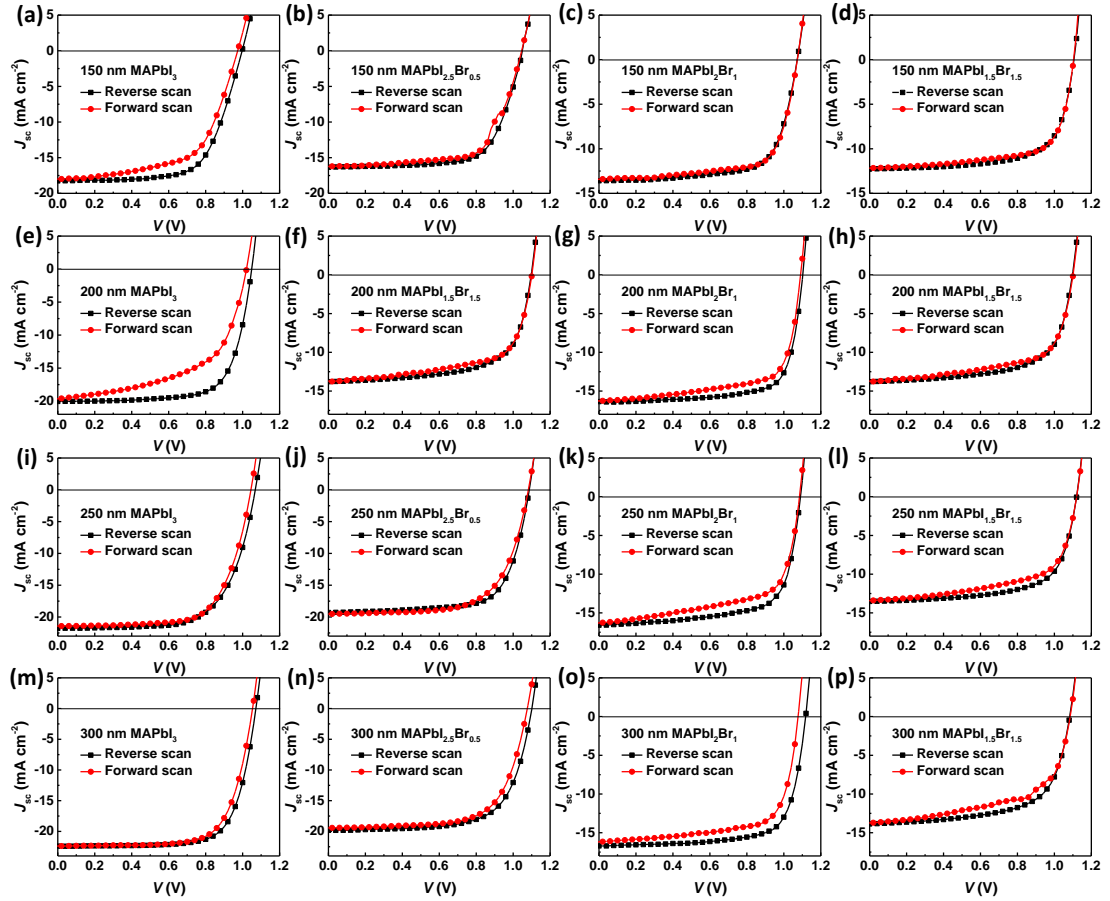


Figure S3. J - V curves of opaque Pero-SCs with different thicknesses of $\text{MAPb}_{3-x}\text{Br}_x$ ($x=0, 0.5, 1$ and 1.5) film using reverse and forward scans under the illumination of AM 1.5G with power of 100 mW cm^{-2} . Scan range $-0.2 - 1.2 \text{ V}$, scan rate 0.02 V s^{-1} , delay time 100 ms .

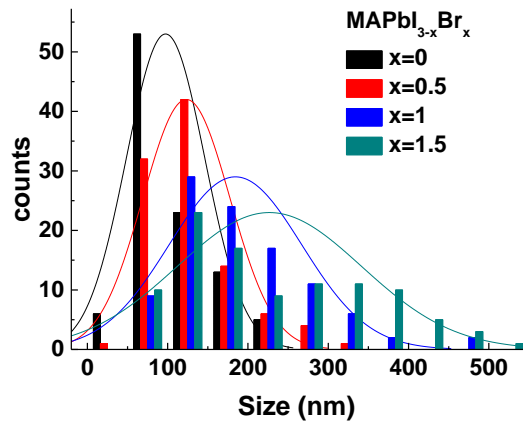


Figure S4. The analysis of grain size in the $\text{MAPb}_{3-x}\text{Br}_x$ ($x=0, 0.5, 1$ and 1.5) films.

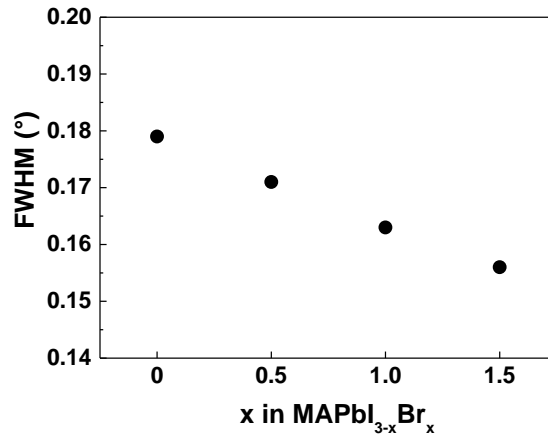


Figure S5. FWHM of the (110) diffraction versus the Br content of MAPbI_{3-x}Br_x films.

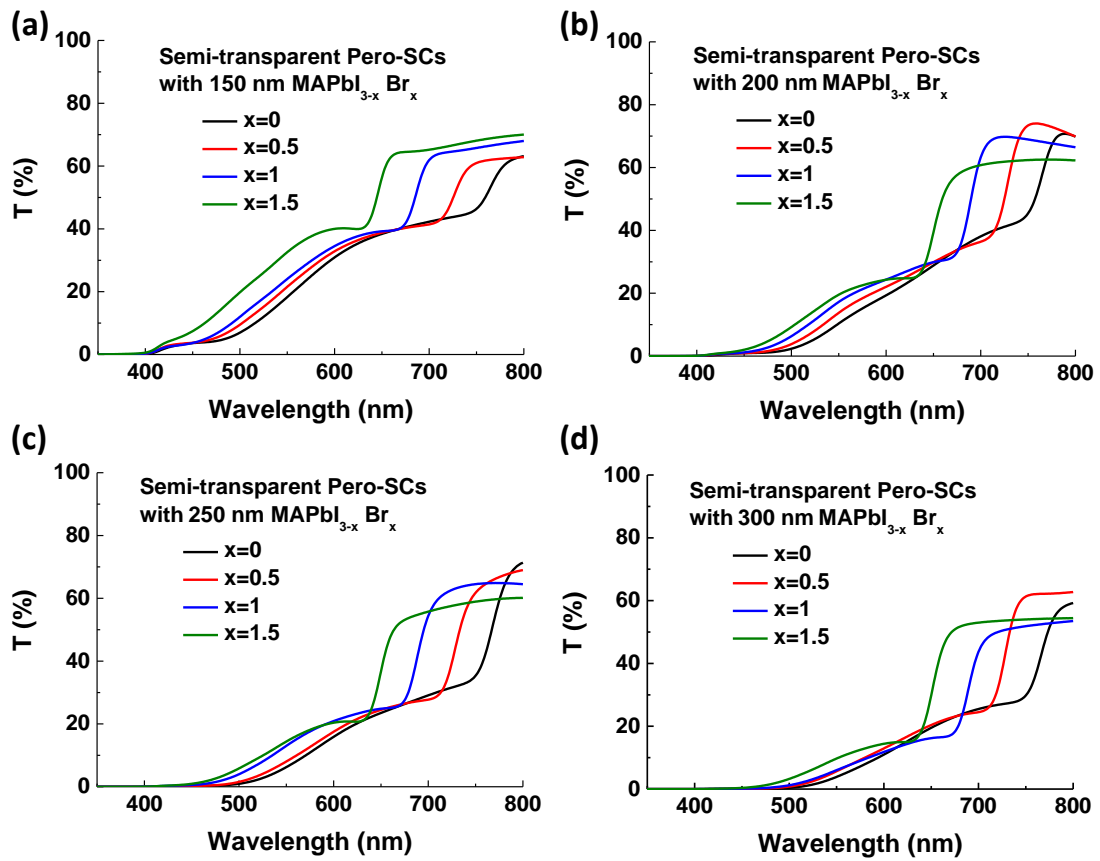


Figure S6. Transparent spectra of semi-transparent Pero-SCs with different thicknesses of MAPbI_{3-x}Br_x ($x=0, 0.5, 1$ and 1.5) film, (a) 150 nm, (b) 200 nm, (c) 250 nm and (d) 300 nm.

Table S2. Photovoltaic parameters of semi-transparent Pero-SCs with different thicknesses of MAPbI_{3-x}Br_x (x=0, 0.5,1 and 1.5) film.

150 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	1.01	15.53	69.0	10.83
x=0.5	1.05	13.58	68.3	9.73
x=1	1.07	11.93	67.1	8.66
x=1.5	1.11	9.77	62.3	6.84

200 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	1.00	17.77	66.6	11.78
x=0.5	1.07	16.21	71.0	12.33
x=1	1.10	14.17	70.7	11.03
x=1.5	1.11	11.85	69.9	9.18

250 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	1.00	19.53	67.6	13.24
x=0.5	1.08	17.12	70.7	13.10
x=1	1.11	15.10	72.8	12.19
x=1.5	1.12	12.37	71.0	9.82

300 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	1.02	20.92	66.3	14.15
x=0.5	1.07	17.60	71.9	13.54
x=1	1.11	15.62	70.2	12.26
x=1.5	1.13	12.79	69.7	10.03

Table S3. Photovoltaic parameters of semi-transparent Pero-SCs with different thicknesses of MAPbI_{3-x}Br_x (x=0, 0.5,1 and 1.5) film measured from Au side.

150 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	0.98	9.09	69.0	5.89
x=0.5	1.01	8.12	66.9	5.50
x=1	1.04	7.11	66.6	4.94
x=1.5	1.05	5.36	58.9	3.41

200 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	0.98	10.82	70.9	7.56
x=0.5	1.04	9.75	72.9	7.38
x=1	1.05	8.15	71.9	6.15
x=1.5	1.06	6.88	70.7	5.17

250 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	0.98	11.56	71.5	8.10
x=0.5	1.04	10.02	72.3	7.59
x=1	1.07	9.13	73.7	7.20
x=1.5	1.06	7.26	71.9	5.56

300 nm thickness of perovskite layer

MAPbI _{3-x} Br _x	V _{oc} (V)	J _{sc} (mA cm ⁻²)	FF (%)	PCE (%)
x=0	0.96	13.42	72.7	9.31
x=0.5	1.04	10.99	71.2	8.29
x=1	1.07	9.67	73.7	7.64
x=1.5	1.08	7.81	69.6	5.88

Table S4. Summary of semi-transparent Pero-SCs reported in the literature.

Active materials	configuration	Active thickness (nm)	Wavelength (nm)	AVT (%)	PCE (%)	Ref.
CH ₃ NH ₃ PbI ₃ island	Glass/FTO/ TiO ₂ / CH ₃ NH ₃ PbI ₃ island /spiro-OMeTAD/Au	-----	370-740	30	3.5	[1]
CH ₃ NH ₃ PbI ₃ island	Glass/FTO/TiO ₂ / CH ₃ NH ₃ PbI ₃ island /Octadecyl-trichlorosilane/spiro-OMeTAD/Au	-----	-----	38	6.1	[2]
CH ₃ NH ₃ PbI ₃ island	Glass/Compact TiO ₂ / CH ₃ NH ₃ PbI ₃ island/Spiro-OMeTAD/Au	-----	370-740	34	6.4	[3]
NH ₂ CH=NH ₂ PbI ₃ island	Glass/Compact TiO ₂ /NH ₂ CH=NH ₂ PbI ₃ island/Spiro-OMeTAD/Au	-----	370-740	28	5.2	[3]
CH ₃ NH ₃ PbI ₃ island	FTO/TiO ₂ /PS interlayer/ CH ₃ NH ₃ PbI ₃ island/PTAA/PEDOT:PSS	-----	-----	20.9	6.17	[4]
CH ₃ NH ₃ PbI ₃ grid	FTO glass/ compact TiO ₂ /mesoporous TiO ₂ /grid of CH ₃ NH ₃ PbI ₃ /Au	-----	400-800	19	4.98	[5]
CH ₃ NH ₃ PbI ₃	Glass/ITO/PEDOT:PSS/CH ₃ NH ₃ PbI ₃ /PCBM/Au/LiF	40	400-800	35	3.4	[6]
		100		29	6.4	
		180		22	7.3	
		280		10	7.73	
CH ₃ NH ₃ PbI ₃	Glass/CuSCN/CH ₃ NH ₃ PbI ₃ /PCBM/Ag	180	-----	25	10	[7]
		240		13	10.7	
CH ₃ NH ₃ PbI _{3-x} Cl _x	ITO glass/PEDOT:PSS/CH ₃ NH ₃ PbI _{3-x} Cl _x /PC ₆₀ BM/ZnO/Ag NW	150	-----	28.4	8.49	[8]
		70		37	7.81	
CH ₃ NH ₃ PbI _{3-x} Cl _x	ITO glass/PEDOT:PSS/CH ₃ NH ₃ PbI _{3-x} Cl _x /PC ₆₀ BM/ZnO/Ag NW	100	370-740	29	9.55	[9]
		129		23	10.81	
		339		14	14	
CH ₃ NH ₃ PbI ₃	ITO Glass/PEDOT:PSS/CH ₃ NH ₃ PbI ₃ /ALD ZnO/Ag NW/ALD Al ₂ O ₃ -coated PET	220	380-750	25.5	10.8	[10]
		54		31	5.3	
CH ₃ NH ₃ PbI ₃	Glass/FTO/TiO ₂ /CH ₃ NH ₃ PbI ₃ /Spiro-OMeTAD/MoO ₃ /Au/MoO ₃	107	370-740	19	8.8	[11]
		141		16	10.1	
		280		7	13.6	
CH ₃ NH ₃ PbI ₃	Glass/FTO/TiO ₂ /CH ₃ NH ₃ PbI ₃ /HTL with PEDOT/ITO glass	5000 rpm	-----	17.3	12.55	[12]
		4500 rpm		15.3	13.25	
		4000 rpm		12.5	14.35	
		3500 rpm		9.6	14.5	

		3000 rpm		7.8	15.1	
		2500 rpm		6.3	15.8	
CH ₃ NH ₃ PbI ₃	Glass/FTO/ZnO/PCBM/CH ₃ NH ₃ PbI ₃ / Spiro-OMeTAD/MoO ₃ /In ₂ O ₃ :H	----	----	----	14.5	[13]
CH ₃ NH ₃ PbI _{3-x} Cl _x	Glass/Au/PEDOT: PSS/CH ₃ NH ₃ PbI _{3-x} Cl _x / PCBM/DMD	240	500-800	15.9	8.67	[14]
CH ₃ NH ₃ PbI _{3-x} Cl _x	TO/PEDOT:PSS/ CH ₃ NH ₃ PbI _{3-x} Cl _x : PVP/CYTOP/PCBM/PEIE/Ag	90	400-800	34	5.36	[15]
CH ₃ NH ₃ PbI ₃	glass/ITO/PEDOT:PSS/CH ₃ NH ₃ PbI ₃ /P CBM/C ₆₀ /Al	150 110	400-800	29 34	9.4 8.2	[16]
CH ₃ NH ₃ PbI _{3-x} Cl _x	Glass/FTO/compact TiO ₂ /SiO ₂ HC/ CH ₃ NH ₃ PbI _{3-x} Cl _x /Spiro-OMETAD/Ag	----	380-780	28	9.5	[17]
CH ₃ NH ₃ PbI ₃	FTO/TiO ₂ /PCBM/ CH ₃ NH ₃ PbI ₃ /Sprio- OMeTAD/PEDOT:PSS	100	----	23	8.23	[18]
CH ₃ NH ₃ PbI ₃	Glass/ITO/PEDOT:PSS/CH ₃ NH ₃ PbI ₃ /P CBM/Au	150 -----	370-740	18 3	9.1 12	[19]

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