

Extra-high short-circuit current for bifacial solar cells in sunny and dark-light conditions

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Experimental Details

Preparation of Pt/Ti/Pt CE

In order to realize the fabrication of bifacial solar cell device, metallic Ti foil was used as a substrate to deposit Pt layers on both sides. Before deposition, the Ti foil was chemically etched to remove the oxides and subsequently cleaned by sonication in deionized water, acetone, and ethanol. Finally, pyrolytic Pt layers were formed on the Ti foil via dropping H_2PtCl_6 isopropanol solution under 290 °C ambilaterally, obtaining the two-sided catalytic Pt/Ti/Pt CE.

Preparation of FTO/dye-TiO₂/LPP photoanode

TiO₂ colloid was prepared according to our previous report.^{S1} Generally, TiO₂ film was coated onto the surface of FTO glass (12 Ω square⁻¹) with 5 mm × 5 mm active area and 10 μm thickness by a doctor-blade method. Subsequently, 0.25 g mL⁻¹ of LPP material in ethanol were deposited onto TiO₂ film via drop-casting method and standing for 10 min, following annealed at 450 °C for another 30 min in air atmosphere. Then the substrate was immersed in ethanol solution of 0.50 mM N719 for 24 h, cleaned with ethanol and dried with N₂ flow.

Fabrication of bifacial solar cell

In a typical fabrication process, two dye-sensitized photoanodes (FTO/dye-TiO₂/LPP) and a Pt/Ti/Pt CE were assembled into a sandwich-type construction along with injecting liquid electrolyte into the gaps between three electrodes. The liquid electrolyte consisted of 100 mM of tetraethylammonium iodide, 100 mM of tetramethylammonium iodide, 100 mM of tetrabutylammonium iodide, 100 mM of NaI, 100 mM of KI, 100 mM of LiI, 50 mM of I₂, and 500 mM of 4-tert-butyl-pyridine in 50 mL acetonitrile.

Characterizations

The electrochemical catalytic ability of Pt/Ti/Pt CE was characterized on a CHI660E electrochemical workstation (Shanghai Chenhua Device Company, China) with a sputtering Pt electrode as a reference. Cyclic voltammetry (CV) curves were recorded assisted with a three-electrode system consisting a Pt foil as counter electrode, a Ag/AgCl electrode as reference electrode and a Pt/Ti electrode as a working electrode at a scan rate of 50 mV s⁻¹. The supporting electrolyte was composed with 10 mM I₂, 50 mM LiI, and 500 mM LiClO₄ in acetonitrile. The interfacial charge-transfer resistance was characterized employing electrochemical impedance spectroscopy (EIS) at an ac amplitude of 10 mV, and subsequently the obtained results were fitted with Z-view software. Meanwhile, the Tafel polarization was measured by assembling symmetric dummy cells of Pt/Ti|electrolyte|Pt/Ti, which was identical with EIS characterization.

The absorption spectrum of dye molecule and optical transmission spectra of various photoanodes were characterized employing an ultraviolet-visible spectrophotometer (UV-3200, Meipuda). PL spectra of LPP material were measured on a FluoroMax-4 spectrofluorometer. Meanwhile, PL delay characterizations were conducted with a Horiba spectrometer. The IPCE spectra of various devices were recorded by IPCE kit developed by Zolix Instruments Co., Ltd.

The photocurrent density-voltage (*J-V*) plots of various solar cells were recorded on a CHI600E

electrochemical workstation (Shanghai Chenhua Device Company, China) under AM 1.5G simulated solar illumination (100 mW cm^{-2} , calibrated by a standard silicon solar cell). For J - V characterizations at dark condition, bifacial solar cells with LPP material device was exposed to solar light for 5 min before measurement. As a reference, pristine DSSC without LPP material was also fabricated and characterized.

Reference

S1 Y. Duan, Q. Tang, Z. Chen, B. He and H. Chen, *J. Mater. Chem. A*, 2014, **2**, 12459-12465.

Table S1. The electrochemical parameters of Pt/Ti and sputtering Pt electrodes obtained from Figure S1. R_s : series resistance.

device	J_{red1} (mA cm ⁻²)	E_{pp} (V)	R_s (ohm cm ²)	R_{ct} (ohm cm ²)	f_p (Hz)	τ (μ s)
Sputtering Pt	7.93	0.592	23.51	17.34	1211	131.5
Pt/Ti	9.86	0.567	4.92	2.49	2612	60.9

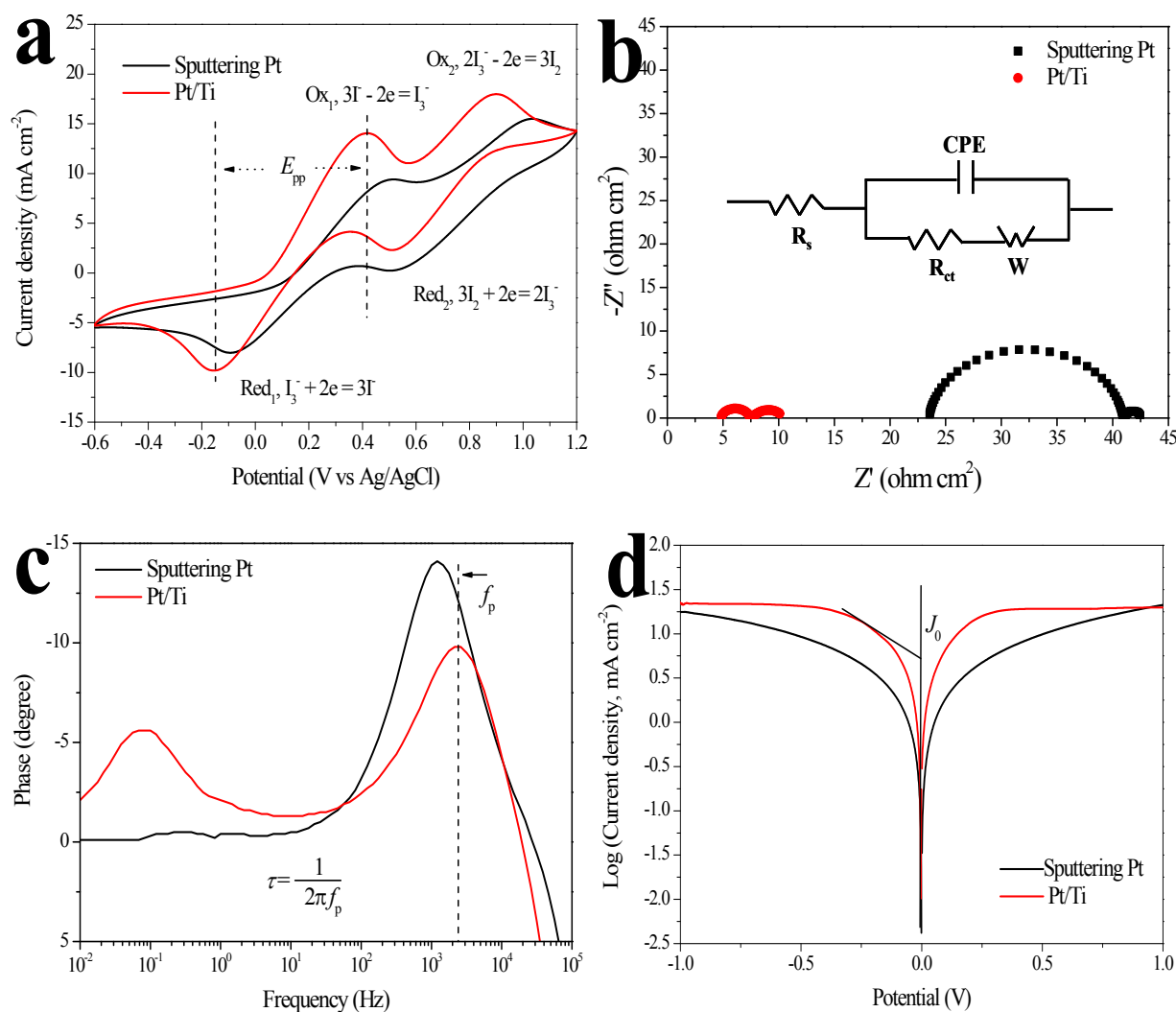


Fig. S1 (a) CV curves of sputtering Pt and Pt/Ti electrodes recorded in I^-/I_3^- electrolyte at a scan rate of 50 mV s^{-1} ; (b) Nyquist and (c) Bode plots as well as (d) Tafel polarization curves from the symmetric dummy cells fabricated by two identical CEs. The inset in Figure S1 represents the equivalent circuit to simulate charge-transfer processes.

It is obviously observed that the electrocatalytic ability of Pt/Ti/Pt electrode is crucial to assemble the bifacial solar cells. Therefore, we employ several electrochemical methods to evaluate the reduction reaction of I_3^- species on the surface of Pt/Ti/Pt CE with a sputtering Pt electrode as reference. As shown in Figure S1a, both electrodes exhibit two pairs of oxidation/reduction peaks (Ox_1/Red_1 , Ox_2/Red_2) along with comparable peak current density of Red_1 (J_{red1}) and peak-to-peak

separation (E_{pp}) between Red_1 and Ox_1 (see Table S1), demonstrating the robust catalytic behaviors for supporting electrolyte. Meanwhile, the interfacial charge-transfer resistance (R_{ct}) is much smaller than that of sputtering Pt electrode, which is highly consistent with the electron lifetime (τ) determined by reaction rate of $I_3^- + 2e \rightarrow 3I^-$ from Nyquist and Bode plots (Figure S1b, c and Table S1). Furthermore, to cross-check the validity of catalytic ability, we measure the Tafel polarization curves for the symmetric dummy cells as shown in Figure S2d. There is a fact that the exchange current density (J_0) is inversely proportional to R_{ct} , verifying the correspondence among above-mentioned characterizations. Therefore, we can obtain the conclusion that the two-sided catalytic Pt/Ti/Pt CE meets all basic requirements to fabricate bifacial solar cells.

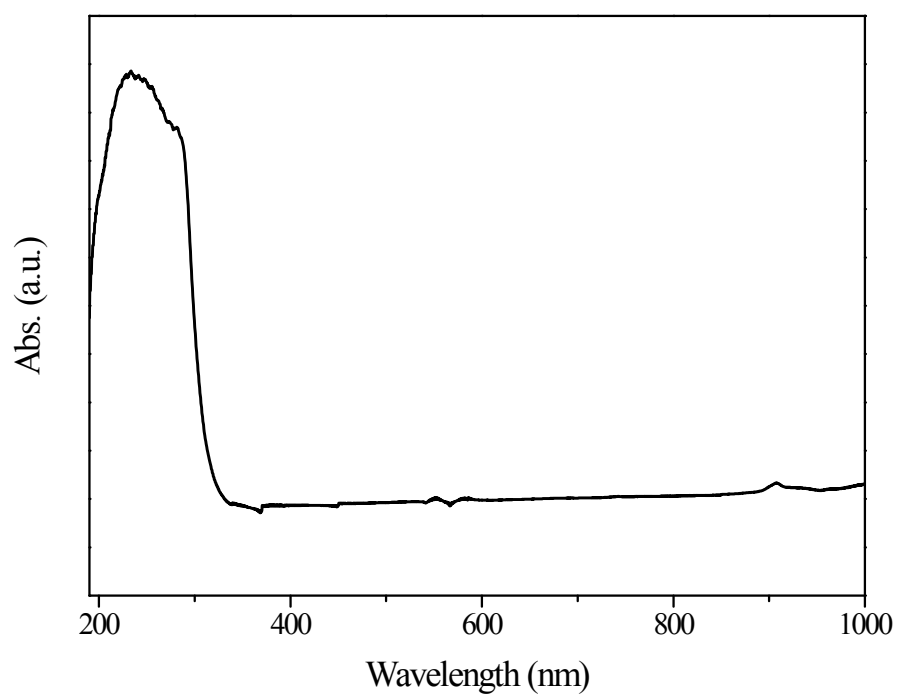


Fig. S2 Absorption spectrum of LPP material.

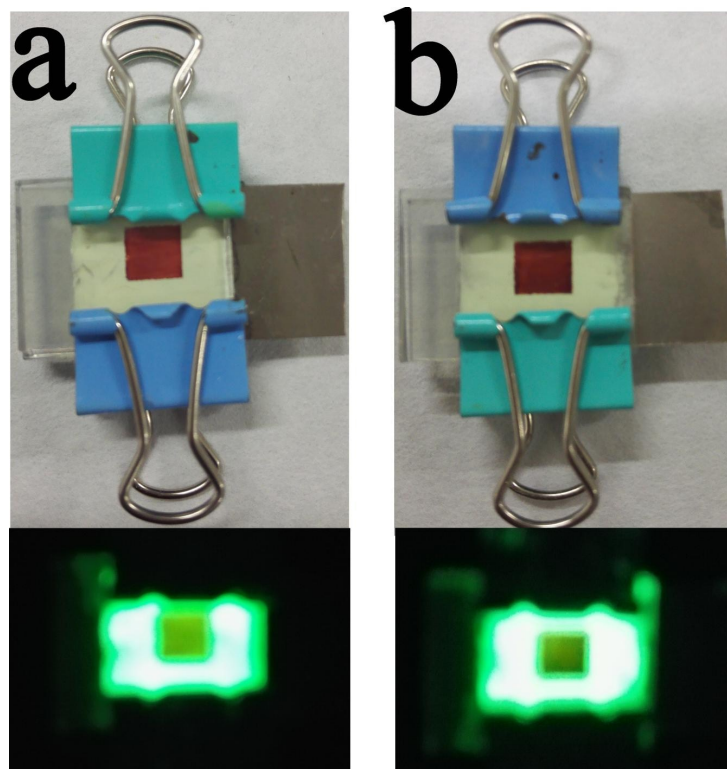


Fig. S3 The photoluminescence images of dye-TiO₂/LPP photoanodes taken at persistent luminescence time of 5 s after irradiating by a simulated sunlight (AM 1.5, 100 mW cm⁻²) for 5 min. The dark regions are related to dye-TiO₂/LPP, while fluorescent regions are only covered by LPP layers. (a) The front side and (b) rear side of bifacial solar cell.

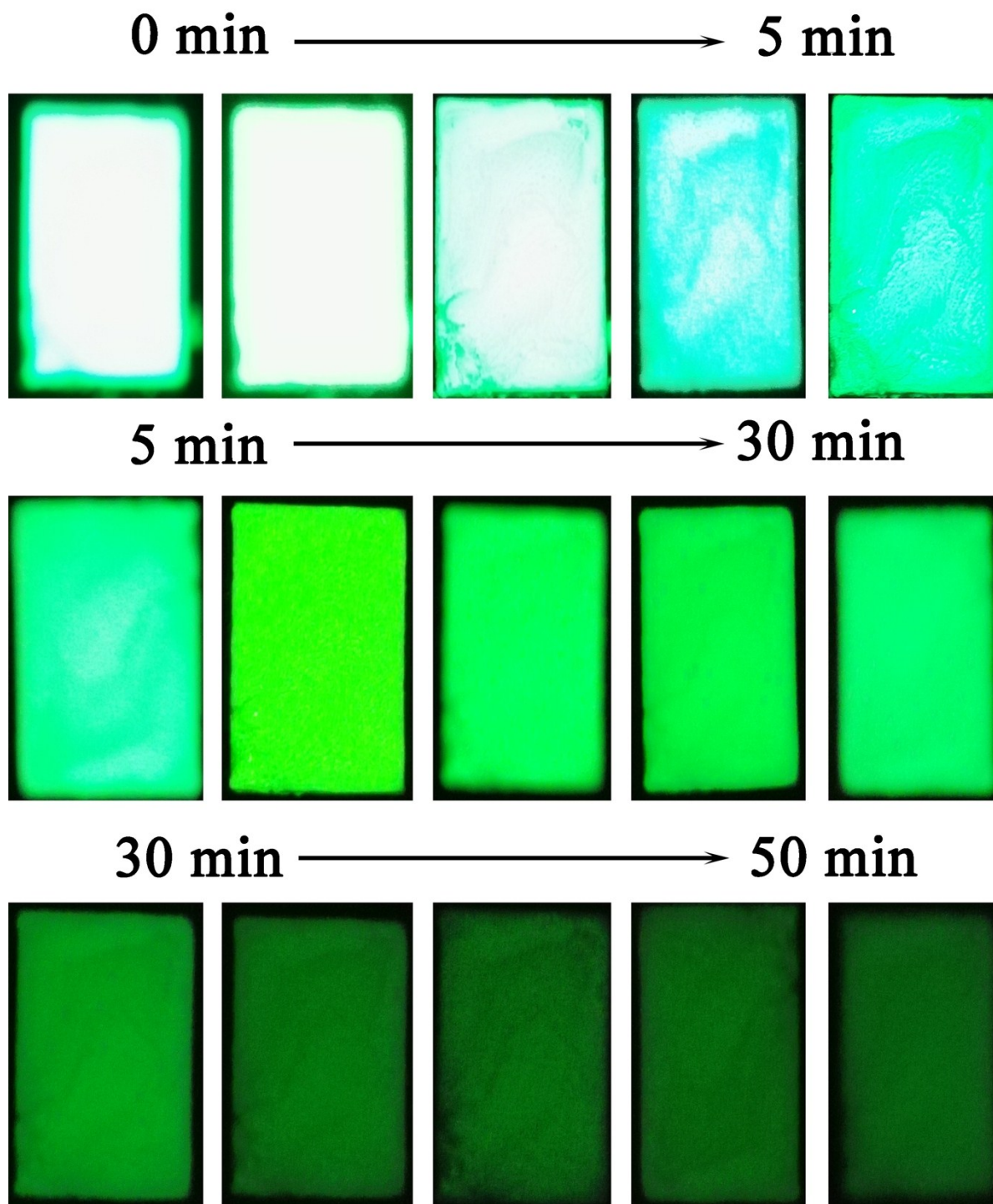


Fig. S4 The evolution of afterglow intensity from TiO₂/LPP after irradiated under solar light for 5 min.

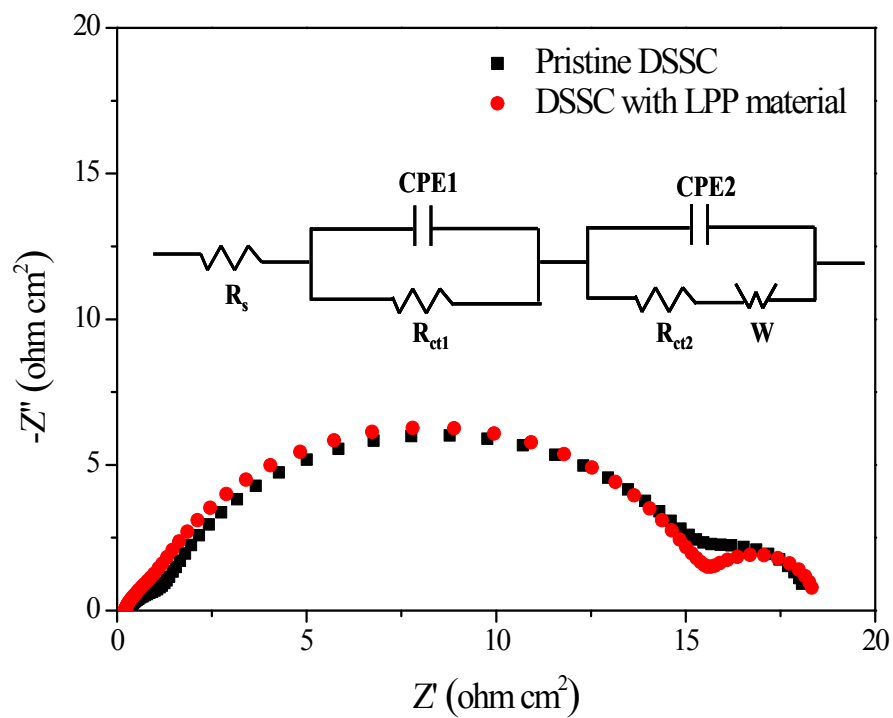


Fig. S5 Electrochemical impedance spectra of various solar cells. The inset represents equivalent circuit.

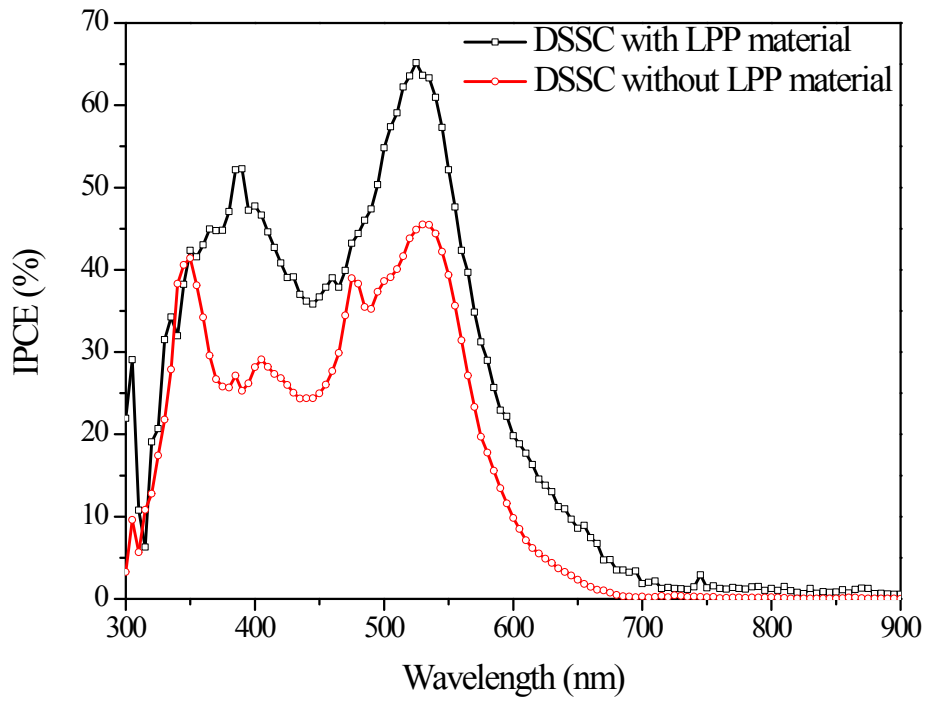


Fig. S6 IPCE spectra of the DSSCs with and without LPP phosphors.

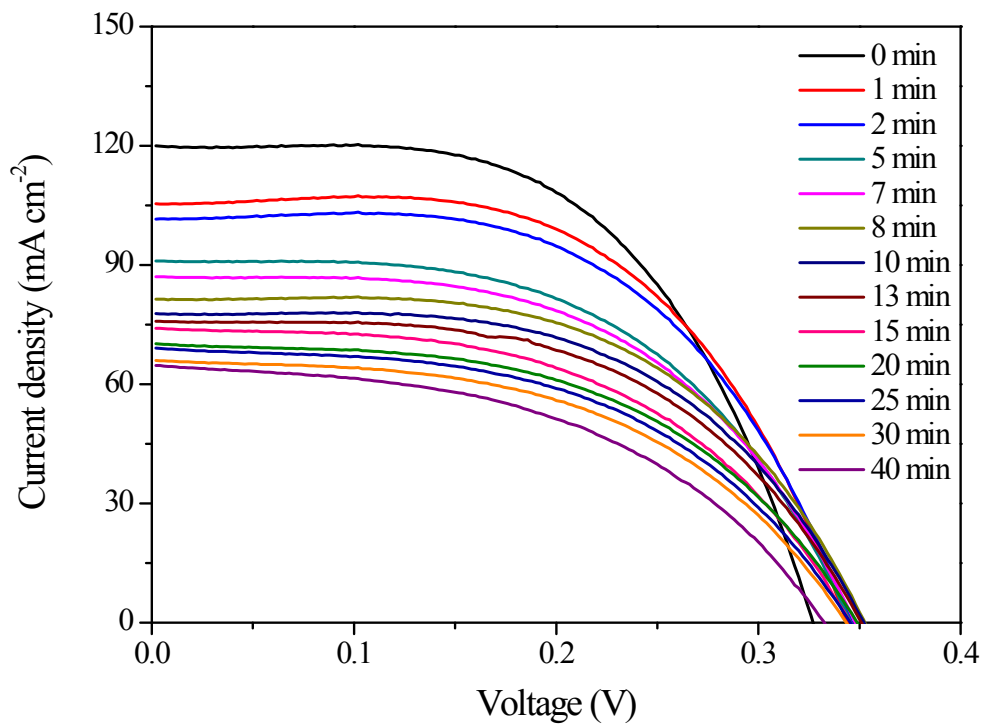


Fig. S7 The stacked J - V curves of bifacial solar cell with LPP material recorded under various storage time in completely dark condition.

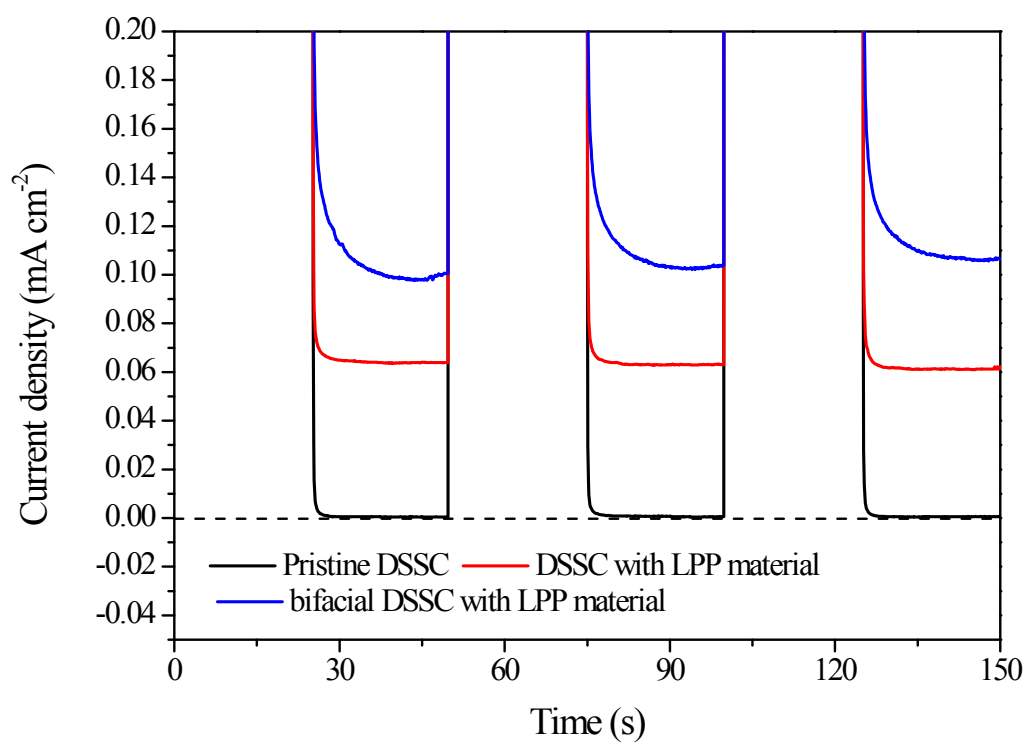


Fig. S8 Corresponding magnified part of red frame area in Figure 3d.