Supporting Information

Ionic Liquid Modified SnO$_2$ Nanocrystals as the Robust Electron Transporting Layer for Efficient Planar Perovskite Solar Cells

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Fig. S1. TEM images of (a) n-SnO$_2$ nanoparticles, (b) fresh TMAH-modified SnO$_2$ nanoparticles and (c) TMAH-modified SnO$_2$ store for 12 hs. (d), (e) and (f) are the corresponding HRTEM images of (a), (b) and (c), respectively.

Fig. S2. Dispersion of SnO$_2$ nanoparticles at 0 h and 12 h. A without TMAH; B with TMAH modification.
**Fig. S3.** Raman spectra of soda lime glass substrate (black line), n-SnO$_2$ on soda lime glass (red line), and TMAH-SnO$_2$ on soda lime glass. The dark dot indicate the Raman shift for soda lime glass. Peak located at about 753 cm$^{-1}$ is a signal of TMAH.

**Fig. S4.** Optimization of the ETL deposition process. The (a) annealing temperature, (b) TMAH concentration, and (c) spin-coating speed dependent performance of the PSCs. It can be learned that 1 % concentration of TMAH, 2000 rpm of spin coating rate, and 150 °C of annealing temperature is optimized for efficient devices.
Fig. S5. Optical transmittance of the (a) bare FTO and SnO$_2$ coated FTO substrates, and (b) bare ITO and SnO$_2$ coated ITO substrates.

Fig. S6. (a) Morphology and (b) $I$-$V$ curve of a FTO substrate from c-AFM measurement, showing ohm contact between the tip and the FTO electrode.
**Table S1.** Summary of hall measurements on SnO$_2$ films

<table>
<thead>
<tr>
<th>Materials</th>
<th>Sheet resistance (MΩ)</th>
<th>Resistivity (ohm·cm)</th>
<th>Mobility (cm$^2$·V$^{-1}$·s$^{-1}$)</th>
<th>Carrier concentration (cm$^{-3}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-SnO$_2$</td>
<td>214</td>
<td>1.81×10$^2$</td>
<td>3.02</td>
<td>1.14×10$^{16}$</td>
</tr>
<tr>
<td>TMAH-SnO$_2$</td>
<td>58</td>
<td>1.20×10$^2$</td>
<td>4.16</td>
<td>1.24×10$^{16}$</td>
</tr>
</tbody>
</table>

**Fig. S7.** Surface SEM images for perovskite deposited on (a) n-SnO$_2$, (b) 0.5% TMAH-SnO$_2$, (c) 1% TMAH-SnO$_2$, (d) 1.5% TMAH-SnO$_2$ and (e) 2% TMAH-SnO$_2$, respectively.
Fig. S8. Stability tests for n-SnO$_2$ based and TMAH-SnO$_2$ based devices sealed with resin. Devices were stored in desiccator under relative humidity of about 15%.

Fig. S9. $J$-$V$ curve of a flexible TMAH-SnO$_2$ based device constructed on ITO/PEN substrate, showing an efficiency of about 15.07%.