Highly Efficient Perovskite Solar Cells with All-Dip-Coating Processed $(CH_3)_3NPbI_{3-x}Cl_x$ Perovskite Materials from Aqueous Non-halide Lead Precursor

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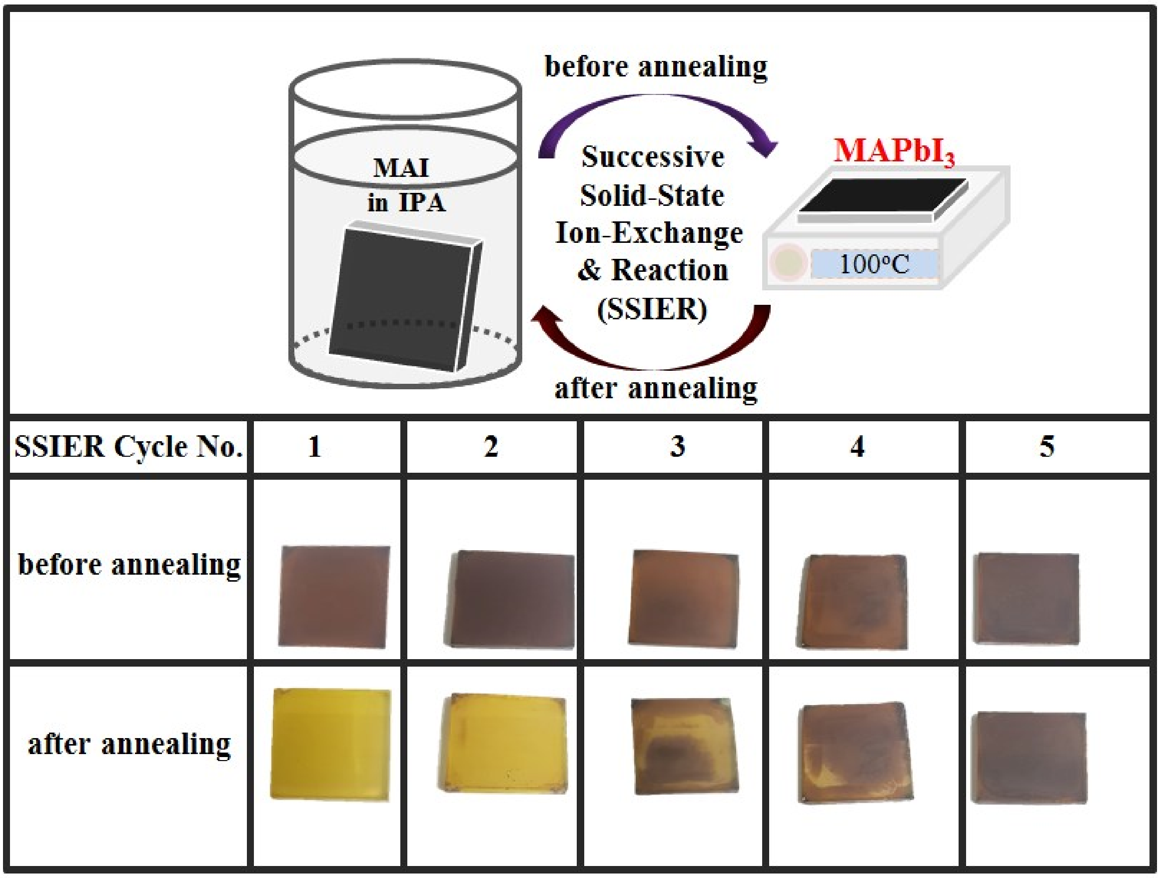

Figure. S1: Photographic images of $MAPbI_3$ perovskite material deposited by sequentially dipping a ZnO-covered TiO_2/FTO substrate in aqueous $Pb(NO_3)_2$ and MAI mixed solutions followed by repetition of the SSIER process before/after annealing at 100°C

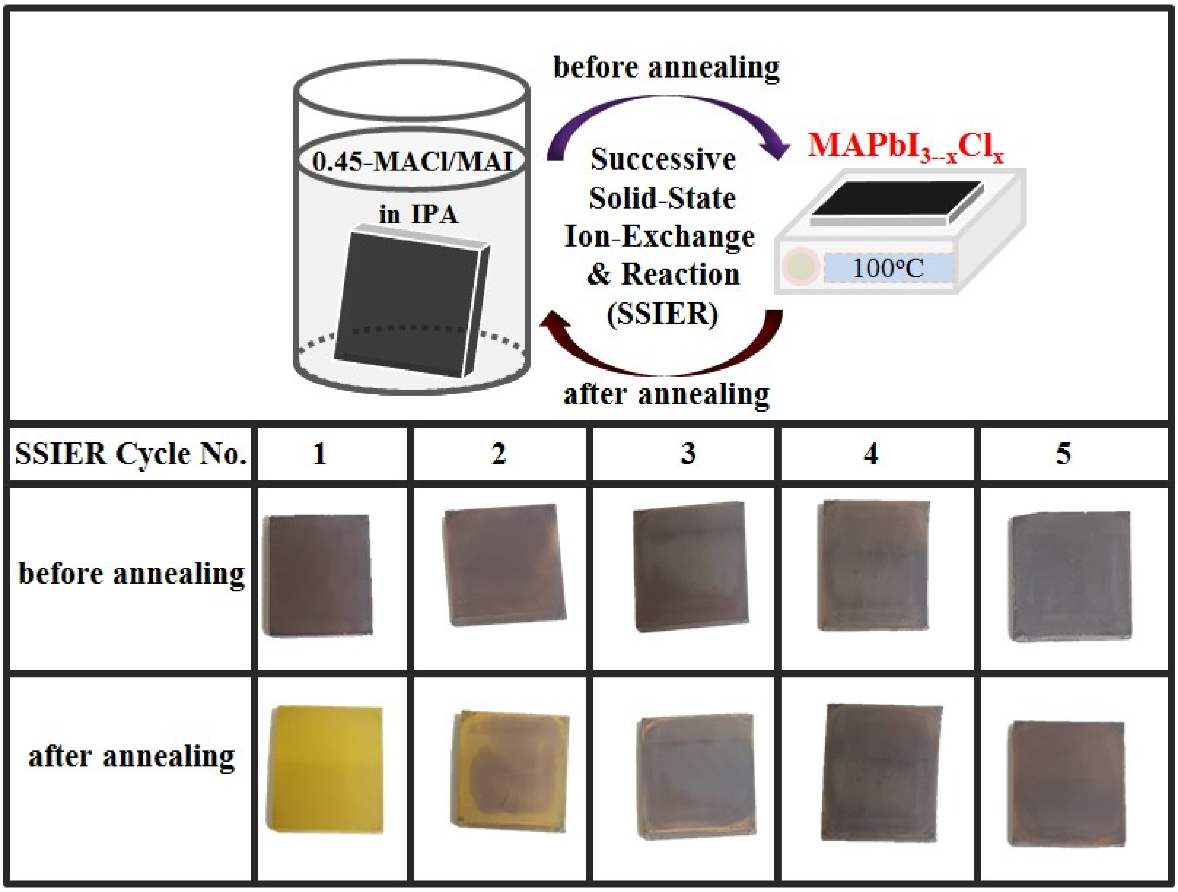

Figure. S2: Photographic images of $MAPbI_{3-x}Cl_x$ perovskite material deposited by sequentially dipping a ZnO-covered TiO_2/FTO substrate in aqueous $Pb(NO_3)_2$ and 0.45-MACl/MAI mixed solutions followed by repetition of the SSIER process before/after annealing at 100°C.

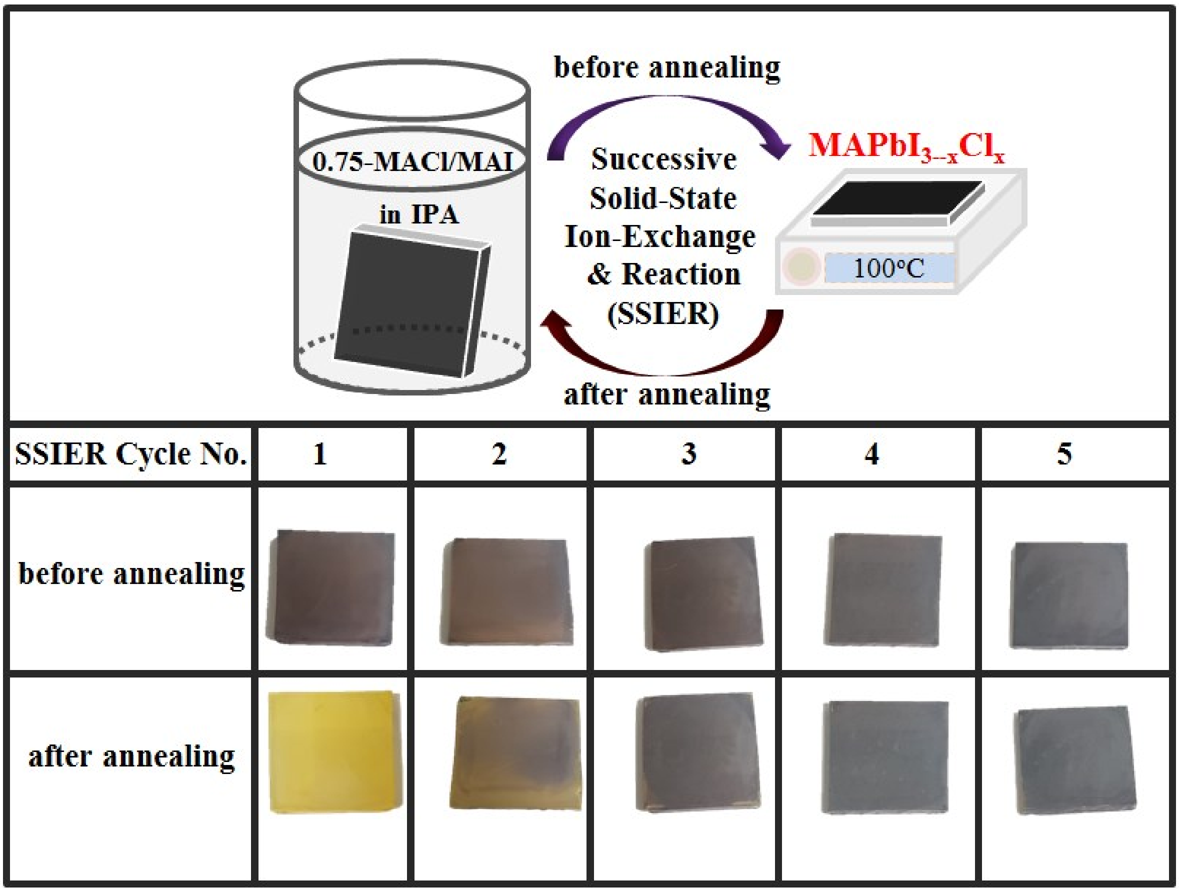

Figure. S3: Photographic images of $MAPbI_{3-x}Cl_x$ perovskite material deposited by sequentially dipping a ZnO-covered TiO_2/FTO substrate in aqueous $Pb(NO_3)_2$ and 0.75-MACl/MAI mixed solutions followed by repetition of the SSIER process before/after annealing at 100°C.

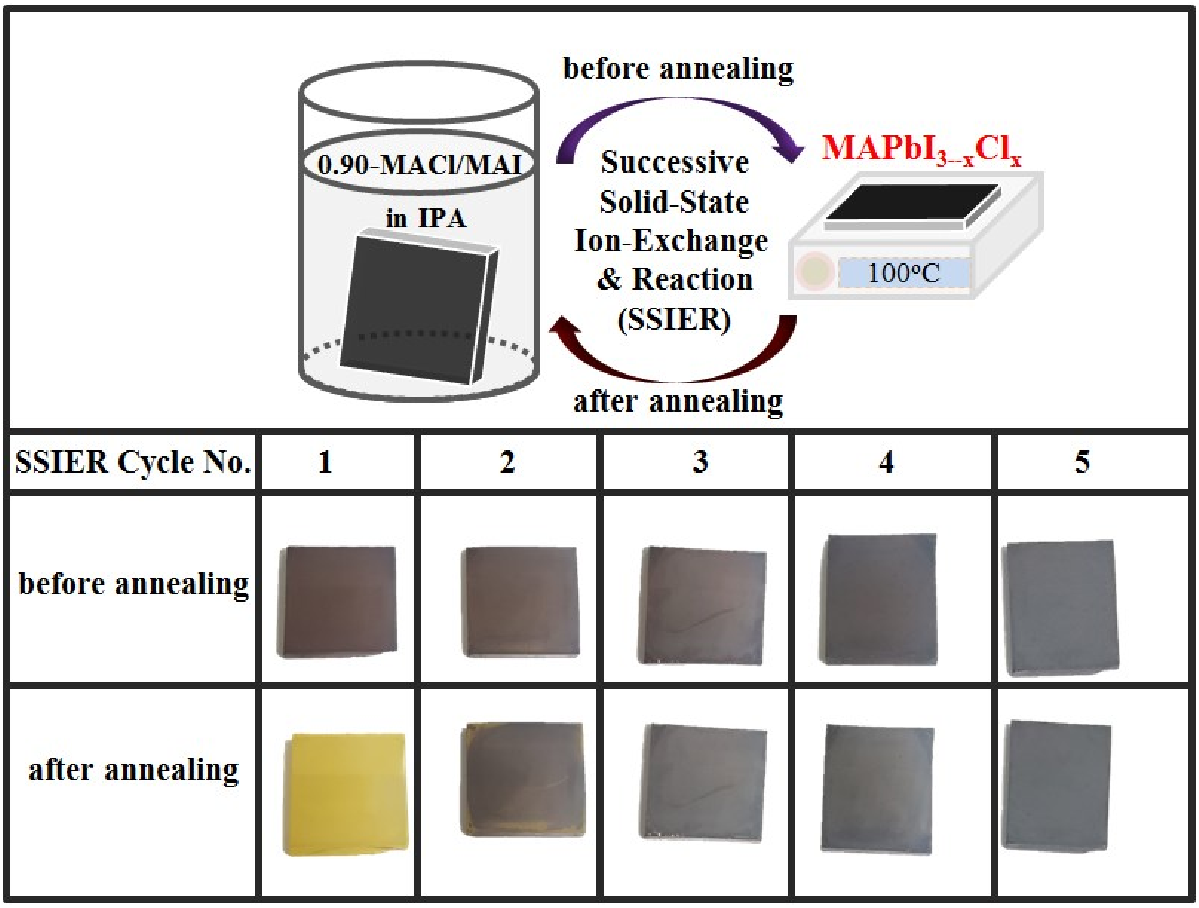

Figure. S4: Photographic images of $MAPbI_{3-x}Cl_x$ perovskite material deposited by sequentially dipping a ZnO-covered TiO_2/FTO substrate in aqueous $Pb(NO_3)_2$ and 0.90-MACl/MAI mixed solutions followed by repetition of the SSIER process before/after annealing at 100°C.

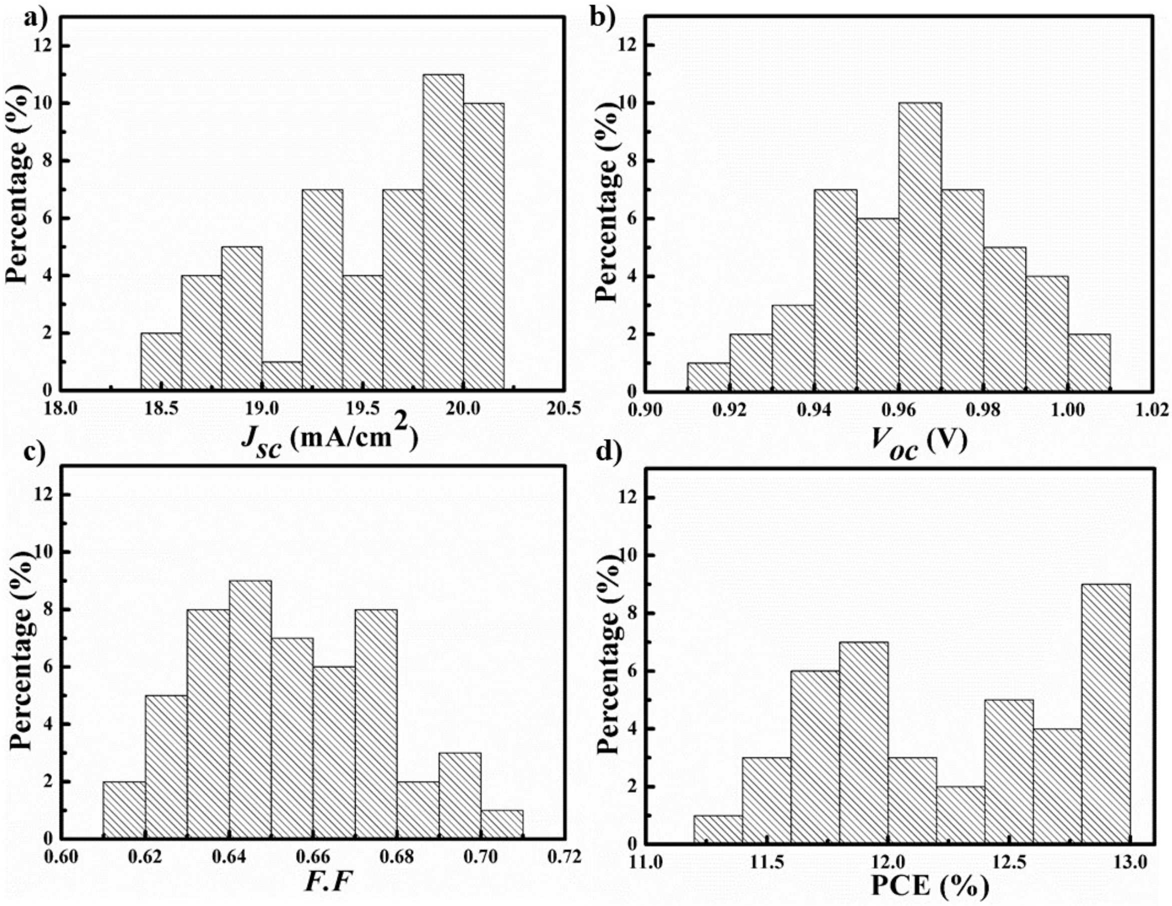

Figure S5: Device performances statistics based on more than 200 individual with $MAPbI_{3-x}Cl_x$ perovskite layers fabricated via a simple all-dip-coating approach in 0.45-MACl/MAI under the optimized conditions.

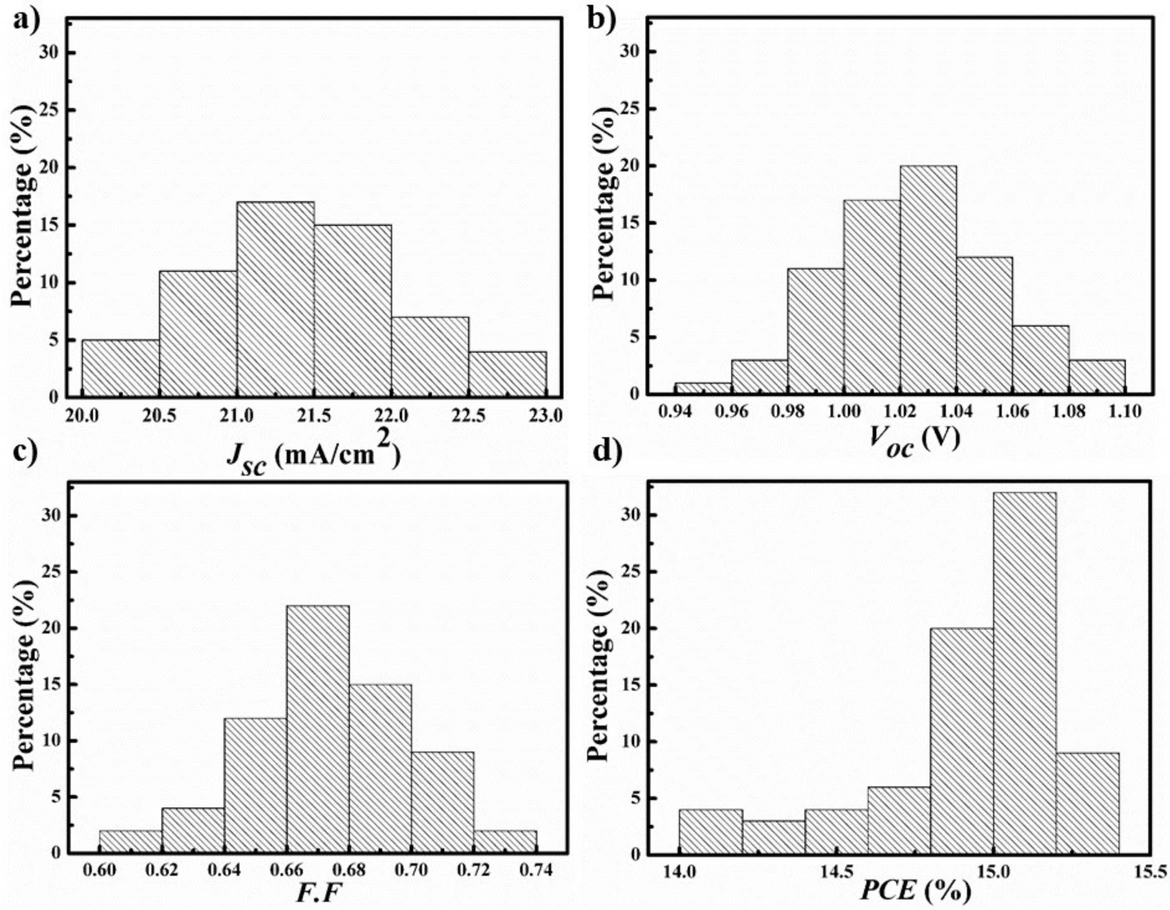

Figure S6: Device performances statistics based on more than 200 individuals with $MAPbI_{3-x}Cl_x$ perovskite layers fabricated via a simple all-dip-coating approach in 0.75-MACl/MAI under the optimized conditions.

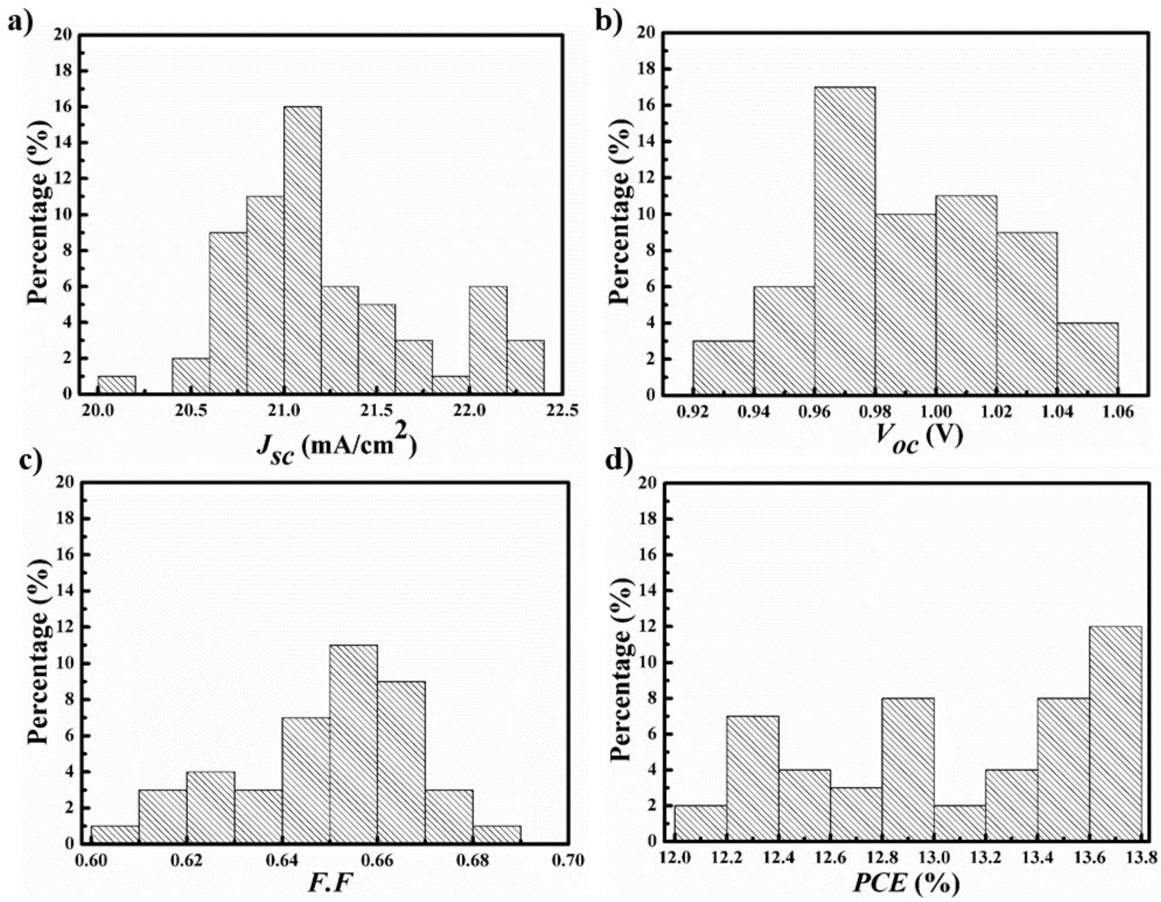

Figure S7: Device performances statistics based on more than 200 individuals with $MAPbI_{3-x}Cl_x$ perovskite layers fabricated via a simple all-dip-coating approach in 0.90-MACl/MAI under the optimized conditions.

Table S1: The core level XPS characterization of composition evolution of Pb, I, and Cl elements found in $MAPbI_{3-x}Cl_x$ perovskite material deposited by sequentially dipping a ZnO-covered TiO_2/FTO substrate in aqueous $Pb(NO_3)_2$ and MACl/MAI mixed solutions.

Elements	0.45-MACl/MAI (%)	0.75-MACl/MAI (%)	0.91-MACl/MAI (%)
Pb	14.31	18.88	20.4
I	85.15	80.17	77.18
Cl	0.54	0.95	2.42
Cl/I	0.63	1.18	3.14

Table S2. Hhysteresis of the photovoltaic performances in both scan directions for the PrSC devices with the $MAPbI_{3-x}Cl_x$ perovskite layer prepared in MACl/MAI.[a]

MACl/MAI	Scan	J_{sc} (mA/cm^2)	V_{oc} (V)	$F{\cdot}F$	$\eta_{max/ave}$(%)
0.45-MACl/MAI	Forward	21.82	0.94	0.58	11.90
	Reverse	20.09	0.99	0.65	12.93
	Average	20.96	0.97	0.62	12.42
0.75-MACl/MAI	Forward	20.82	1.00	0.68	14.16
	Reverse	21.31	1.04	0.69	15.29
	Average	21.07	1.02	0.69	14.73
0.91-MACl/MAI	Forward	22.35	0.94	0.59	12.40
	Reverse	21.11	0.99	0.66	13.79
	Average	21.73	0.97	0.63	13.10

[a)] The performances are determined under simulated 100 mW/cm^2 AM 1.5G illumination. The light intensity using calibrated standard silicon solar cells with a proactive window made from KG5 filter glass traced to the National Renewable Energy Laboratory. A non-reflective metal plate mask with an aperture of 4.5 mm^2 was used for the solar cells.