Supplementary Information

Electrochemical Analysis of Flexible Symmetric Supercapacitors Using WSe₂@Graphite Thin Film Electrodes under Different pH Conditions

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Sputtering conditions			
Target used (Cathode)	Tungsten diselenide (WSe ₂)		
Substrate used (anode)	Graphite sheet		
Deposition time	25 min.		
Base pressure	3 x 10 ⁻⁶ Torr		
Working pressure	10 mTorr		
Applied DC power	75 W		
Applied temperature.	200 °C		
Distance between substrate and target	5 cm		
Gas utilized	20 sccm Argon (Ar)		

Table S1. Sputtering parameters for the fabrication of WSe2@graphite thin film electrode.



Figure S1. XPS spectra (a) full survey spectra, and (b) high resolution spectra for pristine graphite sheets, XPS spectra (c) full survey spectra for pure WSe₂ target, individual high-resolution spectra (d) W4f and (e) Se3d.



Figure S2. (a) High-resolution TEM image with the marked crystallites, (b) histogram showing the quantitative crystallite size distribution analysis of WSe₂.



Figure S3. Top-view FESEM images depicting the progressive morphological evolution of WSe₂@graphite thin films as a function of sputtering duration: (a) 30 seconds, (b) 5 minutes, (c) 15 minutes, (d) 20 minutes, (e) 25 minutes, and (f) 30 minutes. The sequence highlights the transition from initial nucleation to the development of porous cauliflower-like nanostructures, followed by morphological agglomeration at extended deposition times. Cross-sectional FESEM images showing the corresponding film thickness at varying deposition intervals: (g) 30 seconds, (h) 25 minutes, and (i) 30 minutes, demonstrating the thickness growth and structural densification with increased sputtering time.



Figure S4. Schematic representation of electrochemical analysis setup with the connected symmetric supercapacitor.

Electrochemical analysis

The areal capacitance and areal energy density of the fabricated SS device were calculated using the following equations (E1, E2):

$$C_A = \frac{\int i(V)dV}{Av\Delta V} \tag{ES1}$$

$$E_a = \frac{C_A \Delta V^2}{2 \times 3600} \tag{ES2}$$

The Integral $\int i(V)dV$ denotes the area under the CV curve, where *i* is the current (A) and V is the potential (V). A, *v*, ΔV , C_A represents the area of the WE (cm⁻²), scan speed (or scan rate) (mV s⁻¹), working potential window in volts (V), and the areal capacitance of the WE (mF cm⁻²) respectively.

Further, to obtain a more precise capacitance value, GCD measurements were carried out, and the areal capacitance was calculated by the equation (E3):

$$C_A = \frac{i\Delta t}{A\Delta V} \tag{ES3}$$

Here, Δt is the discharge time in seconds (s). The areal energy density (E_a) and areal power density (P_a) of the SS device were determined using the following equations (4,5):

$$E_a = \frac{C_A \Delta V^2}{2 \times 3600} \tag{ES4}$$

$$P_a = \frac{E_a \times 3600}{\Delta t} \tag{ES5}$$

In these equations, C_A indicates the areal capacitance of the working electrode (mF cm⁻²), E_a represents the areal energy density of the working thin film electrode in mWh cm⁻² and P_a is the areal power density in mW cm⁻².

Calculated values of C_A and E_a using the area under CV curves at scan speeds from 50-1500 mV s⁻¹ for WSe₂@graphite thin film electrode based SS device in different electrolytes.

Table S2

Electrolyte – 1M Na₂SO₄

Scan Rate (mV s ⁻¹)	Areal Capacitance (mF cm ⁻²)	Areal Energy density (μWh cm ⁻²)
50	44	24.44
100	30.79	17.10
200	19.13	10.61
500	11.04	6.12
1000	6.12	3.40
1500	4.19	2.32

Table S3

Electrolyte – 1M NaOH

Scan Rate (mV s ⁻¹)	Areal Capacitance (mF cm ⁻²)	Areal Energy density (μWh cm ⁻²)	
50	67.96	37.75	
100	41.51	23.06	
200	25	13.88	
500	12.5	6.94	
1000	7.04	3.91	
1500	4.73	2.63	

Table S4

Electrolyte - 1M H₂SO₄

Scan Rate (mV s ⁻¹)	Areal Capacitance (mF cm ⁻²)	Areal Energy density (μWh cm ⁻²)
50	54.92	30.51
100	43.59	24.21
200	30.29	16.82
500	14.32	7.95

1000	7.82	4.34
1500	5.33	2.96

Calculated values of C_A , E_a and P_a using the discharge time at different current densities from 1 to 10 mA cm⁻² for WSe₂@graphite thin film electrode based SS device in different electrolytes.

Table S5

Electrolyte - 1M Na₂SO₄

Current density (mA cm ⁻²)	Areal capacitance (mF cm ⁻²)	Areal energy density (μWh cm ⁻²)	Areal power density (μW cm ⁻²)
1	92.92	51.62	1000
2	62.26	34.58	2000
4	41.85	23.25	4000
8	21.32	11.84	8000
10	18.23	7.5	1000

Table S6

Electrolyte – 1M NaOH

Current density (mA cm ⁻²)	Areal capacitance (mF cm ⁻²)	Areal energy density (μWh cm ⁻²)	Areal power density (μW cm ⁻²)
1	105.71	58.73	1000
2	212.73	118.18	2000
4	119.25	66.25	4000
8	45.66	25.36	8000
10	34.95	19.41	10000

Table S7

Electrolyte - 1M H₂SO₄

Current density (mA cm ⁻²)	Areal capacitance (mF cm ⁻²)	Areal energy density (μWh cm ⁻²)	Areal power density (μW cm ⁻²)
1	123.73	68.73	1000
2	71.01	39.45	2000
4	46.09	25.60	4000
8	37.70	20.94	8000
10	53.72	29.84	10000