Supporting Information

Boosting the Performance of Planar Heterojunction Perovskite Solar Cell by Controlling the Precursor Purity of Perovskite Materials

Jingjing Chang,†a,b Hai Zhu,†c Bichen Li,a Furkan Halis Isikgor,a Yue Hao,b Qinghua Xu,*c Jianyong Ouyang* a

Figure S1. J-V curves of perovskite solar cell device based on low purity perovskite thin film under different scan directions.
Figure S2. $J$-$V$ curves of perovskite solar cell device based on different impurities in the precursor solutions.
**Figure S3.** The FE-SEM images of low purity (a) and high purity (b) based perovskite thin films. The scale bar is 400 nm.

**Figure S4.** The dark J-V curves of the electron-only devices and hole-only device based on low purity and high purity thin films.
Figure S5. The UPS spectra of MAPbI$_3$ with Fermi level and VBM of around 4.30 eV and 5.70 eV, respectively. Considering its bandgap of about 1.58 eV, the CBM of MAPbI$_3$ is calculated to be around 4.12 eV.

The carrier diffusion length was calculated via the 1D diffusion model, well described in Xing, et al’s work, and temporal total charge number $N(t)$ is given by equation S1:

$$N(t) = \frac{2n_p L}{\pi} \exp(-kt) \sum_{m=0}^{\infty} \left( \exp\left(-\frac{\pi^2 D}{L^2} (m+\frac{1}{2})^2 t \right) \frac{\exp(-\alpha L) \pi (m+\frac{1}{2})^2 + (-1)^m \alpha L}{((\alpha L)^2 + \pi^2 (m+\frac{1}{2})^2)(m+\frac{1}{2})} \right)$$

Where L is the thickness of perovskite thin films, $k$ is the PL decay rate in absence of quenchers.

Table S1. Bleaching kinetics fitting parameters for high and low purity perovskite thin films.

<table>
<thead>
<tr>
<th></th>
<th>$A_1$</th>
<th>$\tau_1$</th>
<th>$A_2$</th>
<th>$\tau_2$</th>
<th>$x_1$</th>
<th>$x_2$</th>
<th>$y_0$</th>
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<tr>
<td>High purity</td>
<td>0.2628</td>
<td>1.639±0.138</td>
<td>0.7056</td>
<td>335.4±2.44</td>
<td>2.645</td>
<td>3.143</td>
<td>0.2376</td>
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<td>Low purity</td>
<td>0.8269</td>
<td>1.727±0.085</td>
<td>0.8231</td>
<td>246.6±11.4</td>
<td>1.471</td>
<td>3.641</td>
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