Data Article

Shelf life stability comparison in air for solution processed pristine PDPP3T polymer and doped spiro-OMeTAD as hole transport layer for perovskite solar cell

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A B S T R A C T

This data in brief includes forward and reverse scanned current density–voltage ($J$–$V$) characteristics of perovskite solar cells with PDPP3T and spiro-OMeTAD as HTL, stability testing conditions of perovskite solar cell shelf life in air for both PDPP3T and spiro-OMeTAD as HTL as per the description in Ref. [1], and individual $J$–$V$ performance parameters acquired with increasing time exposed in ambient air are shown for both type of devices using PDPP3T and spiro-OMeTAD as HTL. The data collected in this study compares the device stability with time for both PDPP3T and spiro-OMeTAD based perovskite solar cells and is directly related to our research article “solution processed pristine PDPP3T polymer as hole transport layer for efficient perovskite solar cells with slower degradation” [2].

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Specifications Table

| Subject area | Physics |
|--------------|---------|
| More specific subject area | Photovoltaics |
| Type of data | Table |
| How data was acquired | Solar Simulator (Xenon lamp-Newport), Agilent semiconductor parameter analyzer 4155C, Springfield precise temp humidity meter |
| Data format | Analyzed |
| Experimental factors | Current density-voltage (J-V) scans of perovskite solar cells with pristine PDPP3T and spiro-OMeTAD based HTL were immediately taken after fabrication. Same cells for stability measurement were used by keeping them in ambient air having 40% RH and scanning at regular interval. |
| Experimental features | J-V scans were carried out in ambient air by illuminating from the bottom electrode FTO contact. |
| Data source location | Department of Electrical Engineering and Computer Science, South Dakota State University, Brookings, SD |
| Data accessibility | Data is with this article. |

Value of the data

- Forward and reverse scanned current density–voltage (J–V) characteristics of perovskite solar cells with PDPP3T and spiro-OMeTAD as HTL can be used to find solar cell performance and demonstrate that PDPP3T is an effective dopant-free HTL. These data can provide guidance to other researchers that conduct similar research.
- Stability testing conditions and perovskite solar cell shelf life in air for both PDPP3T and spiro-OMeTAD as HTL can be used to study lifetime and repeatability measurements [1].
- Individual J–V performance parameters acquired with increasing time exposed in ambient air for both PDPP3T and spiro-OMeTAD based devices can be used to find which HTL leads to longer stability and lower degradation.

1. Data, experimental design, materials and methods

The data here provide device photovoltaic parameters and ambient air stability comparison for two different hole transport layers (PDPP3T and spiro-OMeTAD) based perovskite solar cells. Perovskite solar cells were fabricated with device structure as FTO/compact-TiO₂/mesoporous-TiO₂/Perovskite/HTL/Ag. Two different HTLs were used namely pristine polymer poly(diketopyrrolopyrrole-terthiophene) (PDPP3T) and doped small molecule 2,2',7,7'-tetrakis(N,N-di-p-methoxynaphthalene)-9,9-spirofluorene (spiro-OMeTAD). In our study, we have compared the device performance of perovskite solar cells with PDPP3T and spiro-OMeTAD based HTL. The devices were tested for their stability under the condition mentioned in Table 3. Solar cells were taken out of

| Films                  | FWHM at 14.03° peak | FWHM at 28.36° peak | FWHM at 31.77° peak |
|------------------------|---------------------|---------------------|---------------------|
| TiO₂ + CH₃NH₃PbI₃     | 0.378°              | 0.457°              | 0.476°              |
evaporator in ambient air immediately after fabrication for efficiency testing. We report various data accumulated from Perovskite layer XRD spectrum, $J$–$V$ scans at different interval of time to monitor the ambient air stability for both PDPP3T and spiro-OMeTAD based perovskite devices.

Perovskite films were made using a two-step sequential deposition method and were characterized with X-ray diffraction to determine the crystalline perovskite phase. Full width half maxima (FWHM) of perovskite films determine the crystallinity of perovskite phase. Table 1 shows the FWHM of each characteristic peak of Perovskite (CH$_3$NH$_3$PbI$_3$) phase.

Perovskite solar cells fabricated using PDPP3T and spiro-OMeTAD-based HTL were characterized for their $J$–$V$ scans in both forward and reverse scan, immediately after evaporation of top silver electrode. The illuminated $J$–$V$ scans in both forward and reverse scans were recorded and individual

| Devices with | Scan direction | $J_{sc}$ (mA/cm$^2$) | $V_{oc}$ (V) | FF (%) | Eff. (%) |
|--------------|----------------|----------------------|-------------|--------|---------|
| PDPP3T as HTL | 1-Forward | 18.98 | 0.95 | 45.20 | 8.16 |
| | 1-Reverse | 18.12 | 0.95 | 63.70 | 10.98 |
| | 2-Forward | 19.62 | 0.96 | 47.80 | 9.01 |
| | 2-Reverse | 20.52 | 0.98 | 61.25 | 12.32 |
| | 3-Forward | 19.9 | 0.94 | 52.10 | 9.75 |
| | 3-Reverse | 19.5 | 0.97 | 62.80 | 11.89 |
| Spiro-OMeTAD as HTL | 1’-Forward | 22.57 | 0.87 | 55.90 | 10.99 |
| | 1’-Reverse | 22.54 | 0.88 | 62.20 | 12.34 |
| | 2’-Forward | 22.65 | 0.90 | 57.13 | 11.64 |
| | 2’-Reverse | 22.82 | 0.89 | 58.98 | 11.98 |
| | 3’-Forward | 20.09 | 0.90 | 53.10 | 9.60 |
| | 3’-Reverse | 20.24 | 0.83 | 52.47 | 8.81 |

Table 3
Overview of organic–inorganic perovskite stability testing.

| ISOS (D – 1) shelf time |
|--------------------------|
| Test setup | Light setup | Dark |
| Load | Open circuit |
| Storage temperature | Ambient (28 °C) |
| Storage R.H. | Ambient (40% RH) |
| Characterization light source | Solar Simulator (Xenon lamp) |
| Test setup | Storage temp./R.H. | 28 °C/40% RH |
| Min. measurement intervals | Daily (approximately every 24.5 h) |
| Characterization temperature | 35 °C |
| Characterization irradiance level | 100 mW/cm$^2$ |
| Output | Time/date | Time interval for consecutive measurement is shown in Table 4. |
| Characterization light source | Xenon lamp |
| Storage temp./R.H. | 25 °C/40% RH |
| Instantaneous performance parameters | $J_{sc}, V_{oc}, FF$ and $\eta$ |
| Stability performance parameters | $J_{sc}, V_{oc}, FF$ and $\eta$ after each interval of time |
| Description of measurement protocol and testing setup | All measurement were done in ambient air. The cells were stored in an ambient air in drawer after each measurement and taken out only when re-measured after each day. |
| Required equipment | Characterization light source | Xenon lamp |
| Temperature monitoring | Springfield Precise Temp humidity meter |
| Humidity monitoring | Springfield Precise Temp humidity meter |
| JV characterization | Solar simulator, Semiconductor parameter analyzer (Agilent 4155C) |
| Storage | Drawer |
device parameters were calculated as shown in Table 2. All $J–V$ curves (forward and reverse scan) were recorded with a scan rate of 1 V/s, with voltage step of 10 mV.

Table 3 shows detailed overview of conditions for test setup, testing protocols, output and equipment used for measuring the cells for air stability measurement. The measurement details described in Table 3 is as per testing protocols mentioned in reference [1].

Table 4 presents device performance parameters recorded for stability testing in air for both PDPP3T and spiro-OMeTAD based devices. $J–V$ curves for all scans were recorded with a scan rate of 1 V/s, with voltage step of 10 mV. Fresh devices were fabricated and were immediately scanned to obtain $J–V$ curves. The cells were then stored in a drawer and taken out to re-measure approximately after each day to see the performance levels for both PDPP3T and spiro-OMeTAD based perovskite solar cells.

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### Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.dib.2016.02.021.

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