Supporting information for

Passivation of oxygen and light induced degradation by the PCBM electron transport layer in planar perovskite solar cells

Chieh-Ting Lin\textsuperscript{ab}, Sebastian Pont\textsuperscript{a}, Jinhyun Kim\textsuperscript{a}, Tian Du\textsuperscript{ab}, Shengda Xu\textsuperscript{b}, Xiaoe Li\textsuperscript{a}, Daniel Bryant\textsuperscript{ac}, Martyn A Mclachlan\textsuperscript{b} and James R Durrant\textsuperscript{*ac}

a. Department of Chemistry and Centre for Plastic Electronics, Imperial College London, Exhibition Road, London SW7 2AZ, U.K.
b. Department of Materials and Centre for Plastic Electronics, Imperial College London, Exhibition Road, London SW7 2AZ, U.K.
c. SPECIFIC IKC, College of Engineering, Swansea University, Bay Campus, Fabian Way, Swansea SA1 8EN, U.K.

Corresponding Author

*James R Durrant. E-mail: j.durrant@imperial.ac.uk
Figure S1. Current voltage characteristic of (a) conventional structure device (FTO/compact-TiO$_2$/meso-TiO$_2$/CH$_3$NH$_3$PbI$_3$/spiro-OMeTAD/Au) (b) Inverted structure device with BCP/Cu contact (ITO/PTAA/CH$_3$NH$_3$PbI$_3$/PCBM/BCP/Cu) (c) Inverted structure device with Au contact (ITO/PTAA/CH$_3$NH$_3$PbI$_3$/PCBM/Au) (d) External quantum efficiency (EQE) of inverted structure and conventional structure devices. The integrated current shown 18.8 mA/cm$^2$ for inverted structure device and 18.0 mA/cm$^2$ for conventional structure. The difference between EQE and JV measurement may attributed to larger barrier for photocurrent while the EQE is measured under low light intensity.
Table S1. The device performance of conventional and inverted structure solar cell shown in Figure S1.

<table>
<thead>
<tr>
<th></th>
<th>Voc [V]</th>
<th>Jsc [mAcm-2]</th>
<th>FF</th>
<th>PCE [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Conventional</td>
<td>1.07 ± 0.01 (1.07)</td>
<td>22.00 ± 0.1 (22.13)</td>
<td>0.71 ± 0.01 (0.72)</td>
<td>16.73 ± 0.25 (17.03)</td>
</tr>
<tr>
<td>b. Inverted (BCP/Cu)</td>
<td>1.10 ± 0.01 (1.10)</td>
<td>22.33 ± 0.62 (22.26)</td>
<td>0.69 ± 0.04 (0.72)</td>
<td>17.05 ± 0.46 (17.7)</td>
</tr>
<tr>
<td>c. Inverted (Au)</td>
<td>1.07 ± 0.03 (1.03)</td>
<td>21.57 ± 0.21 (21.4)</td>
<td>0.57 ± 0.03 (0.61)</td>
<td>13.28 ± 0.19 (13.4)</td>
</tr>
</tbody>
</table>
Figure S2. (a) Normalized PCE stability curve of inverted structure (ITO/PTAA/CH$_3$NH$_3$PbI$_3$/PCBM/Au) and conventional structure (FTO/compact-TiO$_2$/meso-TiO$_2$/CH$_3$NH$_3$PbI$_3$/spiro-OMeTAD/Au). Devices were measured in dry air and continuous illumination as Fig 1. (b) Normalized PCE stability curve of inverted structure device measured in dry air/light condition and N$_2$/light condition.
Figure S3. (a) Photoluminescence of glass/CH$_3$NH$_3$Pbi$_3$ and glass/PCBM/CH$_3$NH$_3$Pbi$_3$ under 1 sun in N$_2$. (b) Normalized optical degradation of glass/CH$_3$NH$_3$Pbi$_3$ and glass/PCBM/CH$_3$NH$_3$Pbi$_3$ film in oxygen and light. Light was provided by LED with 1 sun calibrated by equal Jsc of sealed CH$_3$NH$_3$Pbi$_3$ device under 1 sun measured by solar simulator.
Figure S4. CCD images of films consisted of glass/mesoporous-TiO$_2$/CH$_3$NH$_3$PbI$_3$/PMMA and glass/CH$_3$NH$_3$PbI$_3$/PMMA degraded in dry air/ light condition over time.

Figure S5. Cross-section SEM of (a) glass/ mesoporous-TiO$_2$/CH$_3$NH$_3$PbI$_3$/PMAA (b) glass/CH$_3$NH$_3$PbI$_3$/PMMA
**Experimental Section**

**Perovskite films preparation**
The methylammonium lead iodide (CH$_3$NH$_3$PbI$_3$) precursor solutions were prepared by dissolving PbI$_2$ (Alfa Aesar) and CH$_3$NH$_3$I (Dyesol) into solvent (GBL: DMSO=7:3) at 1.25M and stirred for 6 hours at 25°C. The solutions were filtrated by 0.45 μm filter before deposition. Glass were sonicated in soap, water, acetone and 2-propanol in sequence, dried with nitrogen, followed by oxygen plasma treatment. The perovskite precursor solutions were spin-coated at 4000rpm for 40 seconds and dripped toluene at 20 second before the end of program. At last, the films were dried at 100°C for 10min.

**Conventional structured devices fabrication**
Conventional devices are consisted of FTO/compact-TiO$_2$/meso-TiO$_2$/CH$_3$NH$_3$PbI$_3$/spiro-OMeTAD/Au. The compact TiO$_2$ layer was deposited by spray pyrolysis of titanium diisopropoxide bis(acetylacetonate) solution (Aldrich) on FTO at 400°C. After cooling to room temperature, diluted commercial mesoporous TiO$_2$ paste (Dyesol) was spin-coated on substrate and heated at 450°C to form mp-TiO$_2$ layer. The 0.1M Li-TFSI in acetonitrile were deposited on mp-TiO$_2$ layer and heated at 450°C for 30 minutes. Next, the CH$_3$NH$_3$PbI$_3$ precursor solution was spin-coated on substrates and treated with toluene during the spin-coating program, which is same as film preparation condition. The substrate was dried at 100°C to form the glassy perovskite film. The spiro-OmeTAD (Borun material) in cholorbenzene was doped by bis(trifluoromethane) sulfonimide lithium salt and 4-tert-butylpyridine. After the spiro-OmeTAD layer was spin-coated, the substrate was oxidized in dry box for 24 hours. At last, the Au (70nm) were evaporated on the substrates.

**Inverted structured device fabrication**
Inverted devices are consisted of ITO/PTAA/CH$_3$NH$_3$PbI$_3$/PCBM/BCP/Cu. ITO were rinsed with acetone to remove the photoresist and cleaned with soap, DI water, acetone and 2-propanol, and then blow dry with N$_2$ immediately. Oxygen plasma were treated before deposited PTAA layer. 0.25% PTAA solution were deposited on ITO by spin-coating at 5000 rpm for 20second. Perovskite solution was deposit on substrates by spin-coating with antisolvent treatment and dried at 100°C for 10min. Varies concentration of PCBM solutions (4.5 mg/ml to 27 mg/ml, Ossila) were spin-coated on perovskite at 1300 rpm. BCP solution in ethanol (0.5 mg/ml) was spin-coated at 4000 rpm on substrate. Finally, the 80nm Cu was evaporated on the substrates.

**Environmental stability examination of films**
The stability examination of films was observed in glovebox by monitored the change of average RGB output value.

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\text{Optical degradation} = \frac{|RGBt - RGBdeg|}{|RGB0 - RGBdeg|}
\]

RGBt refer to average value of red-green-blue value at time. RGB0 refer to RGB value of fresh sample. RGBdeg refer to RGB value of degraded sample. The environment of glovebox was controlled by Bridgelux 4000 K LED, humidity control and the atmosphere between dry air and nitrogen. The light intensity of LED was calibrated by matching current of an encapsulated device.
under AM1.5 solar spectrum. Dry air was obtained from ambient air dehumidified by dehumidifier with desiccant column.

**Environmental stability examination of devices**
Initial device performances were determined by JV characteristics which measured in N\textsubscript{2} atmosphere under Xenon lamp. The intensity of Xenon lamp is AM1.5 which is calibrated by silicon reference cell. To investigate the oxygen/light stability of devices, all cells were unencapsulated and placed in chamber with dry air (RH<10%). The temperature is controlled under 35°C. The light intensity is calibrated by matching the current of initial device performances. JV characteristics were scanned every 10 min from 1.2V to -0.5V with the PCE averaged over 60 min periods. Between the measurements the devices were held at open circuit voltage.

**Photoluminescence Spectroscopy**
Photoluminescence spectroscopy (Horiba Jobin Yvon Fluorolog system) and electronic absorption spectra (Shimadazu UV-2600) were used to check the optical material properties. For varying the power density and wavelength of the excitation light for photoluminescence spectroscopy, an external white LED light source with 650 and 700nm short wavelength pass filter was used. Global analyses of the data were carried out by using origin.

**Scanning electron microscopy:**
Scanning electron microscopy (SEM) images were obtained using Gemini LEO 1525, with accelerating voltage of 3-5kv and working distance of 2-5mm.