Electronic Supporting Information

Robust and stable dual-band electrochromic smart window with multicolor tunability

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Experiment

Material

Aniline (C_6H_7N,>99.9%) was bought from Macklin. Dodecylbenzenesulfonic acid ($C_{18}H_{30}SO_3$), and zinc perchlorate hexahydrate ($Zn(ClO_4)_2 \cdot 6H_2O$) were purchased from Sigma-Aldrich. Indium tin oxide (ITO) coated glass ($10\Omega\ sq^{-1}$) was purchased from Foshan Jingjiexin Glass Co., LTD.

Preparation of PANI Film

ITO glass was cut to a size of $10 \times 5\ cm^2$, cleaned with 2% Hellmanex III for 5 minutes, then soaked in deionized water, acetone, ethanol, and isopropanol for 15 minutes and dried in a vacuum drying oven. The cleaned ITO glass was inserted vertically into 0.05 M aniline and dodecybenzenesulfonate solution. In the deposition process, ITO glass was used as the working electrode in the three-electrode system, and platinum sheet ($2 \times 2\ cm^2$) and Ag/AgCl electrode were used as the counter electrode and reference electrode, respectively. The method of pulsed electrodeposition was performed using a CHI660E electrochemical workstation by applying anodic pulse potential to ITO glass. The pulse voltage ranged from 1.6 V to 0 V, where the duty cycle was 1/3, and each cycle time was 9 s, for a total of 200 cycles.

Assembly of DESW Devices

The two deposited PANI films ($10 \times 5\ cm^2$) were used as the working electrode, and the rectangular zinc sheet frame ($10 \times 6\ cm^2$, thickness 1 mm) was used as the counter electrode. The PANI film and zinc sheet were separated and glued to both sides with double-sided adhesive tape (thickness 3 mm). After carefully pressing the electrodes together, $Zn(ClO_4)_2$/PC solution (1 M, dehydrated in a glove box by molecular sieve) was injected into them as the electrolyte, and finally the assembled device was encapsulated with epoxy resin.

Material Characterization and Electrochromic Measurements

The morphology of PANI films was measured by SEM (Zeiss Sigma50, German). FTIR was recorded by a Tracer 100 spectrometer (Thermo Fisher, USA) test. Raman spectroscopy (Witec, German) was used to study the vibration mode of PANI. The electrochemical and electrochromic properties of the films were tested in an argon glove box. Electrochemical tests were performed using AUTOLAB PGSTAT204 electrochemical workstation. In-situ transmission spectra of the films and devices were tested using an AVANTES spectrometer (AvaSpec-ULS2048CL-EVO), where ITO glass was used as the reference for the film test and the air was used as the reference for the device test. A home-built temperature testing system is used to test the thermal regulation ability of DESW, where an AM1.5 light source (Microenerg CME-X305) is used to simulate sunlight, DESW on the platform (with a 3 × 3 cm^2 hole) is used to simulate window, and the temperature of absorber plate used to simulate indoor temperature.

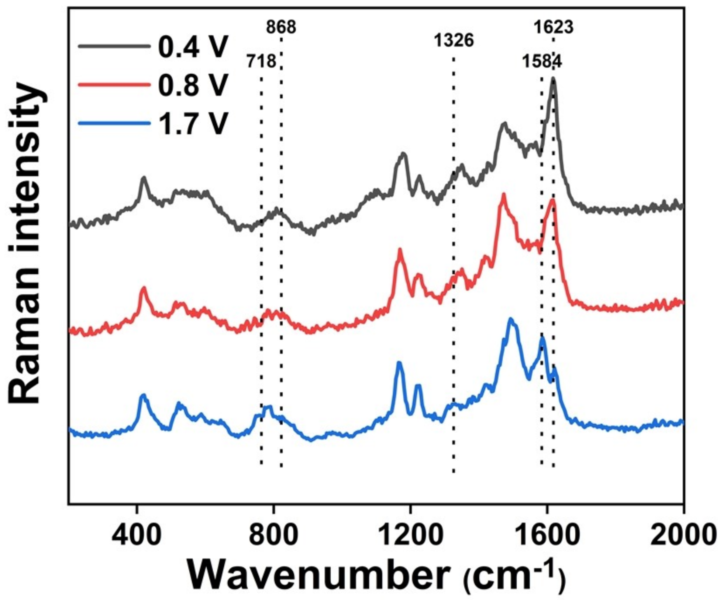

Fig. S1 The Raman spectra of the PANI film at different potentials.

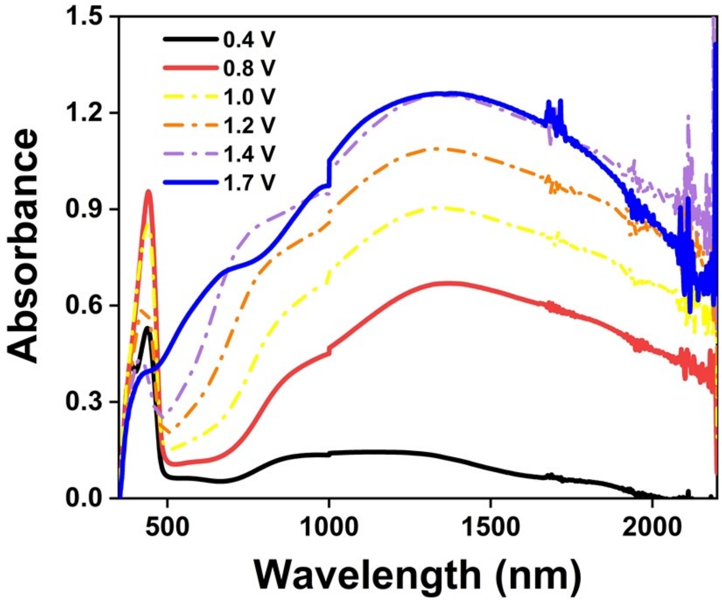

Fig. S2 The absorption spectra of the PANI film under different potentials.

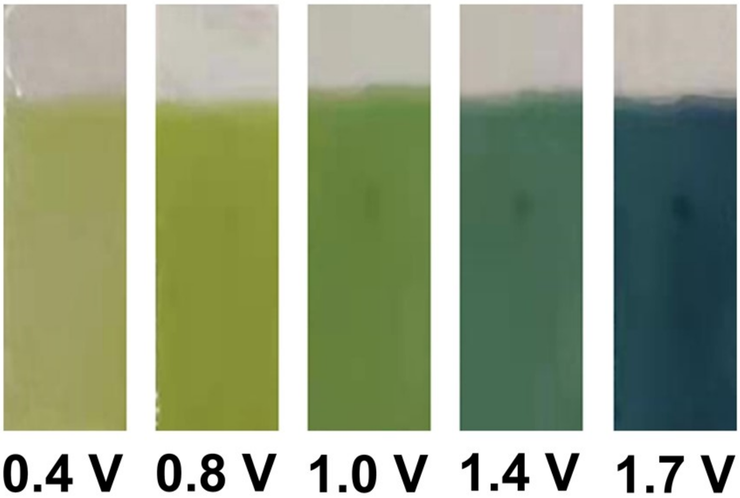

Fig. S3 The PANI film exhibits a variety of colors at different potentials

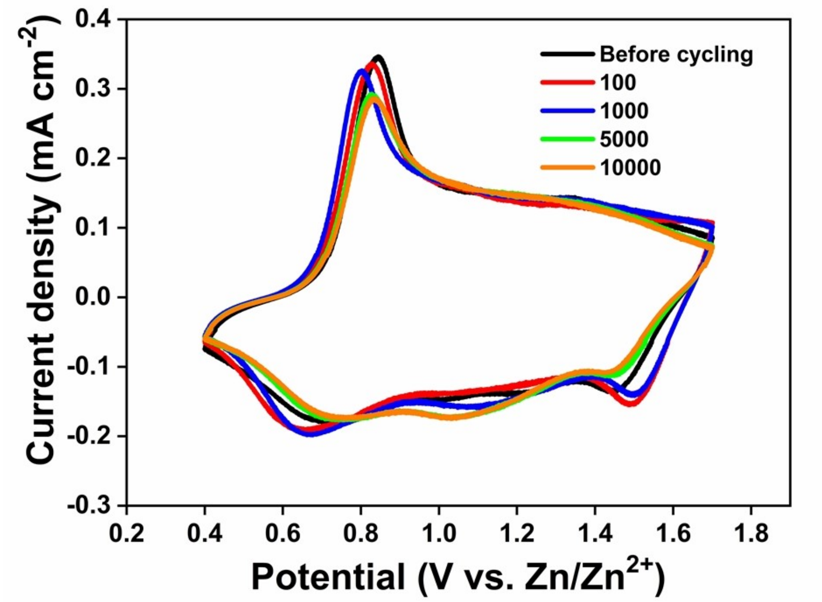

Fig. S4 The PANI film shows excellent cycling stability after 10000 cycles in the CV test.

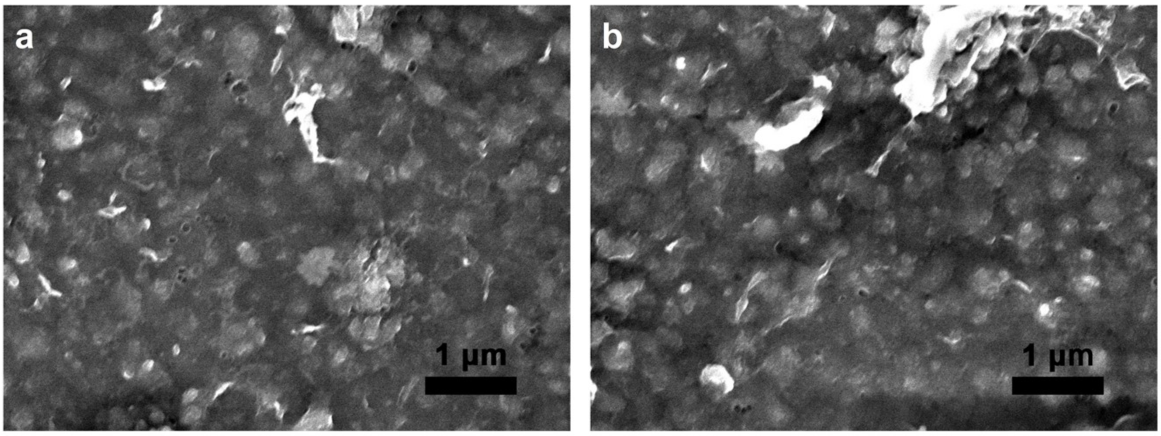

Fig. S5 The SEM images of the PANI film (a) before and (b) after 10000 cycles.

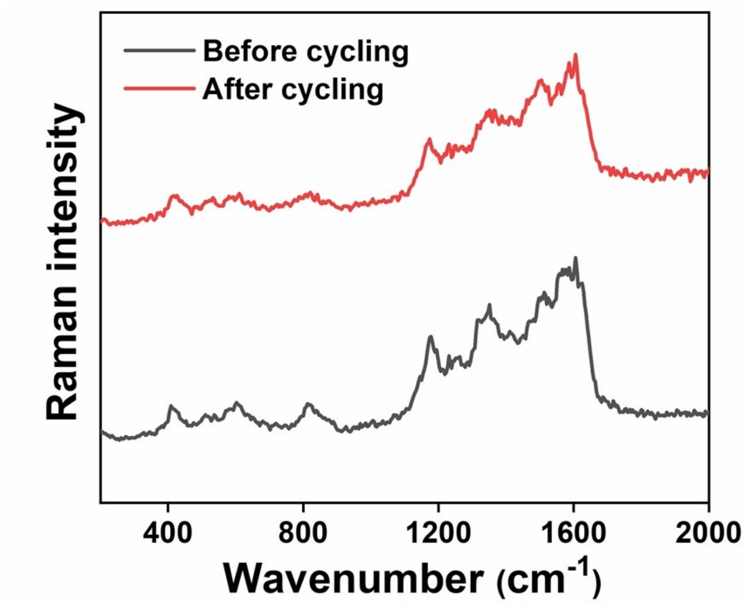

Fig. S6 The Raman spectra of the PANI film before and after 10000 cycles.

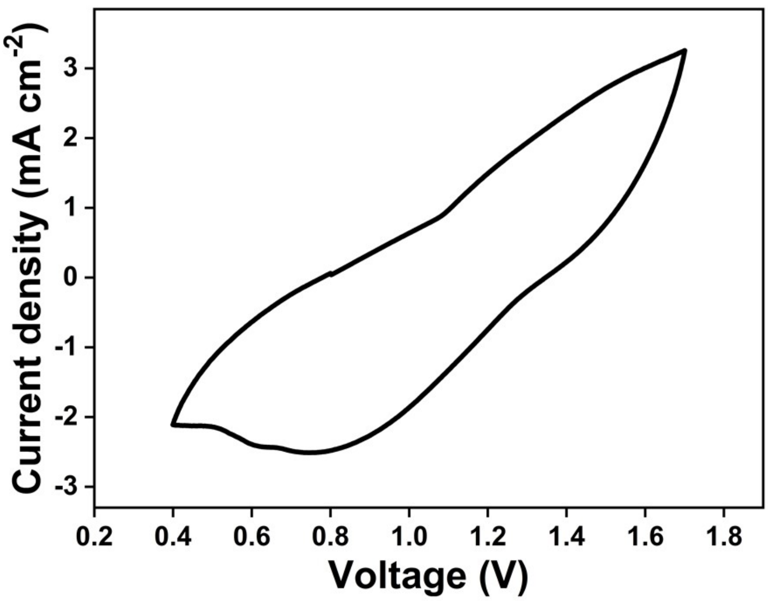

Fig. S7 CV curve of the 10 × 5 cm^2 device at 20 mV s^{-1}.

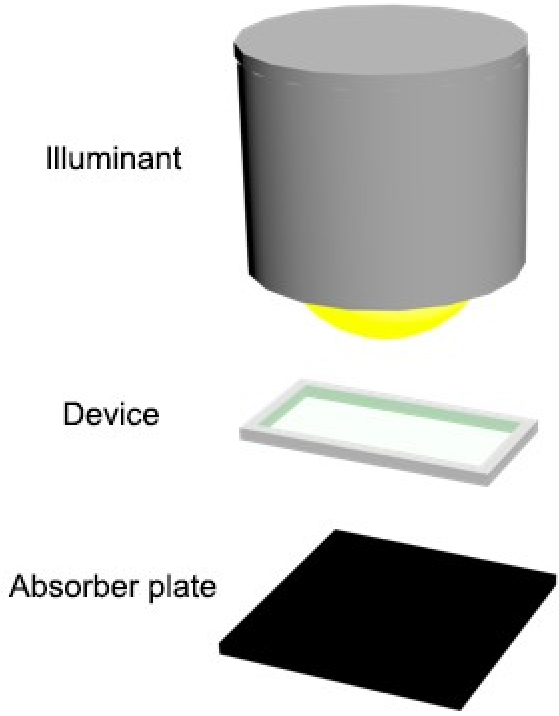

Fig. S8 The schematic diagram of the home-built temperature testing system for the thermal regulation ability of DESW.

Table S1. The comparison of performance parameters among the dual-band electrochromic materials.

Materials	ΔT (VIS)	ΔT (NIR)	CE (cm^2 C^{-1})	τ_c/τ_b (s)	Stability (charge storage)	Stability (optical loss)	Colors	Refs
WO_3 NCs	80.1% (800 nm)	44.3% (1500 nm)	127 (633nm) 210 (1500nm)	220/260 (1500 nm)	/	5% at 1500 nm after 500 cycles	Colorless-Blue	[1]
m-WO_{3-x} NCs	91.7% (633 nm)	94.6% (1200 nm)	121 (633nm) 254 (1200nm)	13/16 (633 nm) 5/8 (1200 nm)	80% (1000 cycle)	7.6% at 633 nm and 10.2% at 1200 nm after1000 cycles	Colorless-Blue	[2]
TiO_{2-x} NCs	95.5% (633 nm)	90.5% (1200 nm)	38.2 (633nm) 112.7 (1600nm)	35.1/9.6 (633 nm) 15.5/3.4 (1600 nm)	95.6% (2000 cycle)	0.1% at 633 nm and 1.3% at 1600 nm ater 2000 cycles	Colorless-Black	[3]
Ta-TiO_2 NCs	89.1% (550 nm)	81.4% (1600 nm)	29.7 (550nm) 121.2 (1600nm)	52.6/9.5 (550 nm) 11.4/3.6 (1600 nm)	95.9% (2000 cycle)	0.2% at 550 nm and 6% at 1600 nm after 2000 cycles	Colorless-Black	[4]
Nb-TiO_2 NCs	64% (500 nm)	67% (2000 nm)	/	105/<8 (500 nm) 10/<8 (2000 nm)	/	/	Colorless-Blue	[5]
$Nb_{12}O_{29}$ NCs	78% (633 nm)	85% (1060 nm)	136 (550 nm) 186 (1200 nm)	/	68% (500 cycle)	/	Colorless-Black	[6]
NbO_x-ITO	/	/	29.5 (500 nm)	/	95% (1000 cycle)	/	Colorless-Black	[7]
$W_{18}O_{49}/TiO_2$	81.4% (633 nm)	91.3% (1800 nm)	/	1.2/0.9#	85% (20000 cycle)	/	Colorless-Black	[8]
PANI	65% (633 nm)	59% (1600 nm)	367.1 (633 nm) 299.6 (1600 nm)	5.9/16.9 (633 nm) 11/32.5 (1600 nm)	97% (10000 cycle)	6% at 633 nm and 4% at 1600 nm after 10000 cycles	Light yellow-Green-Deep Blue	This work

The data is measured by multi-potential steps.

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