Supplementary Information

# Effective stability enhancement in ZnO-based perovskite solar cells by MACl modification

Chunyu Liu,[ab] Wei Wu,[a] Dezhong Zhang,[c] Zhuowei Li,[a] Guanhua Ren,[a] Wenbin Han,[a] Wenbin Guo*[a]

[a] State Key Laboratory of Integrated Optoelectronics, College of Electronic Science and Engineering, Jilin University, 2699 Qianjin Street, Changchun 130012, P. R. China
[b] College of Materials Science and Engineering, Jilin University, 2699 Qianjin Street, Changchun 130012, P. R. China
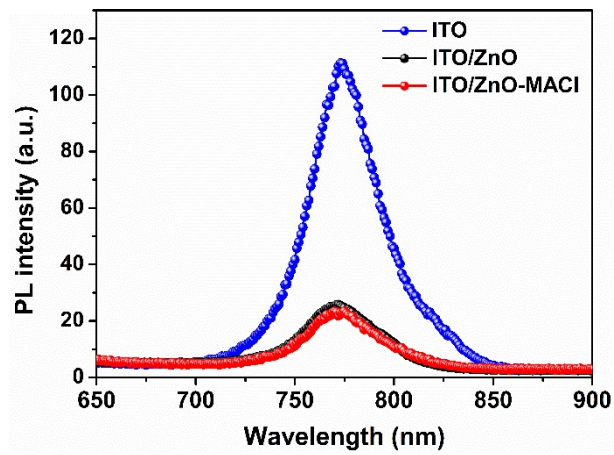[c] State Key Laboratory of Polymer Physics and Chemistry, Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, Changchun 130022, P. R. China
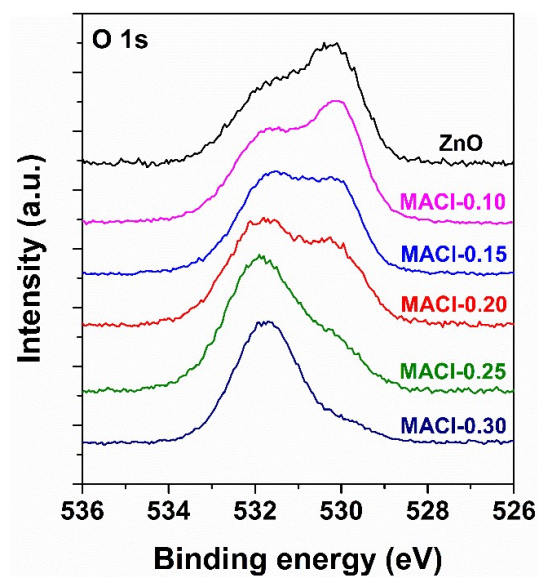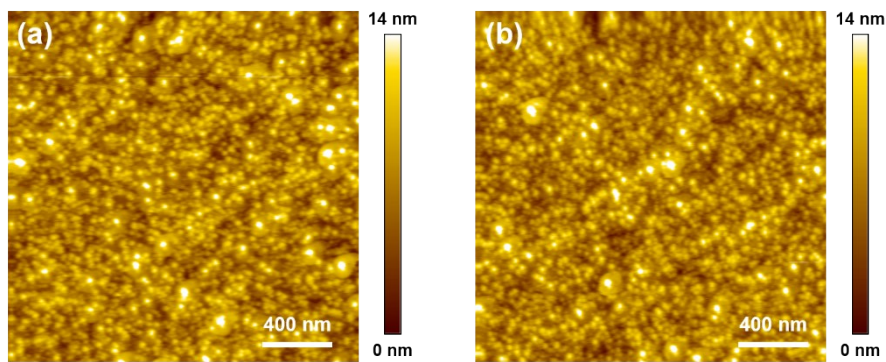
Fig. S1 XPS spectra of ZnO and ZnO-MACl with different concentrations of MACl depicting the O 1s peaks.
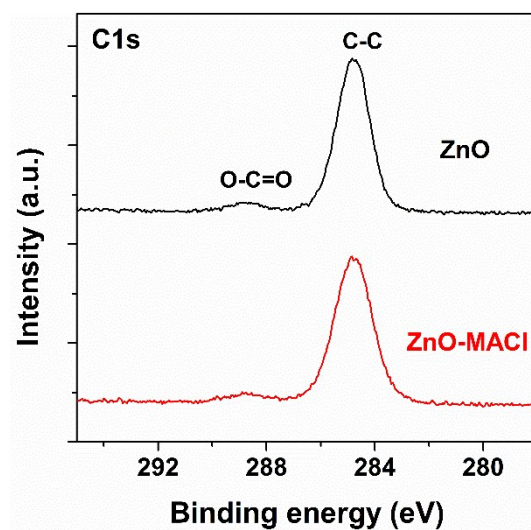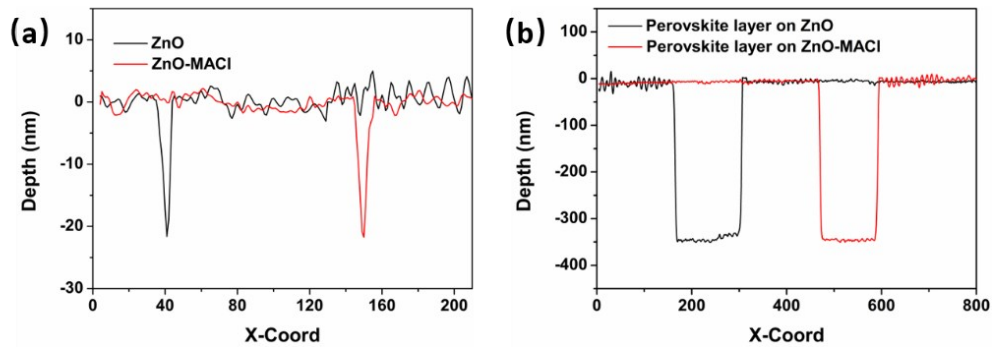

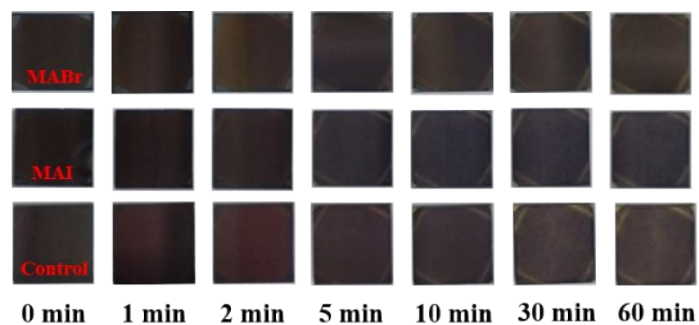**Fig. S2** XPS spectra depicting the C 1s peaks.

Fig. S3 PL spectra of MAPbI$_3$ layers on ITO, ITO/ZnO and ITO/ZnO-MACl.
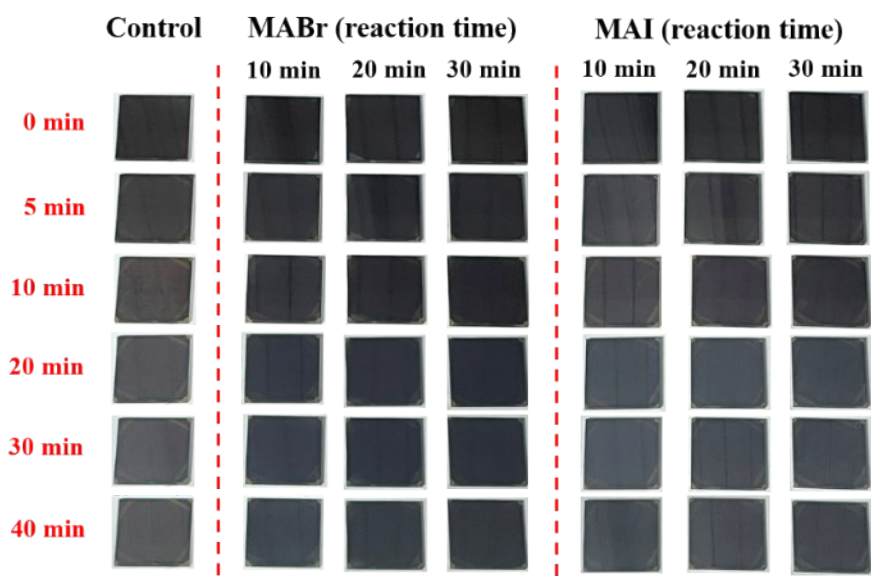

**Fig. S4** AFM images of (a) ZnO and (b) ZnO-MACl with a high magnification.

Fig. S5 Thickness measurements of (a) ETLs and (b) ETL/perovskite layers.

0 min   1 min   2 min   5 min   10 min   30 min   60 min

Fig. S6 Thermal stability of perovskite layers on ZnO-MABr, ZnO-MAI and bare ZnO (control) with the molar concentration of 0.02 mmol/mL.


Fig. S7 Thermal stability of perovskite layers on ZnO-MABr and ZnO-MAI with different reaction time of 10, 20 and 30 min.
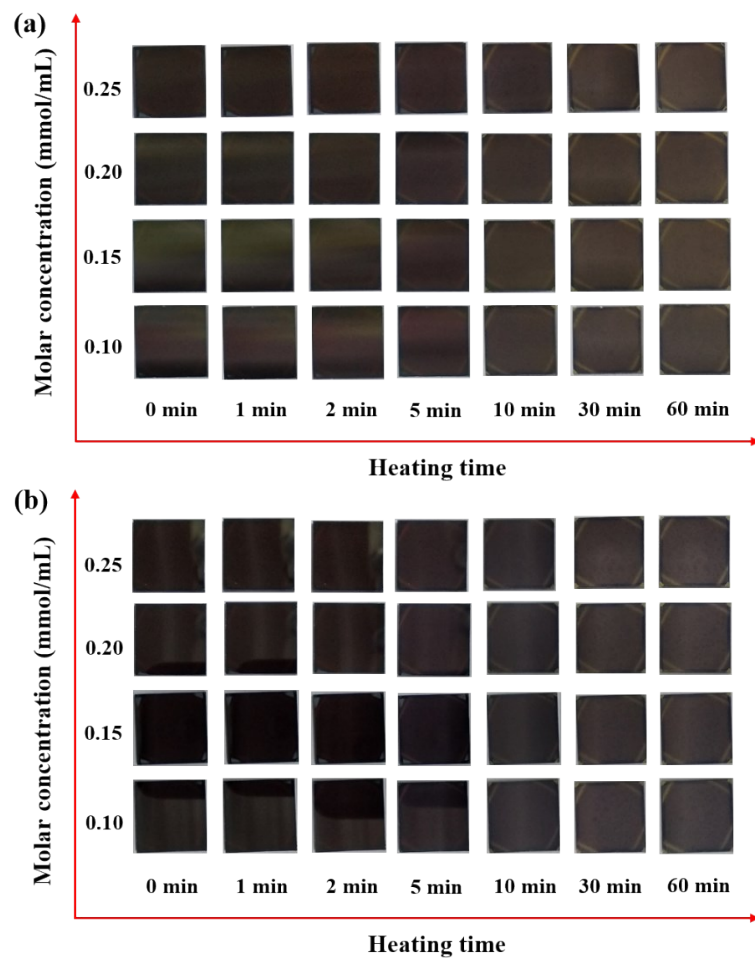
Fig. S8 Photographs of perovskite layer on (a) ZnO-KCl and (b) ZnO-CsCl heated at 100 ℃ for different times, and the molar concentrations of KCl and CsCl are 0.10, 0.15, 0.20 and 0.25 mmol/mL.
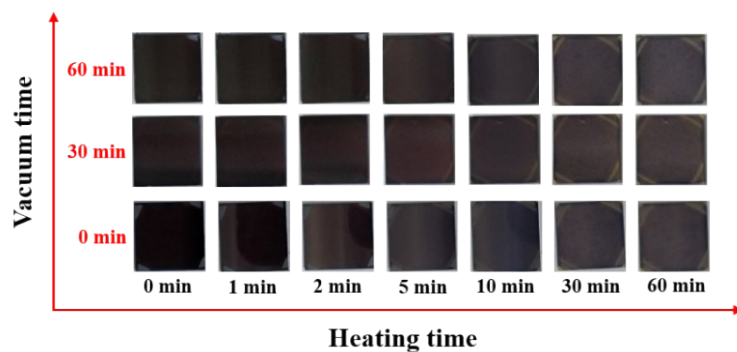
Fig. S9 Photographs of perovskite layers on ZnO/MACl heated at 100 ℃ for different times, and the modified MACl is not annealed but vacuum treated for different times before depositing perovskite layer.
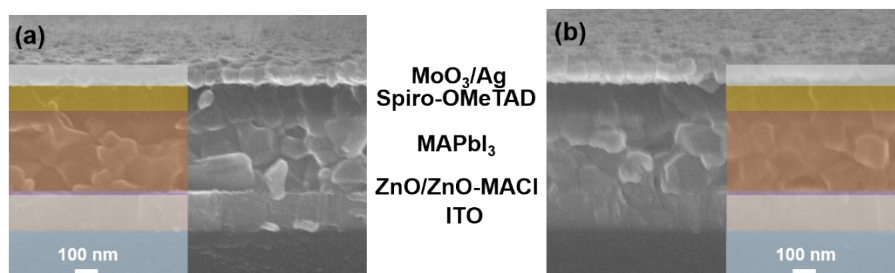
Fig. S10 Cross-sectional SEM images of PSCs based on (a) ZnO and (b) ZnO-MACl layers.
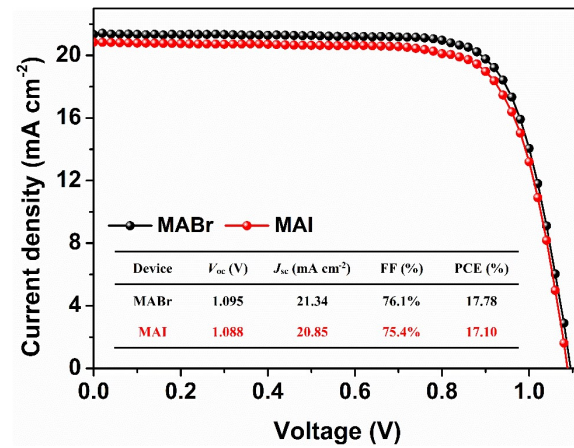
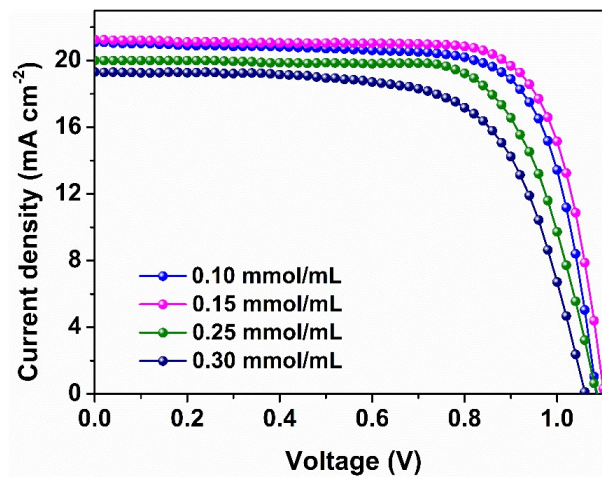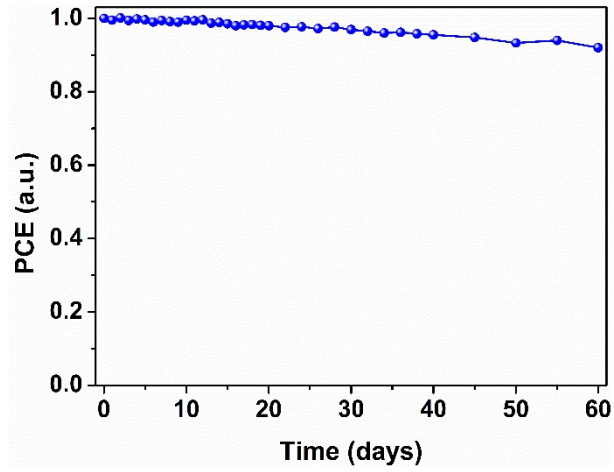**Fig. S11** *J-V* characteristics of PSCs with MABr and MAI modification.

Fig. S12 *J-V* characteristics of ZnO-MACl-based PSCs with different molar concentrations of MACl.

Fig. S13 Long-term stability of inorganic CsPbI$_2$Br-based PSCs with ZnO-MACl layer stored in glove-box for 60 days.

Table S1. Photovoltaic parameters of PSCs with ZnO and ZnO-MACl measured by forward and reverse scans, including V_{oc}, J_{sc}, FF and PCE.

PSCs Devices		V_{oc} (V)	J_{sc} (mA cm^{-2})	FF (%)	PCE (%)
ZnO	Reverse	1.083	20.76	73.6	16.55
	Forward	1.060	19.93	61.4	12.97
ZnO-MACl	Reverse	1.107	21.96	77.1	18.74
	Forward	1.097	21.64	75.3	17.88

Table S2. Detailed photovoltaic parameters of ZnO-MACl-based PSCs with varied molar concentrations of MACl.

Concentrations (mmol/mL)	V_{oc} (v)	J_{sc} (mA cm^{-2})	FF (%)	PCE (%)
0.10	1.085	21.08	74.4	17.02
0.15	1.101	21.49	75.7	17.91
0.25	1.088	20.20	71.4	15.69
0.30	1.061	19.51	67.3	13.93