Faculty of Engineering
School of Photovoltaic and Renewable Energy Engineering

The Effect of Pressing on the Performance of Perovskite Solar Cells

APSRC Canberra Australia Dec. 2019

Lei Shi (Adrian), Meng Zhang, Yongyoon Cho, Trevor L Young, Dian Wang, Haimang Yi, Jincheol Kim, Shujuan Huang, and Anita W. Y. Ho-Baillie
Pressing is an essential step in encapsulation process of commercial solar module

Pressing improves the relative efficiency by 10%
Experiment

**Perovskite solar cell**

- Perovskite = \( \text{Cs}_{0.05}(\text{FA}_{0.85}\text{MA}_{0.15})_{0.95}\text{Pb}(\text{I}_{0.85}\text{Br}_{0.15})_3 \)
- Efficiency 15-17%

---

**Vacuum laminator**

- Room temperature
- Pressing duration 5 min
- Pressing pressure
  - 400 mbar (#LL)
  - 1000 mbar (#LH)
Result (short term)

PCE (%)

25%~75%
Mean ± 1.5 SD
Median Line
Mean

Initial  1st Test
#LL
1st day  3rd day  2nd Test
#LL
3rd day  6th day  10th day

14 15 16 17 18 19 20
14 15 16 17 18 19 20
Result (short term)

- All electrical parameters improved, mainly contributed by FF / $R_S$

- Hysteresis Index = $1 - \frac{PCE (-0.1\ V \to 1.2\ V)}{PCE (1.2\ V \to -0.1\ V)}$
**Experiment**

- Clamp pressing
  - Continuous pressing in N₂ at room temperature
  - Pressing pressure
    - 400-500 mbar (#CL)
    - 1000-1100 mbar (#CH)
Result (long term)

- Initial
- Test #CL 1st day
- Test #CL 7th day
- Test #CL 15th day
- 5th day
- 7th day

PCE (%)

15 16 17 18 19

Initial Test #CL 1st day Test #CL 7th day Test #CL 15th day 5th day 7th day

PCE (%)
Result (long term)

- All electrical parameters improved, mainly contributed by FF / R_s
Result (higher pressure)

Pressing pressure

- 1000 mbar by vacuum lamination (#LH)
- 1000-1100 mbar by clamping (#CH)
Result (higher pressure)

- Main contributor of PCE drop was J_{SC}
Characterisation - XRD

- Pressure-induced effect likely originates from the interfaces
Characterisation – EIS in dark

- Better interfaces: ETL/perovskite or perovskite/HTL?
Characterisation - TRPL

- Two testing structures, 400 mbar / 5 min pressing by lamination:
  1. FTO/c-TiO$_2$/mp-TiO$_2$/perovskite
  2. FTO/perovskite/spiro-OMeTAD

- Perovskite/spiro-OMeTAD interface improved after pressing
Summary

- Perpendicular pressurisation improves PCE by more than 10 % relative on average.
- Pressure must be maintained to maintain the PCE improvement.
- The improvement originates from better perovskite/spiro-OMeTAD interface, not bulk.
- For long term, 400-500 mbar is helpful; 1000-1100 mbar is harmful.

Future work

- The finding inspires innovative encapsulation methods for perovskite solar cell
- Investigate pressing effect on
  - Planar structure;
  - Inverted structure;
  - Cells with polymer and/or fullerene based transport layers.
I would like to thank the research and funding support from

*The Australian Centre for Advanced Photovoltaics (ACAP)*

*Australian Renewable energy Agency (ARENA)*
Questions?

Adrian Shi

adrian.shi@unsw.edu.au
Supporting Information
Supporting Information
### Supporting Information

<table>
<thead>
<tr>
<th>Initial</th>
<th>$R_s$ (Ω·cm²)</th>
<th>$R_c$ (Ω)</th>
<th>$C_c$ (nF)</th>
<th>$R_{Rec}$ (Ω)</th>
<th>CPE-Y (ηMho)</th>
<th>CPE-N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1V</td>
<td>4.8</td>
<td>58.5</td>
<td>58.1</td>
<td>38.3</td>
<td>1260</td>
<td>0.881</td>
</tr>
<tr>
<td>0.9V</td>
<td>4.8</td>
<td>502</td>
<td>48.5</td>
<td>353</td>
<td>128</td>
<td>0.824</td>
</tr>
<tr>
<td>0.8V</td>
<td>5.0</td>
<td>2580</td>
<td>44.5</td>
<td>4310</td>
<td>16.1</td>
<td>0.764</td>
</tr>
<tr>
<td>0.6V</td>
<td>4.8</td>
<td>4790</td>
<td>38.7</td>
<td>86300</td>
<td>2.72</td>
<td>0.821</td>
</tr>
<tr>
<td>0.4V</td>
<td>3.7</td>
<td>6460</td>
<td>39.1</td>
<td>387000</td>
<td>1.35</td>
<td>0.9</td>
</tr>
<tr>
<td>0.2V</td>
<td>4.8</td>
<td>6270</td>
<td>39.3</td>
<td>983000</td>
<td>1.08</td>
<td>0.905</td>
</tr>
<tr>
<td>After Test #L</td>
<td>$R_c$ (Ω)</td>
<td>$C_c$ (nF)</td>
<td>$R_{Rec}$ (Ω)</td>
<td>CPE-Y (ηMho)</td>
<td>CPE-N</td>
<td></td>
</tr>
<tr>
<td>1V</td>
<td>4.6</td>
<td>81.2</td>
<td>60.1</td>
<td>58.5</td>
<td>767</td>
<td>0.86</td>
</tr>
<tr>
<td>0.9V</td>
<td>4.5</td>
<td>642</td>
<td>52</td>
<td>519</td>
<td>78.9</td>
<td>0.83</td>
</tr>
<tr>
<td>0.8V</td>
<td>4.7</td>
<td>2460</td>
<td>45.7</td>
<td>6100</td>
<td>9.1</td>
<td>0.842</td>
</tr>
<tr>
<td>0.6V</td>
<td>4.8</td>
<td>4050</td>
<td>37.1</td>
<td>204000</td>
<td>2.85</td>
<td>0.84</td>
</tr>
<tr>
<td>0.4V</td>
<td>3.5</td>
<td>5100</td>
<td>37.4</td>
<td>1450000</td>
<td>1.49</td>
<td>0.9</td>
</tr>
<tr>
<td>0.2V</td>
<td>3.5</td>
<td>5010</td>
<td>37.5</td>
<td>6020000</td>
<td>1.19</td>
<td>0.905</td>
</tr>
</tbody>
</table>