

Electronic Supplementary Information

Stable and efficient dye-sensitized solar cells: photophysical and electrical characterizations

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Gel electrolyte preparation. Silica nanoparticles (10 wt%) with a primary particle size of ~10-nm were mixed with E2 to form a gel electrolyte, which can be transformed into liquid after a 5-min sonication.

Device fabrication. A double-layer titania film was used as the negative electrode. A 10- μm -thick transparent layer of 23-nm-sized titania particles was first screen-printed onto a pre-cleaned fluorine-doped tin oxide (FTO) conducting glass electrode (Nippon Sheet Glass, Solar, 4-mm-thick), and subsequently coated by a 5- μm -thick second layer of scattering titania particles (WERO-2, Dyesol). A cycloidal titania electrode ($\sim 0.28 \text{ cm}^2$) was stained by immersing it into a dye solution containing C106 (150 μM) and chenodeoxycholic acid (2 mM) in the mixture of acetonitrile and *tert*-butanol (volume ratio: 1/1) overnight. The dye-coated titania electrode was subsequently washed with acetonitrile, and then assembled with a thermally platinized FTO positive electrode (TEC 15 Ω/\square , Libbey-Owens-Ford Industries, 2.2 mm thick). The two active electrodes were separated with a 30- μm -thick Bynel (DuPont) hot-melt gasket and sealed up by heating. The internal space was filled with electrolytes using a vacuum back filling system. The electrolyte-injecting hole on the counter electrode was made with a sand-blasting drill, and was sealed with a Bynel sheet and a thin glass cover by heating.

Photovoltaic measurements and stability Tests. A Keithley 2400 source meter and a Zolix Omni- λ 300 monochromator equipped with a 500 W xenon lamp were used to measure photocurrent action spectra, with a wavelength sampling interval of 10 nm and a current sampling time of 2 s under the full computer control. Monochromatic incident photon-to-collected electron conversion efficiency (IPCE) is defined by $\text{IPCE}(\lambda) = hcJ_{\text{sc}}/e\phi\lambda$, where h is the Planck constant, c is the light speed in vacuum, e is the electronic charge, λ is the wavelength, J_{sc} is the short-circuit photocurrent density and ϕ is the incident radiative flux. A Hamamatsu S1337-1010BQ silicon diode used for IPCE measurements was calibrated

in National Institute of Metrology, China. During the photocurrent action spectrum measurements, a white LED is used to bias a testing cell with $\sim 1.0 \text{ mA cm}^{-2}$ background current.

A model LS1000-4S-AM1.5G-1000W solar simulator (Solar Light Company, USA) in combination with a metal mesh was employed to give an irradiance of 100 mW cm^{-2} . The light intensity was tested with a PMA2144 pyranometer and a calibrated PMA 2100 dose control system. $J-V$ characteristics were obtained by applying a potential bias to a testing cell and measuring the photocurrent with a Keithley 2602 source meter under the full computer control. The measurements were fully automated using Labview 8.0. A metal mask with an aperture area of 0.158 cm^2 was covered on a testing cell during all measurements. An antireflection film ($\lambda < 380 \text{ nm}$, ARKTOP, ASAHI Glass) is adhered to the DSC photoanode during IPCE and $J-V$ measurements. Solar cells covered with a $50\text{-}\mu\text{m}$ -thick of polyester film (Preservation Equipment Ltd, UK) as a 400 nm UV cut-off filter were irradiated at open circuit under a Suntest CPS plus lamp (ATLAS GmbH, 100 mW cm^{-2}) in ambient air at $60 \text{ }^\circ\text{C}$. $J-V$ measurements were carried out at room temperature after allowing the cells to cool down and equilibrate in 30 min.

Transient absorption measurements. Transient absorption measurements were carried out with a LP920 laser flash spectrometer in conjunction with a nanosecond tunable OPOlett-355II laser. The sample was kept at a 45° angle to the excitation beam. The probe light from a pulsed xenon arc lamp was passed through various optical elements, samples and a monochromator before being detected by a fast photomultiplier tube and recorded with a TDS 3012C digital signal analyzer.

Electrical impedance measurements. Electrical impedance experiments were carried out under illumination of a red LED with an IM6ex electrochemical workstation, with a frequency range from 50

mHz to 100 kHz and a potential modulation of 20 mV. A bias potential was applied to equal the open-circuit voltage at each irradiation intensity. The obtained impedance spectra were fitted with the Z-view software (v2.80, Scribner Associates Inc.).

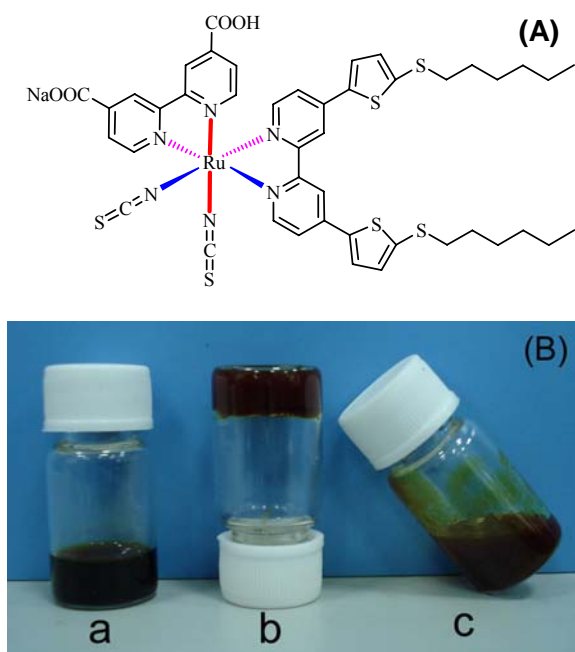


Fig. S1. (A) Molecular structure of the C106 sensitizer. (B) Photograph of (a) electrolyte E2 and (b) its quasi-solid state counterpart with silica nanoparticles. A 5-min sonication of the solid electrolyte can generate a colloidal solution as depicted in photograph (c).

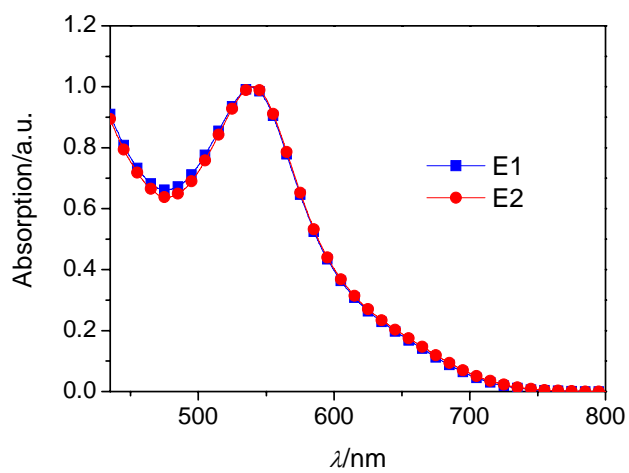


Fig. S2 Normalized absorption spectra of the C106-coated titania films immersed in electrolytes E1 and E2.

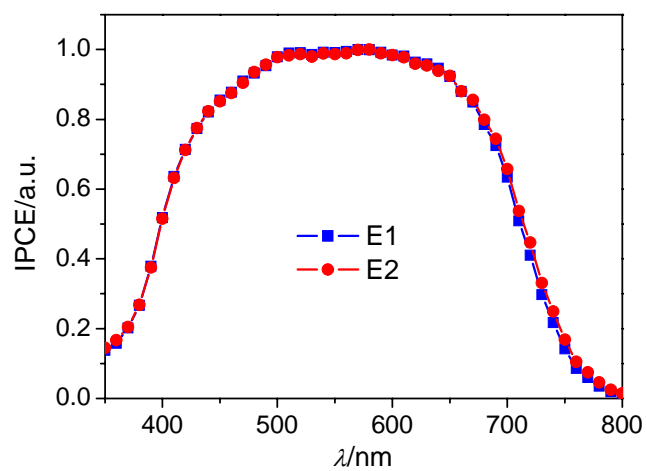


Fig. S3 Normalized photocurrent action spectra of the C106 sensitizer in conjunction with electrolytes E1 and E2.

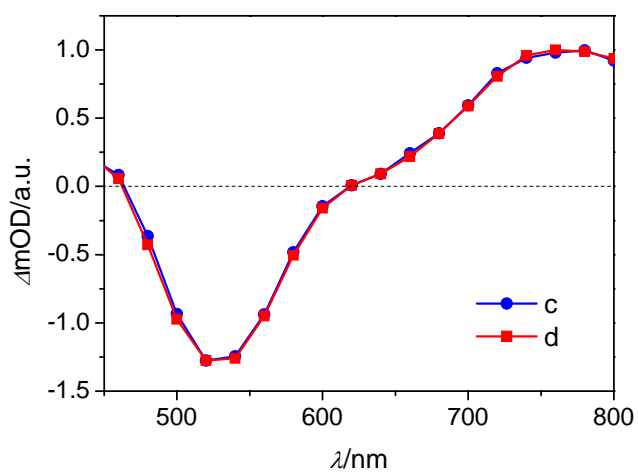


Fig. S4 Normalized transient absorption spectra of the C106-coated titania films immersed in electrolytes c and d.

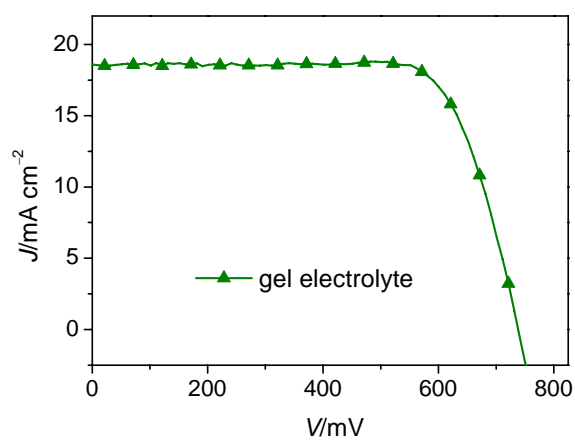


Fig. S5 J - V characteristic of C106 in combination with the gel electrolyte measured under irradiation of 100 mW cm^{-2} AM1.5G sunlight. Test was carried out using a metal mask with an aperture area of 0.158 cm^2 . An antireflection film was adhered to the cell during the measurement.

Table S1 Detailed photovoltaic parameters of DSCs in conjunction with the three electrolytes measured at different incident light intensities.^a

electrolyte	$P_{in}/\text{mW cm}^{-2}$	$J_{sc}/\text{mA cm}^{-2}$	V_{oc}/mV	FF	$\eta/\%$
E1	14.39	2.17	724	0.81	8.9
	26.14	3.95	742	0.81	9.1
	53.26	7.88	761	0.80	9.0
	100	14.97	782	0.75	8.8
E2	14.39	2.51	699	0.81	10.0
	26.14	4.66	717	0.80	10.2
	53.26	9.46	736	0.77	10.1
	100	17.57	753	0.76	10.0
gel electrolyte	14.39	2.57	686	0.81	9.9
	26.14	4.65	703	0.80	10.0
	53.26	9.41	723	0.78	10.0
	100	17.62	741	0.75	9.8

^aThe spectral distribution of our light resource simulates AM1.5G solar emission with a mismatch less than 4%. Lights at different intensities were obtained by attenuating the AM1.5G full sunlight with a set of neutral meshes. Incident power intensity: P_{in} ; Short-circuit photocurrent density: J_{sc} ; Open-circuit photovoltage: V_{oc} ; Fill factor: FF; Total power conversion efficiency: η . Cell area tested with a metal mask: 0.158 cm^2 . An antireflection film was adhered to testing cells during measurements.

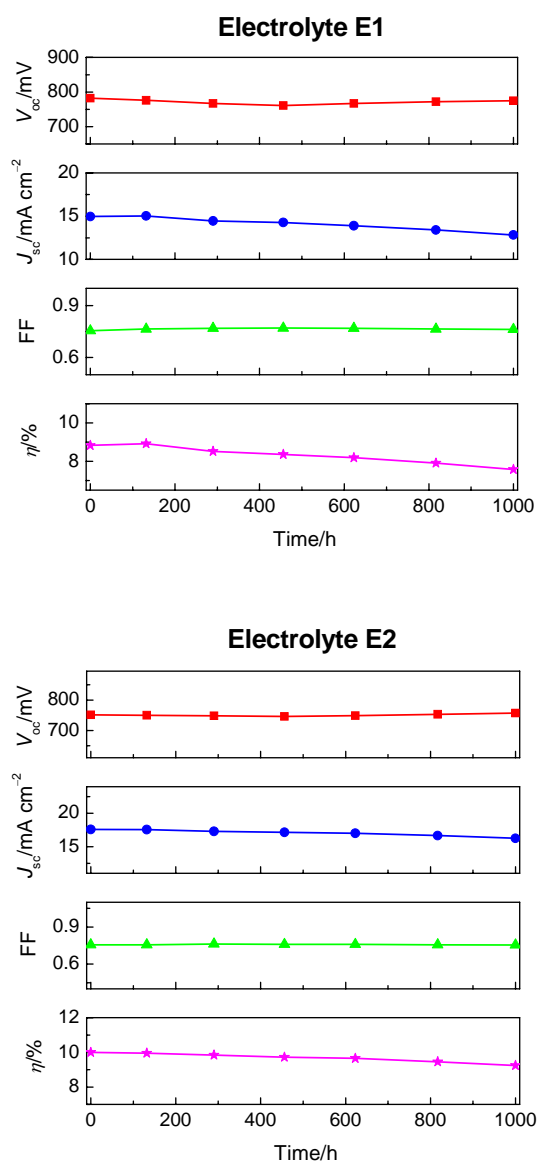


Fig. S6 Detailed photovoltaic parameters measured under the irradiance of $100\ mW\ cm^{-2}$ AM1.5G sunlight for cell in combination with electrolytes E1 and E2 during successive full sunlight soaking at $60\ ^\circ C$ for 1000 h.