An Innovative Anode Interface Combination for Perovskite Solar Cells with Improved Efficiency, Stability, and Reproducibility

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1. Introduction

Solution-processed organic–inorganic hybrid halide perovskites have emerged as promising materials for photovoltaic applications owing to their excellent optoelectronic properties, such as excellent carrier transport, and defect tolerance.[1,2] Significant efforts have been devoted by the community to improving the power conversion efficiencies (PCEs) of perovskite solar cells (PSCs), and a record efficiency of 25.7% for PSCs has been recently achieved.[3–8] Despite the impressively high PCEs of PSCs, the perovskite-based photovoltaic technology must be treated seriously also from an industrial point of view, especially when taking the long-term stability, cost, and large-area processing features into consideration.[9–16] Printable carbon electrode as top electrode has been demonstrated as one of the promising strategies to solve these issues.[17] Carbon is chemically stable with halides[16] and exhibits very high resistance to heat transference.

Rational design and engineering of top interface layers with combined properties of effective passivation, high thermal- and photo-stability are effective methods to advance the commercialization of perovskite photovoltaics. Here, an innovative anode interface combination is developed based on alcohol-dispersed poly(3-hexylthiophene-2,5-diyl) (P3HT) nanoparticles as the hole transport material and chlorobenzene-dissolved trioctylphosphine oxide (TOPO) as the passivation agent. It is shown that instead of the commonly used 2D passivation ligands, TOPO-passivated perovskite films exhibit greatly improved thermal stability. Furthermore, the passivation contributes to an enhanced carrier lifetime and reduced surface trap density, yielding an improvement in the quasi-fermi-level splitting of 57 meV. To maintain surface passivation during solution processing of further layers, it is necessary to develop a hole transport layer that can be processed from orthogonal solvents. P3HT nanoparticles formulated in alcohalic media fully meet this requirement, clearly benefiting from their high vertical conductivity and extremely low contact resistance with carbon electrodes. Based on this configuration, device efficiency of up to 18.4% is demonstrated for perovskite solar cells with fully solution-processed carbon electrodes, along with significantly improved device stability and reproducibility.
and moisture.\textsuperscript{[18–20]} The carbon electrode can be easily fabricated by blading or printing methods, which can greatly reduce the material and fabrication costs for large-area production. However, the hole extraction barrier and the large density of defects at the perovskite surface still limit the device’s efficiency and stability.\textsuperscript{[21]} Rational design and engineering of interface layers can play an essential role in further improving the performance and industrial viability of PSCs.\textsuperscript{[22–30]}

So far, highly efficient PSCs have been mostly demonstrated for the n–i–p device configuration, with 2,2’7,7’-tetakis(N,N-di-p-methoxyphenylamine)-9,9’:spirobifluorene (Spiro-MeOTAD) or poly(triarylamine) (PTAA) as the hole-transporting layer (HTL) and an ultrathin molecular layer, e.g., phenethylammonium iodide (PEAI), to passivate the perovskite top surface.\textsuperscript{[31–33]} However, not all of these concepts are equally scalable. On the one hand, some of these hole-transporting materials have the drawback of high cost and are sources of degradation due to ionic dopants.\textsuperscript{[11,34,35]} On the other hand, maintaining the integrity of ultrathin molecular passivation layers during processing or during stability test is challenging, which frequently leads to stability issues at elevated temperatures. Therefore, high-temperature annealing has to be avoided after the deposition of HTLs, which generally limits the usability of these passivation concepts for high-temperature operation. In addition, for PSCs incorporating printed carbon electrodes, a high-temperature thermal annealing process is always required to fully remove the residual solvent of the carbon paste. To develop carbon-based PSCs with excellent device efficiency and stability, instabilities at the perovskite/HTL interface have to be fully overcome.

Organic molecules, like polymethylmethacrylate (PMMA) and TOPO are alternative passivation materials.\textsuperscript{[17,35]} Their passivation ability and thermal stability have been well demonstrated in the literature. However, these materials have good solubility in Chlorobenzene (CB). The deposition of an HTL with a CB solution process method would cause damage to the TOPO film. This makes them incompatible due to their similar solubility behavior. Instead, alcohol dispersed P3HT nanoparticles (NPs) meet the requirements of orthogonal processing, and therefore appear as a very attractive alternative for an effective interface layer for PSCs. Poly[3-hexylthiophene-2,5-diy] (P3HT), which has relatively low material costs, high thermal stability and was already scaled to the multiple kg scale further fulfills important criteria as a suitable HTL for low-cost carbon electrode-based PSCs.\textsuperscript{[36,37]} These NPs are dispersed in alcohol solvents and are processed at low temperatures, which makes them fully compatible with the perovskite and passivation films.

Based on this, we propose a device architecture for highly efficient and thermally stable PSCs using P3HT NPs as the top HTL and employing chlorobenzene-dissolved TOPO as the passivation material. We show that the alcoholic solvent does not damage the nonpolar passivation layer, which greatly releases the restriction for bottom passivation materials. The TOPO-passivated perovskite film exhibits a photoluminescence quantum yield (PLQY) of 8.5%, as high as 7 times of the pristine perovskite film. Besides, the combined HTL has the advantages of low cost and ease of fabrication. In particular, with a 1.57 eV bandgap perovskite (FA\textsubscript{0.83}MA\textsubscript{0.17}Pb\textsubscript{1.12}I\textsubscript{2.86}Br\textsubscript{0.34}) as the photoactive layer, an improved V\textsubscript{OC} of 1.10 V and a champion PCE of 18.4% were achieved for PSCs with printed carbon electrodes. Moreover, the optimized films indicate good thermal stability. And the PSCs kept 98% of the initial PCE after 110 h of continuous illumination at 60 °C, demonstrating the potential of this interface concept for scalable PSCs. Our results propose an innovative combination of anode interfaces for well working carbon-based PSCs with improved open voltage, stability, and reproducibility.

2. Results and Discussions

Various materials,\textsuperscript{[38]} like organic small molecules, polymers, inorganic materials, or low-dimensional perovskites have been demonstrated to show passivation ability on perovskite surfaces. However, when they were applied in devices, besides the passivation abilities, other factors like their thermal stability and solvent resistance have to be taken into consideration (Figure 1a). In particular, the deposition of an HTL from CB and subsequent annealing can decrease or even destroy the passivation effect. Here, the passivation effect, the thermal stability, and the solvent resilience of the passivation process were evaluated by testing the PLQY values as shown in Figure 1b and Table S1, Supporting Information. The perovskite samples were coated on bare glass, followed by the deposition of the passivation material. The thermal treatment of the film samples was performed by placing the sample on a 100 °C hotplate for 10 mins. For the washing treatment, 200 μL CB was deposited on the top of the sample, followed by a spin-coating process at a speed of 3000 rpm for 30 s. We found that the PLQY of pristine perovskite film (PLQY\textsubscript{ref}) is 1.2%, while the PEAI-, BAI-, and MAI-coated perovskite films show increased PLQY of 3.72%, 2.53%, and 1.45%, respectively. The quasi-Fermi-level splitting (QFLS), which is an internal quantity representative of the density of free photogenerated charges in the CB and valence band (VB) of the absorber, was then employed to quantify the improvements. According to the detailed-balance theory, the QFLS represents the ideal V\textsubscript{OC} of the device. Consequently, the variation in the QFLS (here refers to ΔQFLS) can stand for the corresponding potential increments of V\textsubscript{OC} (ΔV\textsubscript{OC,potential}). The corresponding potential increments of V\textsubscript{OC} can be calculated by the equation

\[
\Delta V_{OC,potential} = \frac{q \Delta QFLS = kT \ln \left( \frac{PLQY_{sample}}{PLQY_{ref}} \right)}{}
\]

The corresponding ΔV\textsubscript{OC,potential} for the PEAI, BAI, and MAI samples were calculated to be 29, 19, and 5 mV, respectively. PEAI is one of the most commonly used 2D ligands to passivate perovskite films. The increased QFLS confirms its passivation ability. However, it has been also reported that the passivation achieved by this method shows poor thermal stability and the surface states would revert to their initial state after 100 °C thermal annealing treatment.\textsuperscript{[190]} By performing the thermal annealing treatment on these films, the PLQY values reduced. The thermal instability of the passivation concept is indeed a challenge that needs to be overcome.

Both, TOPO and PMMA, were reported to possess excellent passivation ability together with good thermal stability. However, these passivation materials are rarely used on the
top surface as they show poor resistance to organic solvents, which are commonly used for the HTL deposition. The perovskite films passivated by TOPO exhibited a PLQY of 8.5%, which is 7 times higher than the value of the neat perovskite film and is the highest of all the measured films in our series. Potential improvement of 57 mV in QFLS was calculated for the film with TOPO passivation. An even further slight increment of the PLQY can be found for the passivated films after heating. However, the CB washing process significantly damages the passivation layer and the PLQY dropped to 3.1%.

To address these two issues, we adopted alcohol-processed P3HT NPs as HTM. Figure 1c shows the schematic diagram for P3HT NPs dispersion and the configuration of the anode. The nanoparticles were dispersed in isopropanol (IPA), which is orthogonal to the solubility space of TOPO. The P3HT NPs were synthesized according to our previous work. The P3HT NPs were blade coated on the substrate at 50 °C forming a mesoporous structure before the thermal heating treatment (Figure S1, Supporting Information). The NP could form a compact and uniform film upon thermal annealing at 150 °C for 15 min. The film thickness can be controlled by repeating the coating and thermal annealing process. Figure 2b shows the scanning electron microscope (SEM) images of the films prepared from the IPA dispersion. The sample was directly deposited on bare glass. As a comparison, the sample prepared from CB solution was fabricated by spin-coating at a speed of 3000 rpm. The same thermal annealing process at 150 °C was performed. As shown in the images, both methods could deliver compact P3HT films.

To further confirm the P3HT NP morphology and electrical properties on top of a perovskite film, samples with the structure of glass/perovskite/P3HT were prepared. Measurements on these samples with photoluminescence (PL) mapping and atomic force microscope (AFM) were performed. Figure 2c,d shows the PL images for these two samples, the intensity of the PL is reflected by the color bar on the right. The samples were illuminated from the top side with a 532 nm wavelength laser, and the luminescence of the perovskite films was collected over the full wavelength range. The two comparably smooth PL maps, as well as the PL intensity distribution (Figure 2e,f), indicate a similar electrical property like the hole extraction ability. Figure 2g,h shows the AFM images with the root mean square (RMS) of 28 and 14 nm for film processed from NPs dispersion and solution, respectively. Though a slightly higher surface roughness was observed for the NPs films, it is still negligible considering the large roughness of the bare perovskite surface (Figure S2, Supporting Information). The absorbance and PL
spectra for the two films were measured. (Figure 2i) The almost overlapped absorption spectra and PL curves of the two films confirm again their similar crystallinity and morphology.

The conductivity of P3HT thin films with different layer thicknesses prepared from the NP dispersion was analyzed in a vertical architecture of ITO/P3HT NPs/Carbon, as shown in Figure 2j. The I–V measurements were performed by scanning the samples from $-1$ to $1$ V. The linear dependence indicates an Ohmic contact behavior between ITO and P3HT as well as at the P3HT/carbon interface. This is extremely important for efficient charge extraction and minimized recombination losses at the interfaces. The conductivities of these films ranged from $\approx 1.8 \times 10^{-2}$ S m$^{-1}$, as summarized in Figure S3, Supporting Information.

All these investigations demonstrated that P3HT NPs dispersion can result in uniform and compact P3HT layers with promising charge extraction, good transport behavior, and a low contact resistance to the electrode. We further employed the film in carbon-electrode-based PSCs. The perovskite films with the composition of FA$_{0.83}$MA$_{0.17}$Pb$_{1.12}$I$_{2.86}$Br$_{0.34}$ were deposited on the electron transport layer (ETL) using a one-step method. The optical bandgap of the perovskite film was calculated from the external quantum efficiency (EQE) edge to be $1.57$ eV, which corresponds to a $V_{OC}$ limit of $1.32$ V for an ideal device under $1$ sun illumination. A printed carbon electrode and thermally evaporated metal electrode were applied for comparison. Other details for the device fabrication are summarized in the experimental section. In the HTL-free configuration (Figure 3a), the champion device exhibited a $V_{OC}$ of $0.811$ V and a fill factor (FF) of $0.422$ at a forward scanning direction, while the $V_{OC}$ and FF are $0.976$ V and $0.593$, respectively, when scanning from the reverse direction (Table 1). Such large hysteresis was reported for carbon-electrode-based HTL-free PSCs in the literature and was ascribed to a large amount of trap states on the perovskite surface.$^{[42]}$ Figure 3b shows the $J–V$ curves for the champion device with the P3HT interface layer (which was taken as the reference device hereafter). Here, the P3HT layer was produced from the P3HT CB solution. The corresponding $V_{OC}$, $J_{SC}$, FF,
and PCE are 1.05 V, 22.2 mA cm$^{-2}$, 0.756%, and 17.6%, respectively. A similar hysteresis to the HTL-free device was observed. A worse performance was present when scanning from the forward direction. The large hysteresis factor (33%) indicates a large density of remaining surface trap states in the device. PSCs with an HTL prepared from P3HT NP dispersion were well fabricated for comparison. Comparable parameters are observed for PSCs based on P3HT NPs, as presented in Figure S4a, Supporting Information. Figure S4b,c, Supporting Information, show the statistical diagram for the thicknesses dependent $V_{OC}$ and FF, when PSCs were scanned from the reverse direction. The 60 nm film provides the most efficient and effective charge extraction and transport abilities. The thinner P3HT layer cannot provide good coverage on the perovskite top surface, while a thicker layer shows increased series resistance, resulting in reduced device performance. To further reduce the nonradiative recombination losses, the TOPO layer was introduced between the perovskite and the P3HT layer. PSCs with an architecture of ITO/SnO$_2$/PCBM/Perovskite/TOPO/P3HT NPs/Carbon were fabricated as shown in the inset of Figure 3c. An increased efficiency of up to 18.4% was achieved with a short-circuit current ($J_{SC}$) of 22.5 mA cm$^{-2}$, $V_{OC}$ of 1.10 V, and FF of 0.743 in the reverse scanning direction. When scanning from the forward direction, the same increment in $V_{OC}$ was observed. Besides, the FF in the forward scanning direction remained as high as 0.668, as compared to 0.520 for devices without TOPO. The corresponding calculated hysteresis factor was 11.1%. It is about three times smaller than the control device and is already approaching the regime reported for the highest performing devices. In this context, we want to explicitly point out the carbon electrode as a special feature of our device architecture. Perovskite solar cells based on gold electrodes were also fabricated (structure: ITO/SnO$_2$/PCBM/Perovskite/TOPO/P3HT NPs/Au), and delivered a PCE of approaching 20%
Table 1. Parameters of the photovoltaic devices with various HTL configurations. The table presents the device with champion PCE values among 12 cells.

| HTL Configuration | $V_{OC}$ [V] | $J_{SC}$ [mA cm$^{-2}$] | FF | PCE | HI$^{a}$ |
|-------------------|--------------|--------------------------|----|-----|--------|
| HTL free          | 0.811        | 21.9                     | 0.422 | 7.5% | (6.1%) 24.5% |
| P3HT dispersion   | F$^{d}$      | 1.01                     | 22.3 | 0.513 | 11.6% (9.9%) 35.3% |
|                   | R$^{d}$      | 1.03                     | 22.4 | 0.731 | 16.8% (14.4%) |
| P3HT solution     | F$^{e}$      | 1.02                     | 22.2 | 0.520 | 11.8% (10.5%) 33.0% |
|                   | R$^{e}$      | 1.05                     | 22.2 | 0.756 | 17.6% (14.7%) |
| P3HT dispersion   | F$^{f}$      | 1.07                     | 22.5 | 0.668 | 16.1% (15.2%) 11.1% |
|                   | R$^{f}$      | 1.10                     | 22.5 | 0.743 | 18.4% (17.1%) |

$^{a}$HI represents hysteresis index. It is calculated as $\text{PCE}_{PCE(\text{rec})}/\text{PCE}_{PCE(\text{pass})}$. $^{d}$F means the device was scanned along the direction from $J_{SC}$ to $V_{OC}$ point; $^{e}$The value in brackets represents the average PCE of 12 devices; $^{f}$R means the device was scanned along the direction from $V_{OC}$ to $J_{SC}$ point.

(Figure S5, Supporting Information). The EQE of the carbon-electrode-based devices is depicted in Figure 3d. The two curves are almost identical and both devices deliver integrated photocurrents of around 20 mA cm$^{-2}$.

Reproducibility is one of the primary criteria for the commercialization of PSCs to ensure low manufacturing costs. The PCE distributions for the two P3HT NP device architectures were recorded as shown in Figure 3e. For each device, 3 substrates including 18 pixels were recorded. The PCE of control devices varied from 11% to 17%, whereas the devices passivated with TOPO ranged between 15% and 18%. The light intensity dependent $V_{OC}$ was investigated for PSCs, as shown in Figure 3f. The slope of $V_{OC}$ versus light intensity is frequently used to discuss trends in recombination behavior. A slope value of $2.0 \pm 0.1$ indicates bimolecular recombination, while monomolecular or defect-assisted recombination exhibits a slope equal to $2.0 \pm 0.1$. The control PSCs exhibited a slope of $2.02 \pm 0.1$, suggesting a severe loss due to defect-assisted recombination. A lower slope value of $1.45 \pm 0.1$ was achieved with the passivated TOPO/P3HT NPs interface, underlining the passivation effect with TOPO. The stabilized power output of PSCs was further monitored at the maximum power point (MPP), as shown in Figure 3g. Stabilized PCEs of 17.2% and 14.1% were recorded for PSCs with and without surface passivation.

To further check the resistance of the passivation layer to IPA, we fabricated film samples with the structure of glass/perovskite/(TOPO)/P3HT. The reference samples were prepared by depositing the P3HT CB solution on top of the perovskite film. For the passivated samples, the TOPO layer was firstly deposited, and then over-coated with the P3HT NP dispersion. PL measurements were carried out, as depicted in Figure 3h. It shows that the TOPO surface-passivated film demonstrates a ten times higher PL intensity as compared to the control structure, predicting a substantial QFLS improvement of 59 meV.$^{[43–47]}$ This is actually confirmed by the $V_{OC}$ values recorded on full devices, as listed in Table 1. This confirmed that the passivation effect remained stable under the HTL deposition process. The lifetime of charge carriers in these samples was analyzed using transient PL (TRPL), as shown in Figure 3i. In accordance with the results from the steady-state PL test, the passivated samples displayed a longer $\tau_1$ of 110 ns and $\tau_2$ of 445 ns, while the $\tau_1$ and $\tau_2$ for the unpassivated samples were 62 and 340 ns, respectively. This is ascribed to a reduced recombination velocity at the interface caused by passivation.

Figure 4a shows the Nyquist plots of perovskite solar cells with (Figure 3c) and without (Figure 3b) passivation. The samples were placed under 1 sun illumination and a bias voltage of equal to $V_{OC}$ was applied to the device. As we can find from the experimental result, only 1 semicircle could be observed in the plotted curve. A simple equivalent circuit model$^{[48]}$ was applied to analyze the series resistance ($R_s$) and recombination resistance ($R_{rec}$) and an excellent fit of the experimental curve was found. The perovskite solar cells with and without passivation deliver a comparable $R_s$ of $\approx 50$ Ohm. However, the recombination resistance is obviously higher for the sample with TOPO passivation, indicating a relatively lower carrier recombination velocity at the interface. We further performed the measurements under lower illuminations (0.3, 0.1, and 0.08 suns) and found there is no significant change in series resistance for all of these PSCs (Figure 4b). However, when we compare $R_{series}$ at the illumination intensity, the values for passivated devices are significantly higher than that for the reference device. To investigate the nature of ion migration in the perovskite films, the ionic conductivity versus frequency is plotted in Figure 4c. Here, the total ionic conductivity was determined
from Jonscher’s law. For both devices, nearly flat frequency-independent conductivity behavior was observed at low frequencies. The ionic conductivity for the reference film is estimated to be $\approx 3 \times 10^{-4}$ S m$^{-1}$, while the film with passivation delivers a relatively higher conductivity of $\approx 5 \times 10^{-3}$ S m$^{-1}$. This proves a lower ionic density for the passivated films, and is in agreement with the smaller hysteresis for optimized devices obtained from $J$–$V$ measurement.

Understanding and improving the long-term stability of perovskite films and devices is critical to developing this technology. Therefore, film stability measurements were performed by placing the unsealed samples with the architecture glass/perovskite/(w/wo)TOPO/P3HT NP under continuous 85 °C thermal treatment in two stages: first in an N$_2$-filled glovebox for 320 h and then in the air for another 640 h. The average humidity of the ambient environment for the second stage was $\approx 50\%$. The intensity at the PL peak positions was recorded using a home-built high-throughput setup as shown in Figure 5a.

For the passivated perovskite films, the PL counts are fairly stable at a regime of $\approx 10^5$. This proves excellent resistance to heat and humidity. For the reference perovskite films, we could still observe good thermal stability during the first 320 h when the PL was stable at about $\approx 10^4$ counts. However, when exposed to air, the intensity first experienced a sharp increment, and then dropped rapidly. The increment was deduced to be related to the film passivation with H$_2$O at the beginning. As the exposure time increases, humidity accelerated film degradation, most likely via halide interaction and PbI$_2$ formation. Besides, a blue shift appeared for the PL spectra which is strong evidence for the increased defect formation in the film, as shown in Figure S6, Supporting Information. Figure 5b displays the photograp of the two samples after degradation. The film without TOPO has turned yellowish, indicating the formation of PbI$_2$. It can be concluded that humidity is the dominant factor that induces film degradation and the perovskite films with passivation exhibited excellent resistance to both heat and humidity.

![Figure 5](image-url)

**Figure 5.** The stability tests of the films and devices. a) In-situ PL intensity under continuous 85 °C thermal treatments for the reference and passivated perovskite films. For the first 320 hours, the samples were kept in a N$_2$-filled glovebox. After that, the samples were moved outside and kept in ambient air. The average humidity for the ambient air during the test was 50%. b) Photograph for the two films after the aging test. c–f) The lifetime for the devices were tested at $J_{sc}$ state and $V_{oc}$ state, respectively. The devices were placed in a N$_2$-filled chamber. The temperature for the chamber was 60 °C, and the LED illumination intensity was 0.3 suns. The solid black curve indicates the average value for six single cells. The top edge and bottom edge of the coloured area represent the maximum and minimum values among the six cells, respectively. Details on the stability performance of the individual cells can be found in Figure S8, Supporting Information.
For the solar cell operation, light has to be included. Here, to probe the operational stability, devices were placed under continuous light-emitting diode (LED) illumination with about 0.3 suns and a temperature of about 60 °C. To exclude the effect of humidity on the degradation, all these devices were placed in an N2-filled chamber which was placed on a hot stage. As shown in Figure 5c, passivated devices were able to maintain 98% of their initial PCEs after 110 h aging under JSC conditions. The devices show a small VOC decrease, while the FF and JSC remained unchanged (Figure S7, Supporting Information). It is worth noting that the passivated cells on two separate substrates displayed a very small efficiency spread during aging under JSC and VOC conditions (Figure S8a-c, Supporting Information). For the control devices, we can find a significantly larger spread in efficiency evolution from the very beginning (Figure S8b-d, Supporting Information). The average efficiency after about 100 h of aging under JSC conditions is around 85% of the initial PCE, displaying lower stability than the passivated device (Figure 5d). The device stabilities at VOC state were also compared as shown in Figure 5e, f. We observed lower stability under VOC conditions than under JSC conditions. Open circuit represents the condition with no current flow, hence maximal accumulation of photo-induced charge carriers, which would cause severe degradation.[56] Nevertheless, the passivated devices again performed better in terms of efficiency spread during degradation. We extensively tested the device stability under 1 sun illumination and at room temperature, and found a similarly improved stability for the passivated device (Figure S9, Supporting Information). In summary, reduced interfacial defects between the perovskite and the HTM are crucial for achieving reproducible long-term device stability against bias and light.

3. Conclusion

We developed an innovative anode interface combination based on alcohol-dispersed P3HT NPs and TOPO for carbon electrode-based PSCs. The electrical properties and morphology of the P3HT films were demonstrated to be very comparable to the ones processed from organic solvents. We explored the limitations and choices for the passivating layer hand-in-hand with the processing conditions. The chemical orthogonality of IPA enables the fabrication of HTLs without negatively impacting the underlying TOPO layer. TOPO combined with P3HT NPs preserves a greatly reduced defect density at the top perovskite surface through the whole processing cycle. Perovskite layers coated with TOPO and P3HT NPs consequently showed enhanced thermal stability. With the TOPO/P3HT NPs system, we fabricated fully passivated PSCs with a printed carbon top electrode, achieving a maximum PCE of 18.4% and enhanced stability. This study provides a novel anode structure for efficient and stable carbon-electrode-based PSCs.

Supporting Information

Supporting Information is available from the Wiley Online Library or from the author.

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Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

The data that support the findings of this study are available in the supplementary material of this article.

Keywords

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