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# Supporting Information

# Highly Efficient Planar Heterojunction Perovskite Solar Cells with Sequentially Dip-Coating Deposited Perovskite Layer from Non-Halide Aqueous Lead Precursor

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**Content**

**S1**. AFM surface images of thin ZnO layers fabricated from ZnO sol-gel precursors prepared with various Zn concentrations of (a) 0.19 M-Zn, (b) 0.25 M-Zn, (c) 0.38 M-Zn, and (d) 0.75 M-Zn over c-$TiO_2$ layer, which were compared to those of the (e) bare FTO substrate and (f) c-$TiO_2$ layer deposited on the FTO.

**S2**. Device performances statistics based on more than 40 PrSCs fabricated by $MAPbI_3$ perovskite layers after the sequential deposition with one SDC followed by two SSIER repetition, then incubated for 600 sec in MAI solution.

**S3**. Device performances statistics based on more than 40 PrSCs fabricated by $MAPbI_3$ perovskite layers after the sequential deposition with two SDC followed by two SSIER cycles, then incubated for 600 sec in MAI solution.

**S4**. Device performances statistics based on more than 40 PrSCs fabricated by $MAPbI_3$ perovskite layers after the sequential deposition with three SDC followed by two SSIER cycles, then incubated for 600 sec in MAI solution.

**Table S1**. Photovoltaic performances based on designated SDC cycles for PHJ PrSCs.[a]

**Table S2**. Photovoltaic performances based on the hysteresis behaviors of PHJ PrSCs fabricated under the optimized condition.[a]

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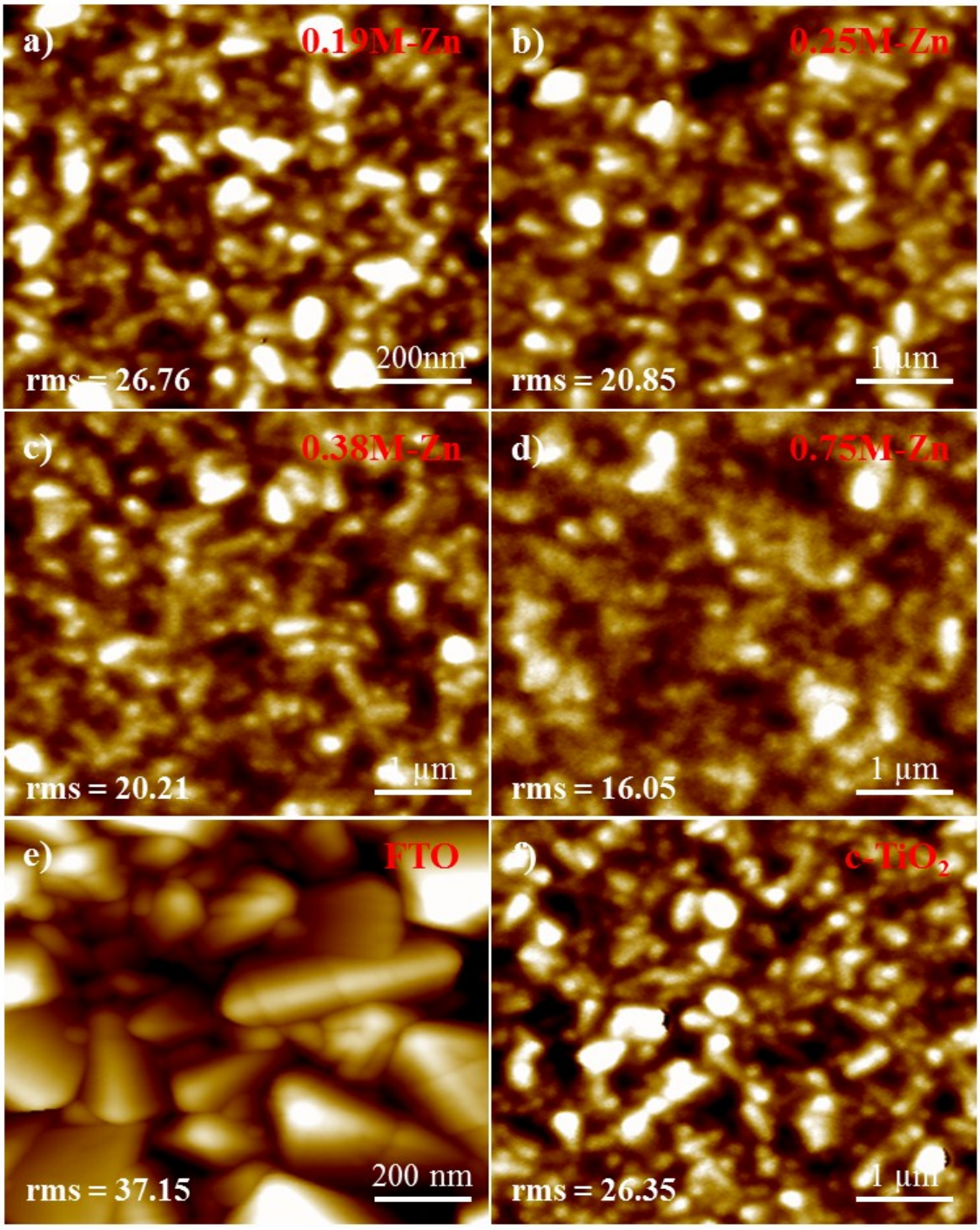
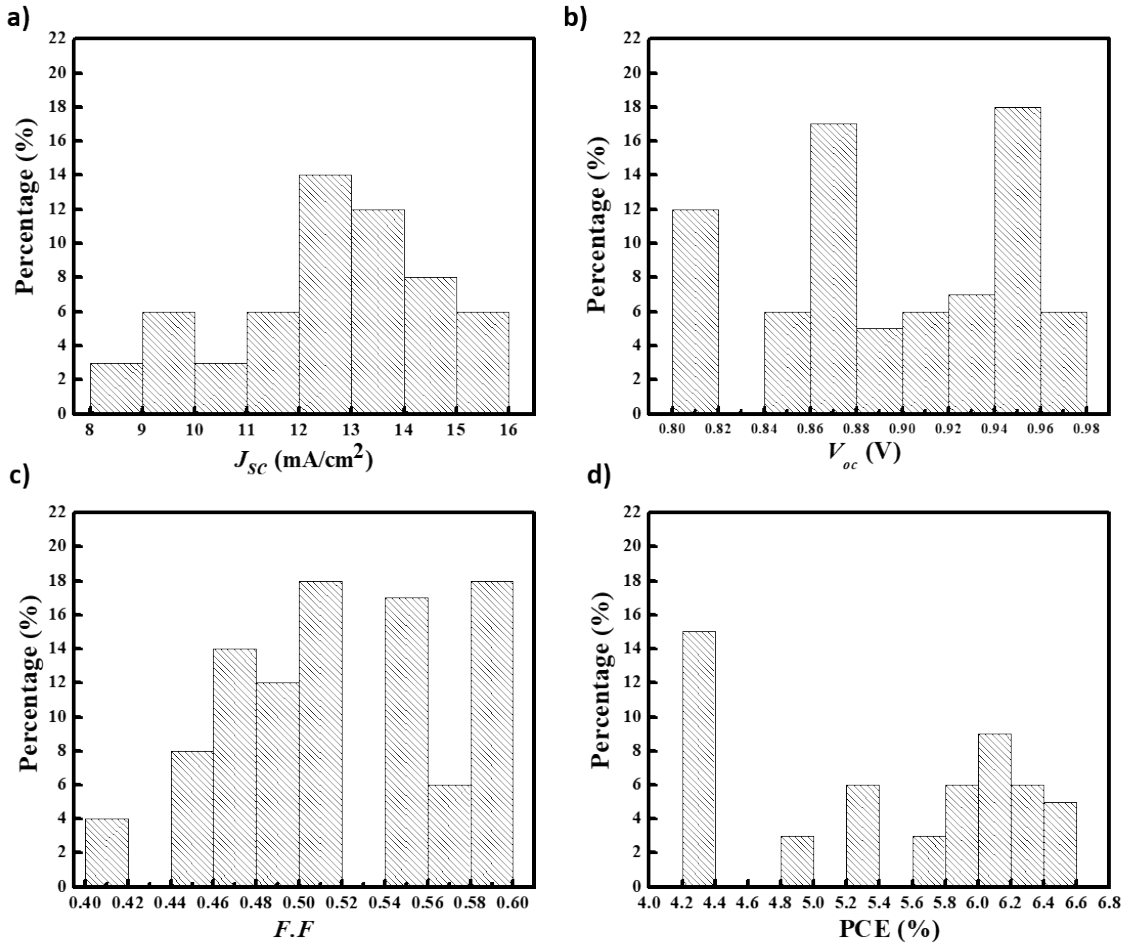
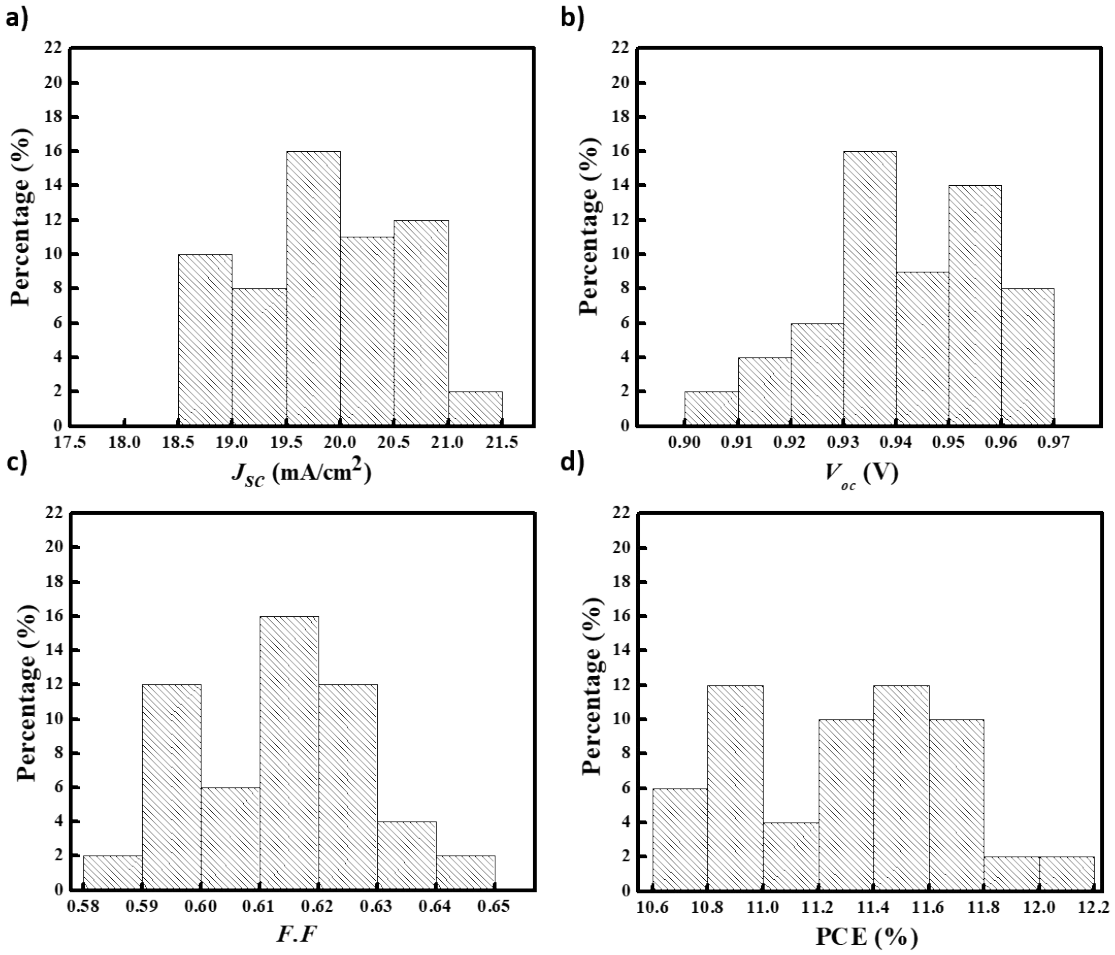


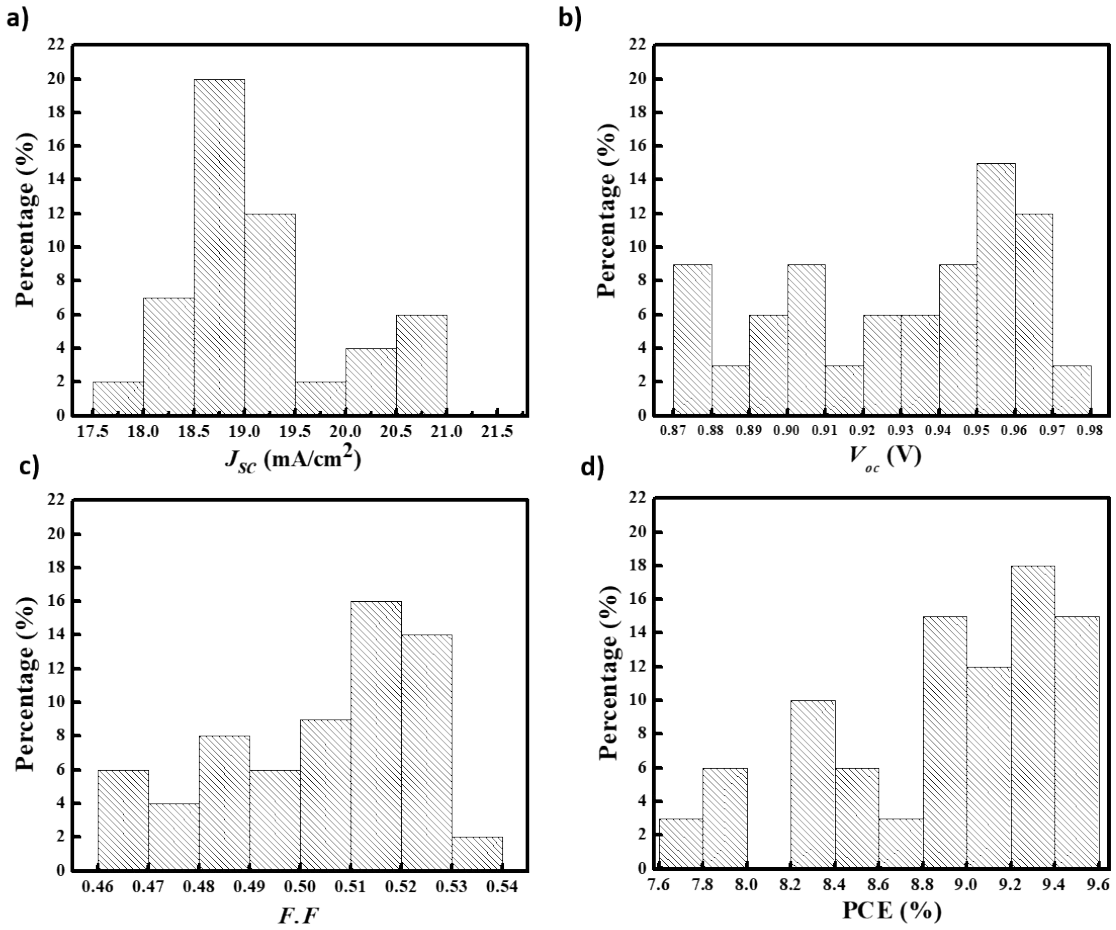
**S2**. Device performances statistics based on more than 40 PrSCs fabricated by $MAPbI_3$ perovskite layers after the sequential deposition with one SDC followed by two SSIER repetition, then incubated for 600 sec in MAI solution.



**S3**. Device performances statistics based on more than 40 PrSCs fabricated by $MAPbI_3$ perovskite layers after the sequential deposition with two SDC followed by two SSIER cycles, then incubated for 600 sec in MAI solution.



**S4**. Device performances statistics based on more than 40 PrSCs fabricated by $MAPbI_3$ perovskite layers after the sequential deposition with three SDC followed by two SSIER cycles, then incubated for 600 sec in MAI solution.



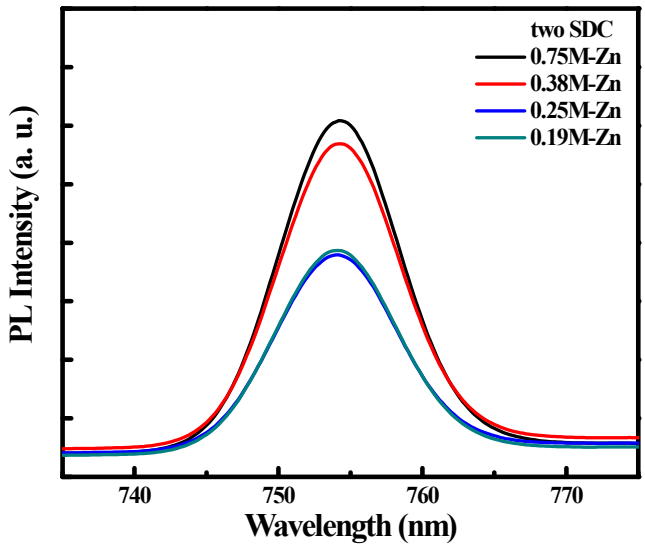



**Figure S5:** Photoluminescence spectra for PHJ $MAPbI_3$ perovskite films deposited on different Zn concentrations under designed two SDC cycles.

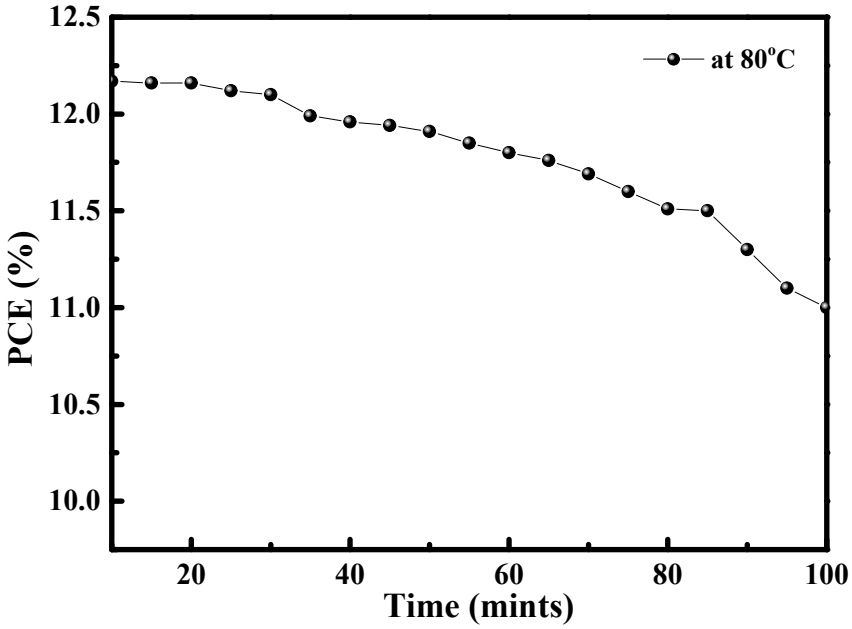



**Figure S6**: Environmental and thermal stability test at 80 °C under N2 atmosphere of PrSC device with PHJ perovskite films fabricated on 0.25 M-Zn under two SDC cycles.

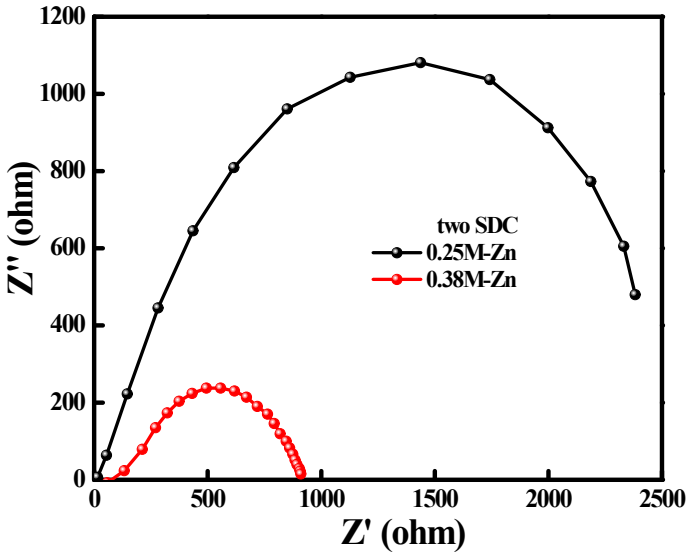



**Figure S7:** Charge transfer resistance under dark environment using optimized two SDC process.

**Table S1**. Photovoltaic performances based on designated SDC cycles for PHJ PrSCs.[a]

| SDC cycles | ZnO | $J_{sc}$ (mA/cm$^2$) | $V_{oc}$ (V) | *F·F* | $\eta_{max/ave}$(%) |
|---|---|---|---|---|---|
| **one** | 0.75M-Zn | 11.78 | 0.91 | 0.43 | 4.61 |
| | 0.38M-Zn | 14.22 | 0.94 | 0.44 | 5.88 |
| | 0.25M-Zn | 14.29 | 0.96 | 0.47 | 6.45 |
| | 0.19M-Zn | 15.40 | 0.83 | 0.43 | 5.50 |
| **two** | 0.75M-Zn | 15.96 | 0.86 | 0.46 | 6.31 |
| | 0.38M-Zn | 13.91 | 0.88 | 0.54 | 6.61 |
| | 0.25M-Zn | 20.33 | 0.95 | 0.63 | 12.17 |
| | 0.19M-Zn | 17.84 | 0.82 | 0.48 | 7.02 |
| **three** | 0.75M-Zn | 15.69 | 0.92 | 0.47 | 6.78 |
| | 0.38M-Zn | 17.22 | 0.93 | 0.58 | 9.29 |
| | 0.25M-Zn | 17.56 | 0.87 | 0.62 | 9.47 |
| | 0.19M-Zn | 16.73 | 0.92 | 0.49 | 7.47 |

[a)] The performances are determined under simulated 100 mW/cm$^2$ AM 1.5G illumination. The light intensity using calibrated standard silicon solar cells with a proactive window made from KG5 filter glass traced to the National Renewable Energy Laboratory (NREL). A non-reflective metal plate mask with an aperture of 4.5 mm$^2$ was used for the solar cells

**Table S2**. Photovoltaic performances based on the hysteresis behaviors of PHJ PrSCs fabricated under the optimized condition.[a]

| SDC cycles | Scan | $J_{sc}$ (mA/cm$^2$) | $V_{oc}$ (V) | F·F | $\eta_{max/ave}$ (%) |
|---|---|---|---|---|---|
| **One** | Forward | 14.76 ± 0.9 | 0.94 ± 0.4 | 0.41 ± 0.3 | 5.69/5.43 |
| | Reverse | 14.29 ± 0.8 | 0.96 ± 0.5 | 0.47 ± 0.3 | 6.45/6.07 |
| | Average | 14.53 ± 0.7 | 0.95 ± 0.4 | 0.44 ± 0.3 | 6.07/5.97 |
| **Two** | Forward | 20.33 ± 0.4 | 0.98 ± 0.2 | 0.58 ± 0.2 | 11.56/11.44 |
| | Reverse | 20.33 ± 0.3 | 0.95 ± 0.3 | 0.63 ± 0.2 | 12.17/12.07 |
| | Average | 20.33 ± 0.4 | 0.97 ± 0.3 | 0.61 ± 0.2 | 12.03/11.94 |
| **Three** | Forward | 17.56 ± 0.7 | 0.86 ± 0.5 | 0.57 ± 0.4 | 8.61/8.43 |
| | Reverse | 17.56 ± 0.9 | 0.87 ± 0.3 | 0.62 ± 0.3 | 9.47/9.17 |
| | Average | 17.56 ± 0.8 | 0.87 ± 0.5 | 0.60 ± 0.4 | 9.17/8.98 |

[a)] The performances are determined under simulated 100 mW/cm$^2$ AM 1.5G illumination. The light intensity using calibrated standard silicon solar cells with a proactive window made from KG5 filter glass traced to the National Renewable Energy Laboratory (NREL). A non-reflective metal plate mask with an aperture of 4.5 mm$^2$ was used for the solar cells.