

Supporting Information

Integrated smart electrochromic windows for energy saving and storage applications

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Experimental part

Preparation of WO₃ electrochromic (EC) film. A transparent indium-tin oxide (ITO) conductive glass (2 cm × 3 cm) was used as substrate. The WO₃ thin film was *in-situ* fabricated on an electrochemical activated ITO glass by dipping in tungstic acid sol as we reported before.

Fabrication of EC device. The Pt-layer deposited ITO glass was used as the counter electrode for EC device, and the 1 M H₂SO₄-PVA gel electrolyte were coated evenly on the surface of the counter electrode. Subsequently, the electrochromic film was stacked on the counter electrode to form the solid-state electrochromic device.

Fabrication of DSSC. The P25 films with diameter of 5 mm were prepared on ITO glasses by screen printing. After annealing at 500 °C for 30 min in air, the film was sensitized in N719 (0.5mM) ethanol solution for 24h. The TiO₂ electrode was subsequently washed with ethanol to remove the unanchored dyes. Finally, the dried TiO₂ electrode was assembled against the Pt electrode by sealing with hotmelt polymer foil (Surlyn), and an electrolyte consisting of DMPII (1.0 M), LiI (0.1 M), I₂ (0.12 M) and 4-TBP (0.5 M) in methoxypropionitrile was injected in to the empty volume between the electrodes, thus a typical dye-sensitized solar cell (DSSC) was formed.

Assemble of integrated smart system. The DSSC driven electrochromic smart window was integrated of two DSSC and a EC device. The P25/dye layers were printed on the edges of both electrodes of the EC device in the assembled self-powered smart window. In the self-powered and energy storage electrochromic smart system, the electrochromic supercapacitors were symmetrically assembled by two WO₃ thin films with H₂SO₄-PVA gel as electrolyte.

Measurements. The morphology of the tungsten oxide film was characterized by field-emission scanning electron microscopy (FESEM, Sirion 200, FEI, Netherlands). The electrochemical and optical properties of the integrated DSSC driven electrochromic smart window during the electrochromic process were in-situ measured synchronously on an electrochemical workstation (CHI760, Shanghai Instrument Co., Ltd.) and a UV-vis spectrophotometer (UV-2500, Shimadzu). Cyclic voltammetry (CV) and galvanostatic charge/discharge measurements of the self-powered electrochromic supercapacitor were also performed on the electrochemical workstation. The light source of the DSSC came from a 500W Xenon lamp.

Calculations.

The photoelectric conversion efficiencies (η) of the DSSC are calculated according to the following formulas:

$$\eta_{\text{power}} (\%) = P_{\text{out}}/P_{\text{in}} = (FF \times J_{\text{sc}} \times V_{\text{oc}})/P_{\text{in}}$$

Where η_{power} presents the photoelectric conversion efficiency, P_{in} and P_{out} is the incident light power and output power, FF is the fill factor for short, and J_{sc} and V_{oc} stand for the short-circuit current density and open-circuit voltage, respectively.

The coloration efficiencies (CE) of EC window are calculated according to the following formulas:

$$CE = OD/Q = \log(T_b/T_c)/(\int Idt)$$

Where OD is the optical density, Q stands for charge, I denote as the current density in the I-t curve, t is the instant time, T_b and T_c refer to the transmittance of the electrochromic device in bleached and colored states, respectively.

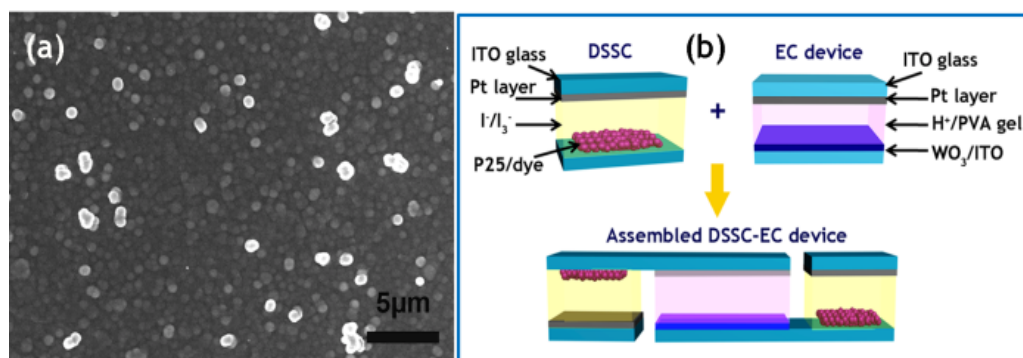


Fig.S1 (a) The SEM image of the WO₃ film. (b) Scheme of a DSSC driven EC smart window.

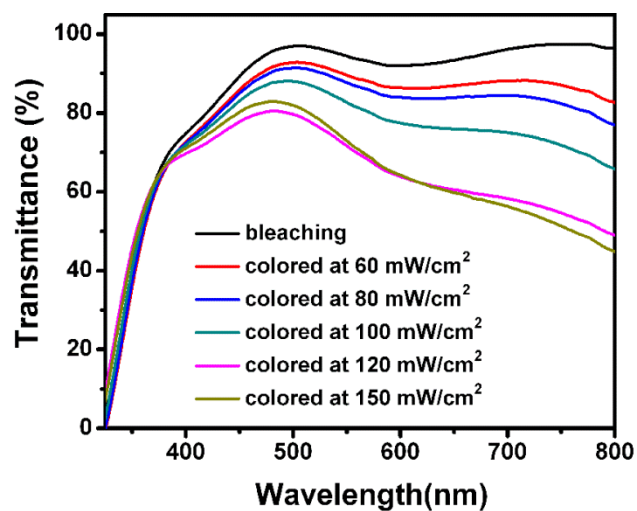


Fig. S2 The optical spectra of the DSSC driven EC smart window under different light intensities.

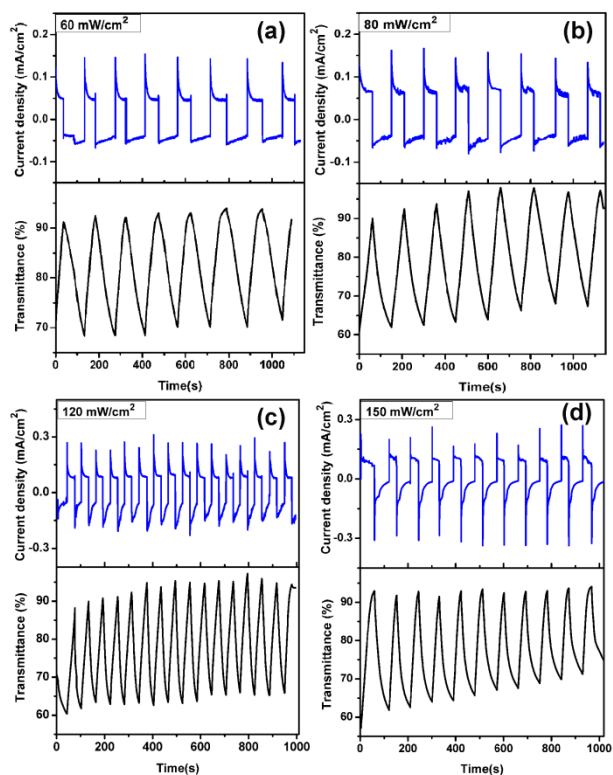


Fig. S3 The switching time characteristics of the integrated DSSC driven electrochromic window under the illumination intensity of (a) 60 mW/cm², (b) 80 mW/cm², (c) 120 mW/cm² and (d) 150 mW/cm².

Table S1 The efficiencies and electrochromic properties of the DSSC driven EC window (Type II).

Light intensity (mW/cm ²)	Energy conversion (DSSC, η_{power} (%))	Switching time (EC, t_c/t_b , sec)	Optical modulation (ΔT , %)	Coloration efficiency (CE, cm ² /C)
60	1.05	90/60	23	36.7
80	1.08	90/60	29.7	42.1
100	1.15	30/30	25.9	47.6
120	1.21	30/30	31.4	57.1
150	1.27	60/30	31	61.6

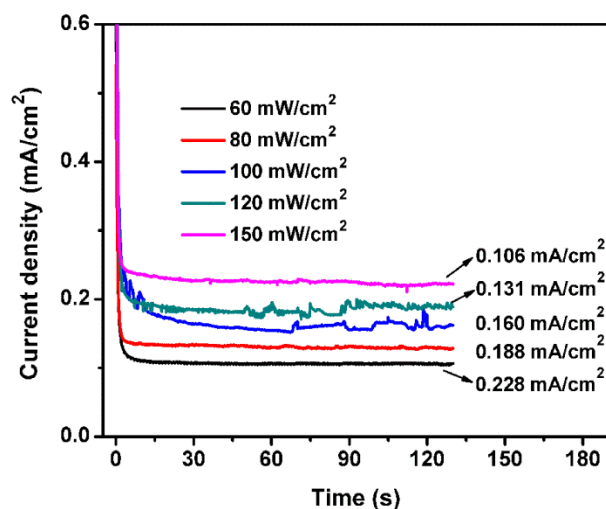


Fig. S4 The amperometric i-t curves of the DSSC charging circuit at different light intensities.

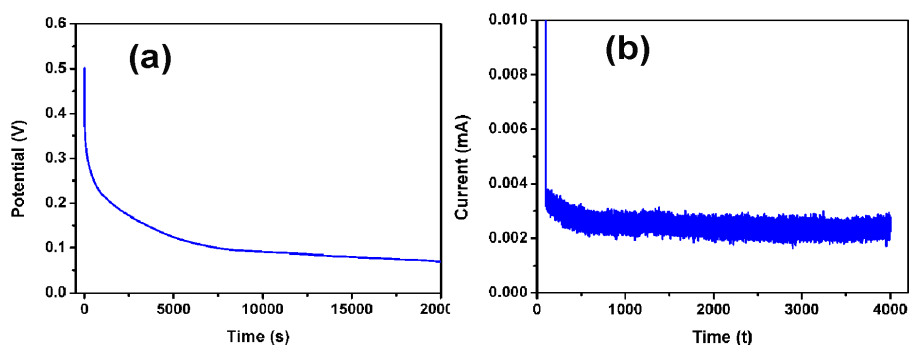


Fig. S5 (a) The open potential curve versus time. (b) Leakage current curve versus time.

As a potential energy storage unit for integration with other devices, the self-discharge and leakage current of the DSSC charging EES device must be considered. After the charge-discharge test for 10 cycles with a potential range from -0.5 V-0.5V, the device is charged to 0.5 V to conduct the open-circuit potential decay. Fig. S5 reveals the potential decay plot versus time, which shows that the potential have been decreased to 0.07 V after about 5 hours, indicating a relatively low self-discharge property. Furthermore, the leakage current is also measured when the device is charged to 0.5 V. As shown in Fig. S5b, the DSSC charging EES device shows a low leakage current of about 2.5 μA , which can be ignored. The low self-discharge and leakage demonstrate that the DSSC charged EES device has practical application value.