Supplementary Information

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

Chunyu Liu,ab Wei Wu,ab Dezhong Zhang,bc 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.
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 °C 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 °C 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.

<table>
<thead>
<tr>
<th>Device</th>
<th>$V_{oc}$(V)</th>
<th>$J_{sc}$(mA cm$^{-2}$)</th>
<th>FF (%)</th>
<th>PCE (%)</th>
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<tbody>
<tr>
<td>MABr</td>
<td>0.995</td>
<td>21.34</td>
<td>74.1%</td>
<td>17.78</td>
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<td>MAI</td>
<td>1.088</td>
<td>20.85</td>
<td>75.4%</td>
<td>17.10</td>
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**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.

<table>
<thead>
<tr>
<th>PSCs Devices</th>
<th>$V_{oc}$ (V)</th>
<th>$J_{sc}$ (mA cm$^{-2}$)</th>
<th>FF (%)</th>
<th>PCE (%)</th>
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<tbody>
<tr>
<td>ZnO Reverse</td>
<td>1.083</td>
<td>20.76</td>
<td>73.6</td>
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<tr>
<td>ZnO Forward</td>
<td>1.060</td>
<td>19.93</td>
<td>61.4</td>
<td>12.97</td>
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<tr>
<td>ZnO-MACl Reverse</td>
<td>1.107</td>
<td>21.96</td>
<td>77.1</td>
<td>18.74</td>
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<tr>
<td>ZnO-MACl Forward</td>
<td>1.097</td>
<td>21.64</td>
<td>75.3</td>
<td>17.88</td>
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Table S2. Detailed photovoltaic parameters of ZnO-MACl-based PSCs with varied molar concentrations of MACl.

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