

Long persistence phosphor assisted all-weather solar cells. Electricity generation beyond sunny days

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Experimental section

Synthesis of long persistent phosphors

For synthesis of $\text{SrAl}_2\text{O}_4\text{:Eu}^{2+}\text{Dy}^{3+}$ and $\text{Sr}_4\text{Al}_{14}\text{O}_{25}\text{:Eu}^{2+}\text{Dy}^{3+}$ phosphors, $\text{Al}(\text{NO}_3)_3$, $\text{Sr}(\text{NO}_3)_2$, $\text{Dy}(\text{NO}_3)_3$ and $\text{Eu}(\text{NO}_3)_3$ at stoichiometric ratios were mixed in solution, and then precipitated by adding $(\text{NH}_4)_2\text{CO}_3$ solution under vigorous stirring. The resulting particulate precipitates were separated by centrifuge and then washed by D.I. water and ethanol. The collected particles were dried at 150 °C for 12 h, and then calcined in a furnace at 1300 °C in air for 4 h, followed by at 1200 °C under a reducing atmosphere for 2 h.

Preparation of dye sensitized TiO_2 /LPP photoanodes

TiO_2 colloid was prepared according to our previous report.¹ Generally, TiO_2 film was coated onto the surface of FTO glass ($12 \Omega \text{ square}^{-1}$) with 5 mm × 5 mm active area and 10 μm thickness by doctor-blade method. Subsequently, 0.25 g mL⁻¹ of LPP materials in ethanol were deposited onto TiO_2 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 AW-DSSCs

In a typical fabrication process, dye-sensitized photoanode and a transparent platinum counter electrode (purchased from Opv. Tech. CO., LTD, YingKou) were assembled into a sandwich-type construction along with injecting liquid electrolyte into the gap between two 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.

Characterization

XRD spectra were collected with a Ultima IV diffractometer using Cu K α X-ray radiation. Energy dispersive spectroscopy analysis (EDS) was investigated employing a Horiba Emax Energy (Model EX-350). The absorption spectrum of dye molecule and optical transmission spectra were characterized employing a Meipuda UV-3200 spectrophotometer. PL spectra of LPP1 and LPP2 materials were measured on a FluoroMax-4 spectrofluorometer. Meanwhile, PL delay characterizations were conducted on with a Horiba spectrometer.

The photocurrent density-voltage (J - V) plots of various AW-DSSCs 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, AW-DSSC devices were exposed to solar light for 5 min before measurement. As a reference, pristine DSSC without LPP materials was also fabricated and characterized.

References

1 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 various devices obtained from Fig. S3. R_s : series resistance of the cell; R_{ct1} : charge-transfer resistance at CE/electrolyte interface; R_{ct2} : charge-transfer resistance at photoanode/electrolyte interface.

device	R_s (ohm cm ²)	R_{ct1} (ohm cm ²)	R_{ct2} (ohm cm ²)	Sum (ohm cm ²)
DSSC	0.58	0.61	9.95	11.14
(AW-DSSC) _{LPP1}	0.55	1.19	9.27	11.01
(AW-DSSC) _{LPP2}	0.58	0.92	9.44	10.94

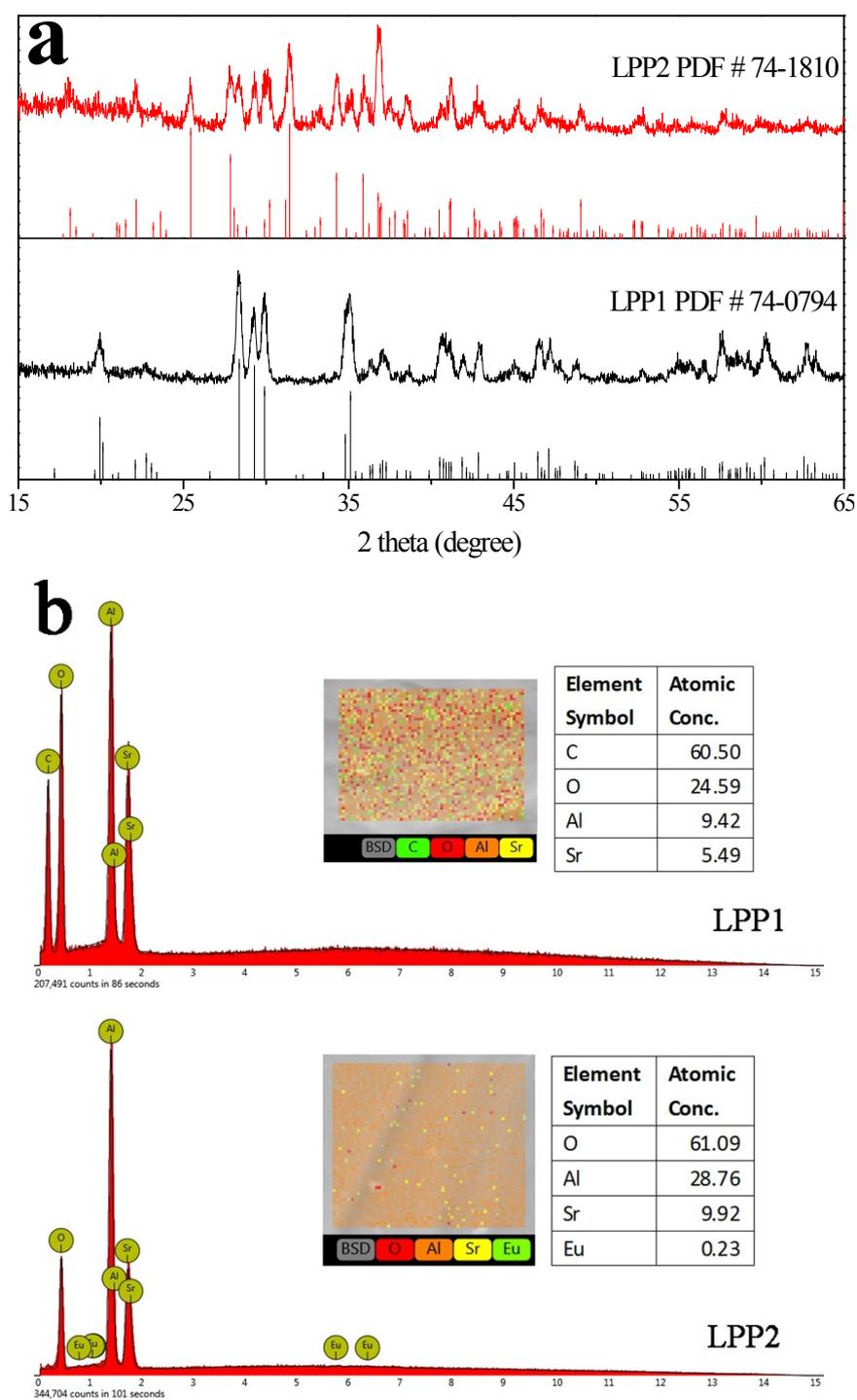


Fig. S1 (a) The XRD patterns and (b) EDS spectra of LPP1 ($\text{SrAl}_2\text{O}_4 : \text{Eu}^{2+}\text{Dy}^{3+}$) and LPP2 ($\text{Sr}_4\text{Al}_{14}\text{O}_{25} : \text{Eu}^{2+}\text{Dy}^{3+}$) materials. Due to the low dosages and equipment accuracy limits, the Eu and Dy elements are not detected in the corresponding LPP phosphors.

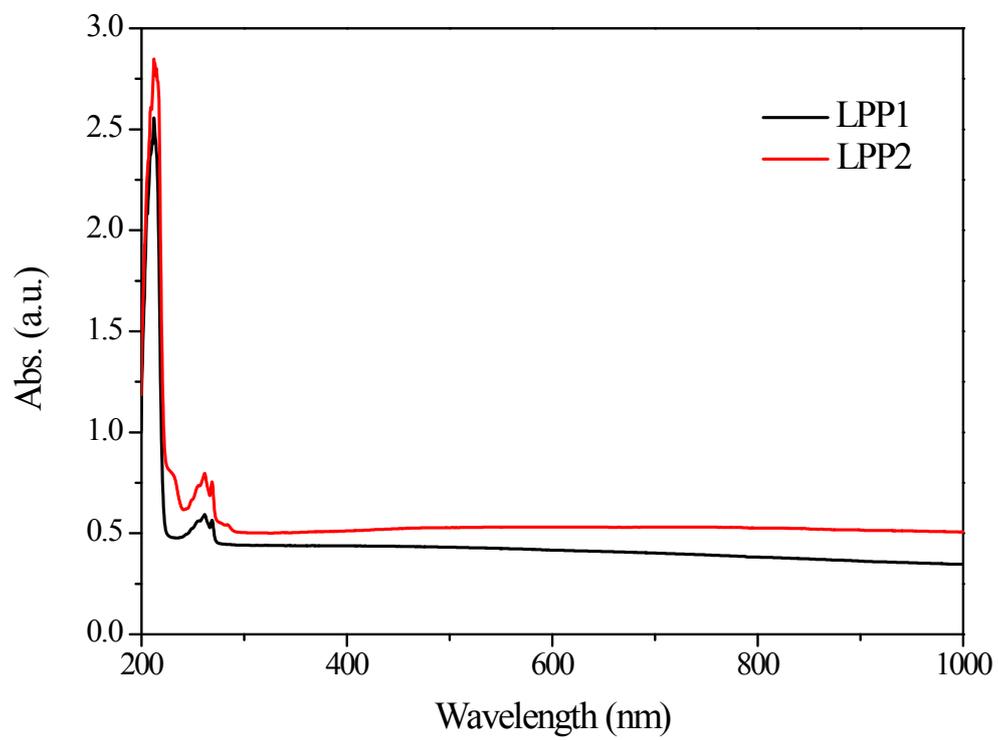


Fig. S2 Absorption spectra of LPP1 and LPP2 materials.

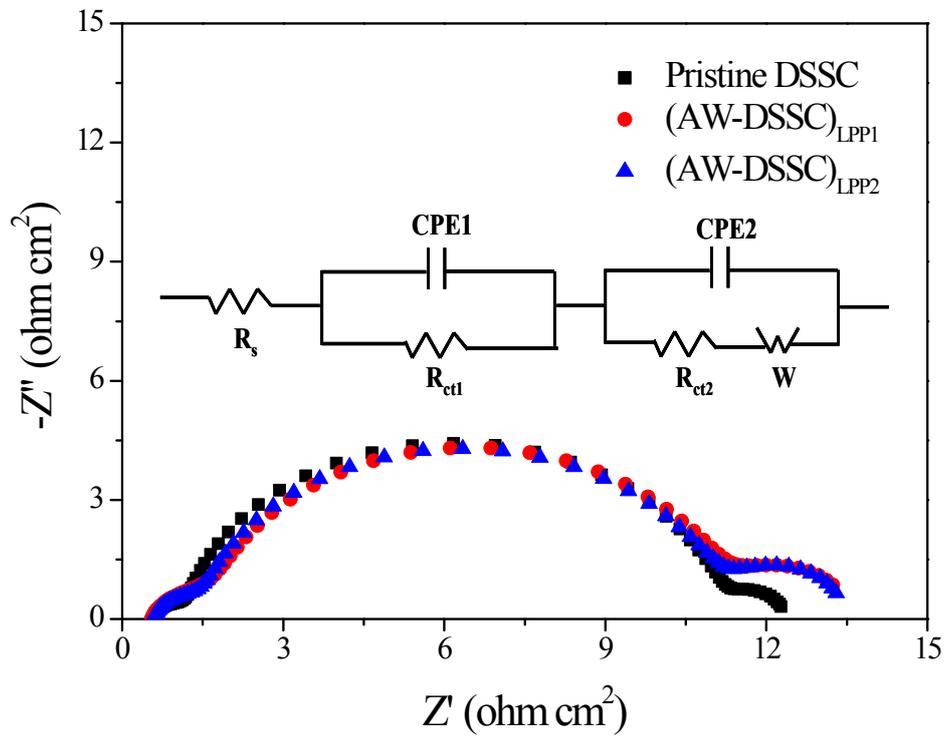


Fig. S3 Electrochemical impedance spectra of various solar cells. The inset represents an equivalent circuit.

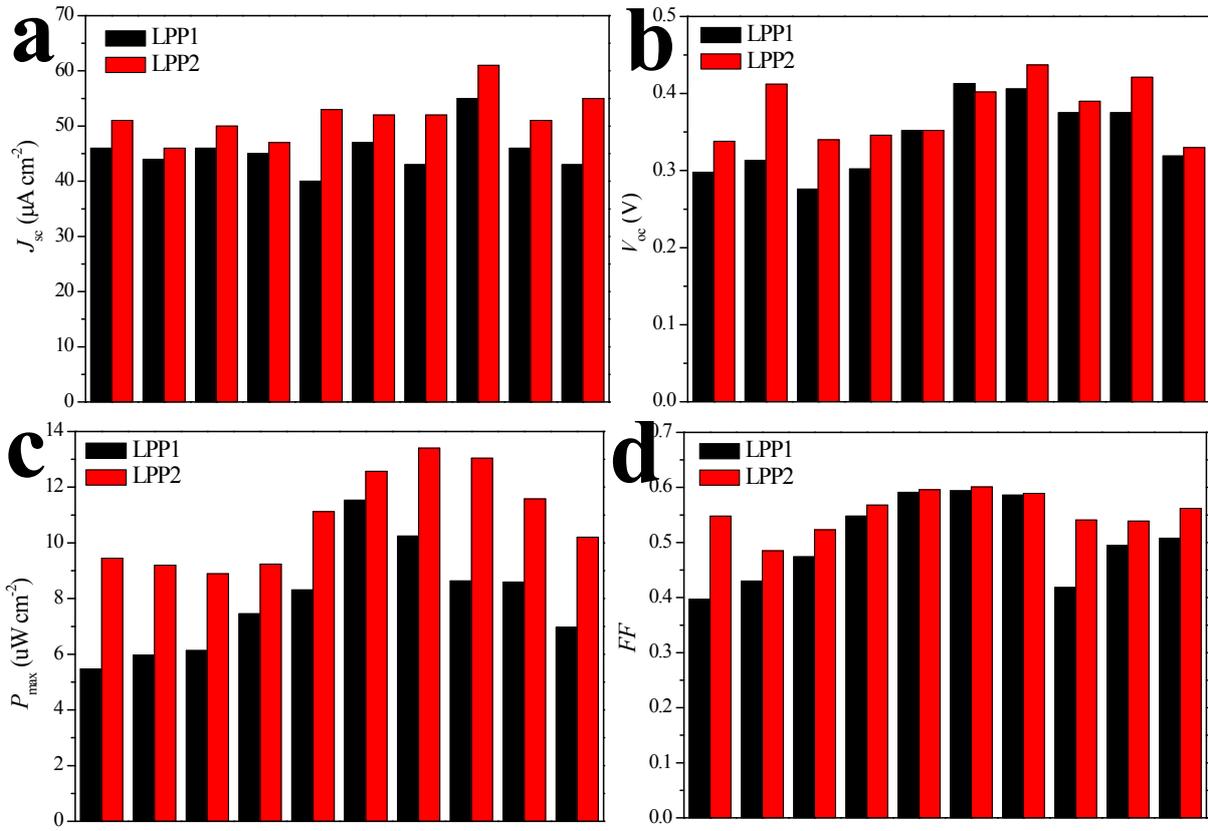


Fig. S4 Statistical histograms of various parameters from 10 LPP1- and LPP2-based AW-DSSCs characterized at dark condition.

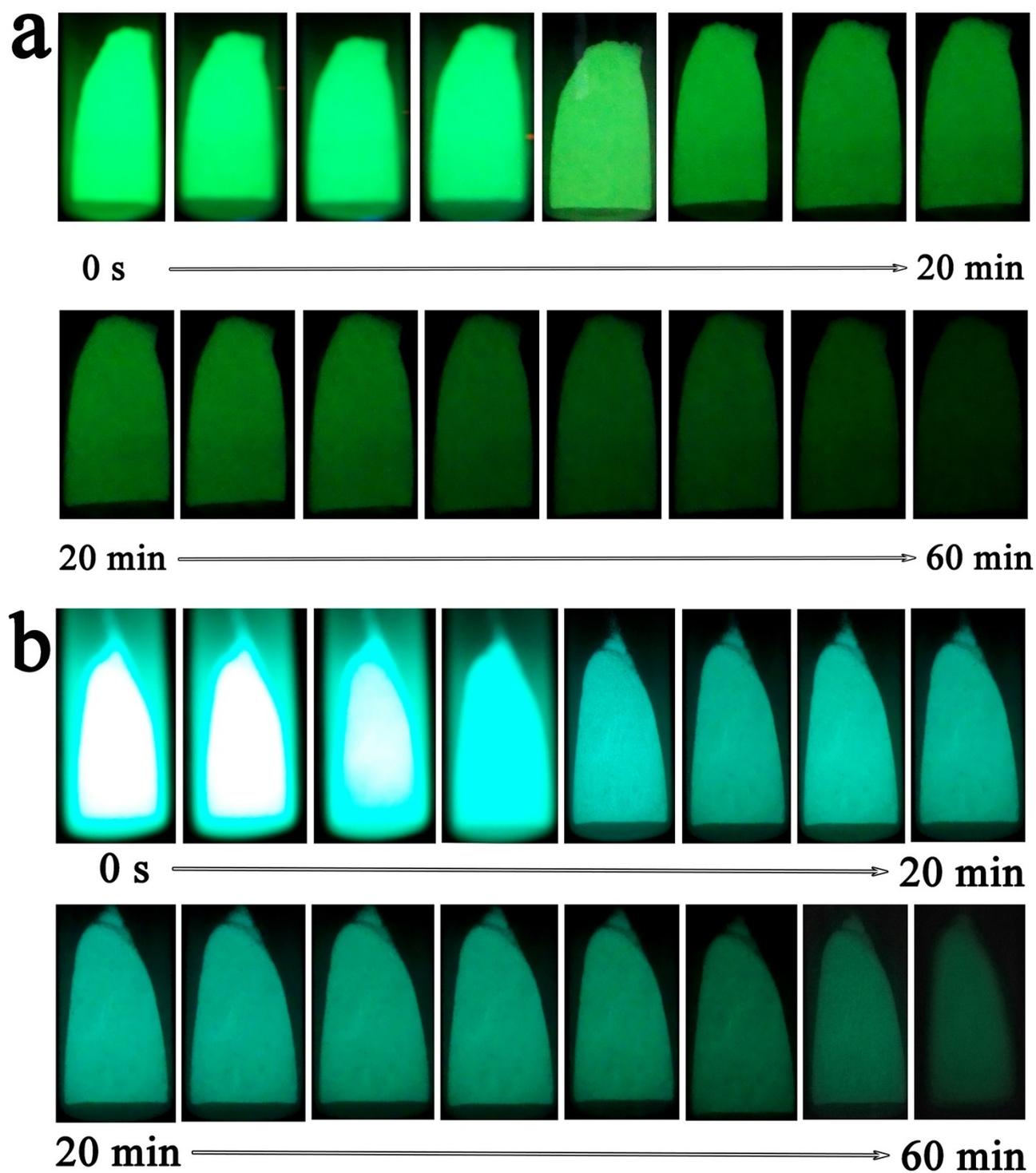


Fig. S5 The evolution of afterglow intensity from (a) TiO₂/LPP1 and (b) TiO₂/LPP2 after irradiated under solar light for 5 min.

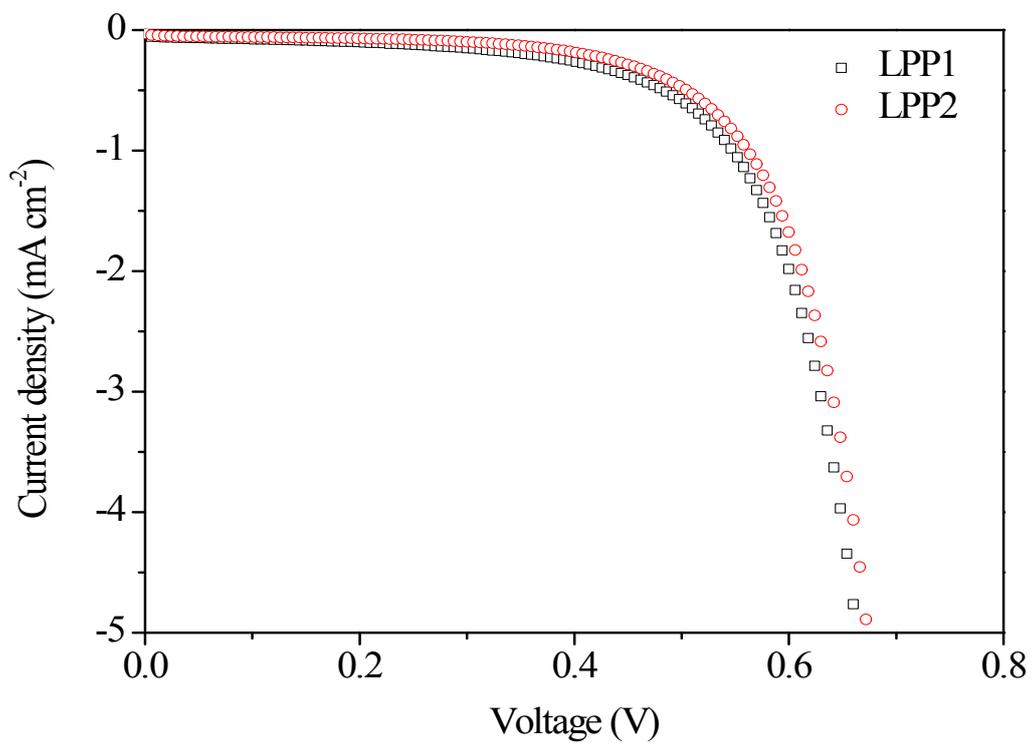


Fig. S6 The J - V curves of AW-DSSCs based on LPP materials determined at an afterglow time of 12 h under dark condition.

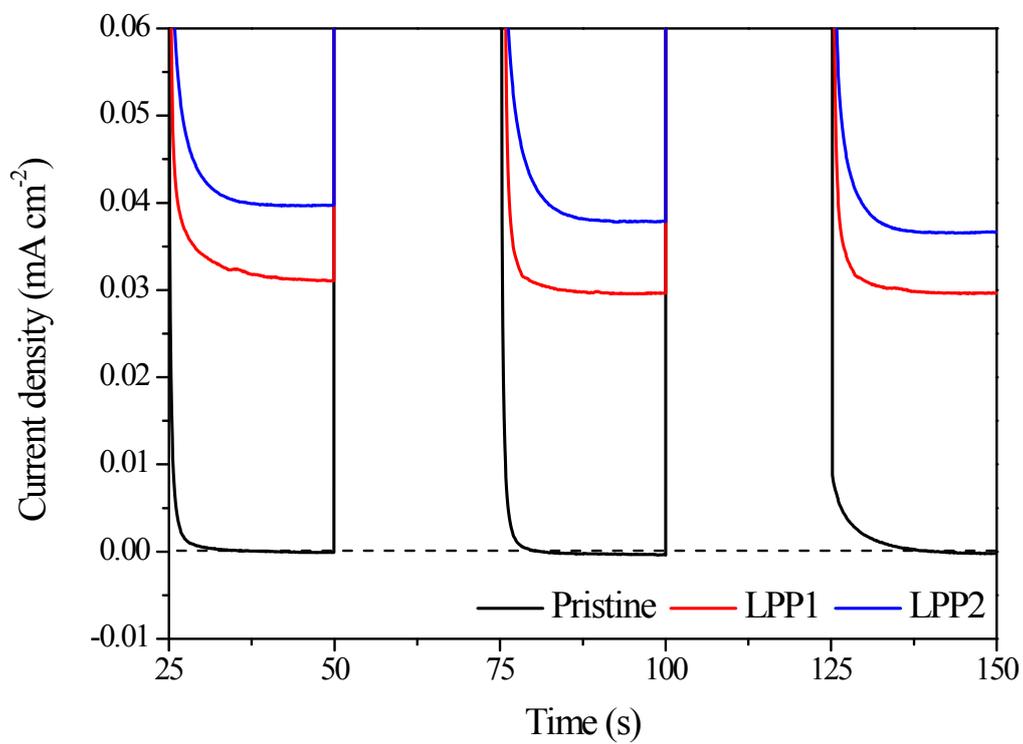


Fig. S7 Corresponding magnified part of red frame area in Fig. 3d.