Electronic Supplementary Material (ESI) for Physical Chemistry Chemical Physics.

Supporting Information

Waste dry cells derived photo-reduced graphene oxide and polyoxometalate composite for solid-state supercapacitor applications

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1. The specific capacitance was calculated from the cyclic voltammetry by the following equation,

$$C = \frac{\int_{V_1}^{V_2} i(V)dV}{v(V_2 - V_1)} \quad \text{....... (S1)}$$

2. Capacitances with energy and power density from charge-discharge were calculated using the following equations for asymmetric arrangements:

Galvanostatic capacitance: $$C = \frac{\int iVdt}{\int_{V_i}^{V_f} VdV} = \frac{2i_m \int Vdt}{V^2 \begin{cases} V_f \\ V_i \end{cases}}$$ F/g .... (S1)

$$C = \frac{i(\triangle t * \triangle V)}{n(\triangle V)^2} = \frac{i(\triangle t)}{m(\triangle V)} = \frac{I(\triangle t)}{\triangle V}$$ F/g .... (S2)

Energy density: $E = 0.5 * C * \triangle V^2$ Wh/kg .... (S3)

Power density: $P = \frac{E}{\triangle t} * 3600$ W/kg .... (S4) where *I, m, t,* and *△V* are discharge current, the mass of single electrode, discharge time, and potential window, respectively.

3. The total impedance is given by,

$$Z(\omega) = Z^{'}(\omega) + jZ''(\omega), \text{ ....(S5)},$$

where $\omega = 2\pi f$, f is the frequency of the input ac signal.

The Total capacitance is given as [34],

$$c(\omega) = c^{'}(\omega) - jc''(\omega) \text{ .... (S6)},$$

where real the part of the capacitance $c^{'}(\omega) = \frac{Z''(\omega)}{\omega|Z(\omega)|^2}$ .... (S7) and

the imaginary part of the capacitance $c''(\omega) = \frac{Z^{'}(\omega)}{\omega|Z(\omega)|^2}$ .... (S8).

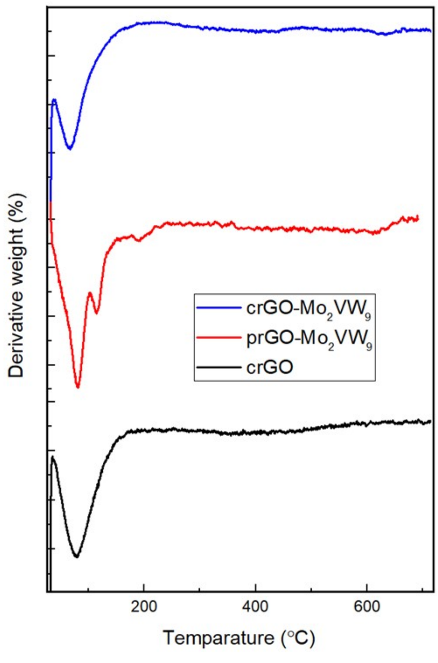


Fig. S1 DTA spectra of crGO, $prGO-Mo_2VW_9$, and $crGO-Mo_2VW_9$ nanocomposites.

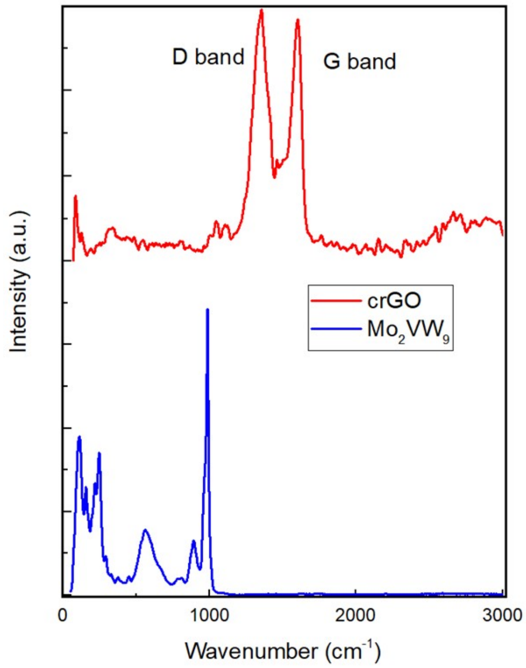


Fig. S2 Raman spectra of crGO and Mo_2VW_9.

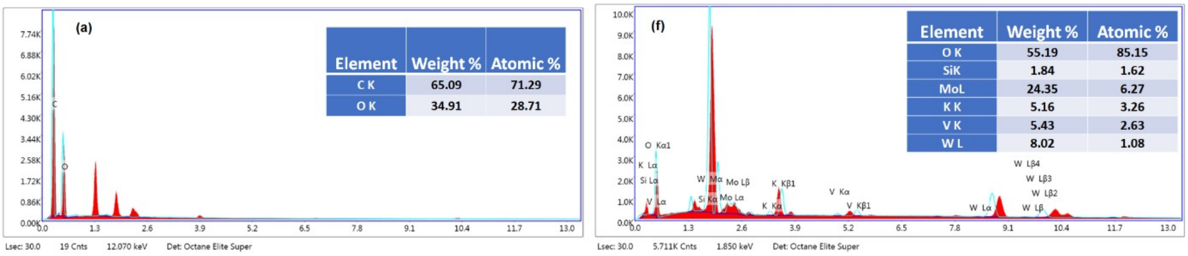
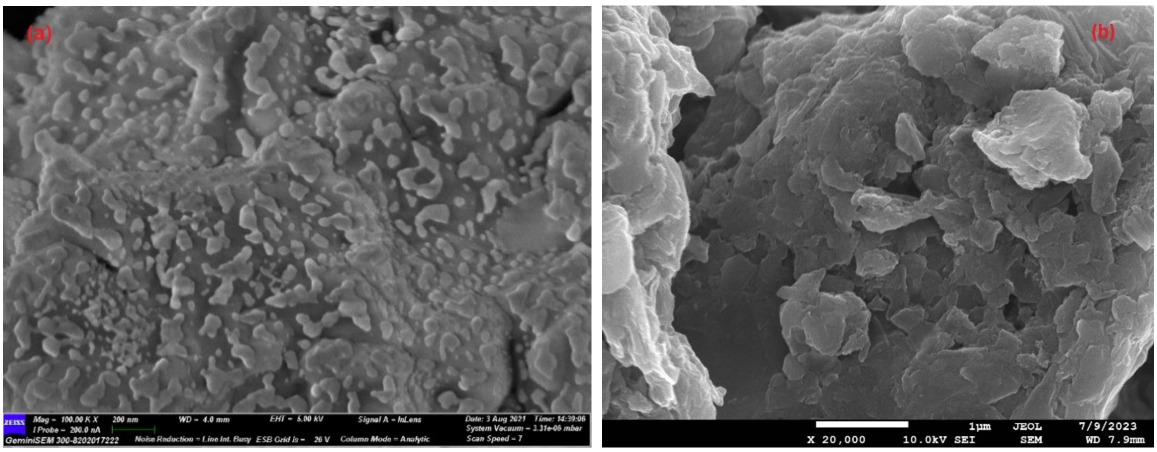


Fig. S3 EDS spectra of (a) crGO and (b) Mo_2VW_9.



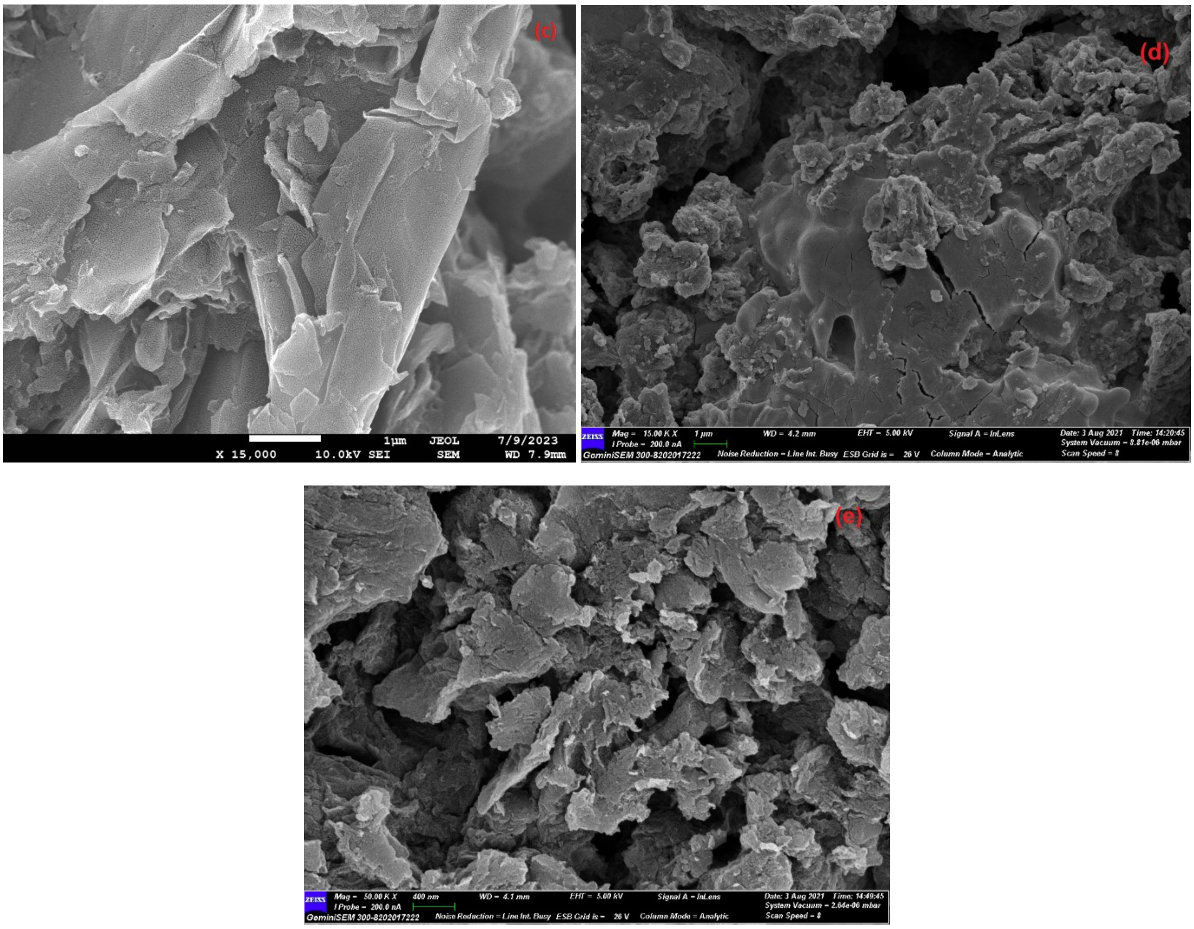
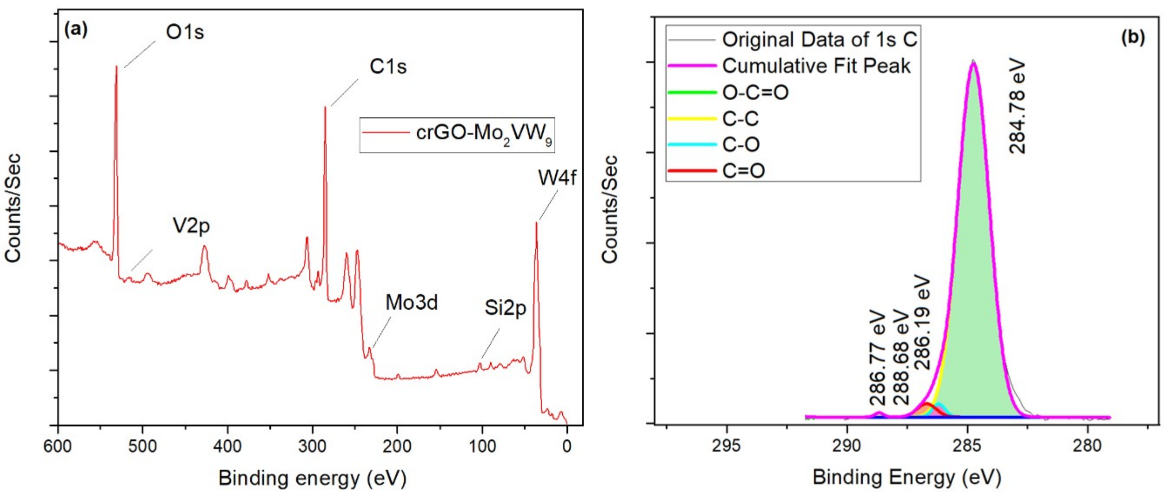


Fig. S4 FESEM micrograph at different magnification for (a-b) prGO-Mo_2VW_9, (c-d) crGO-Mo_2VW_9 nanocomposites, and (e) bare crGO.



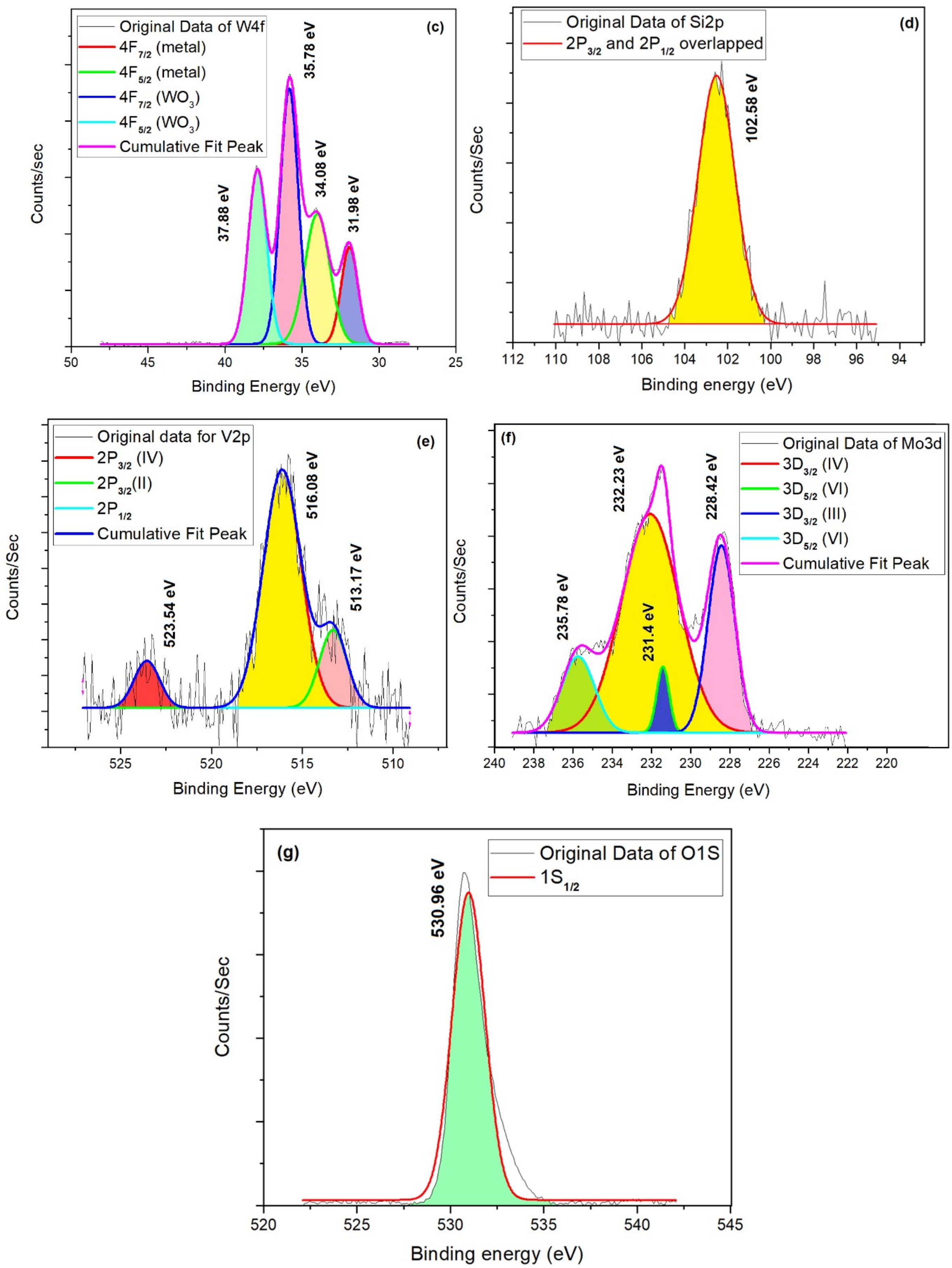


Fig. S5 XPS spectra of (a) overall survey, (b) C 1s, (c) W 4f, (d) Si 2p, (e) V 2p, (f) Mo 3d, and (g) O 1s for crGO-Mo_2VW_9 nanocomposite.

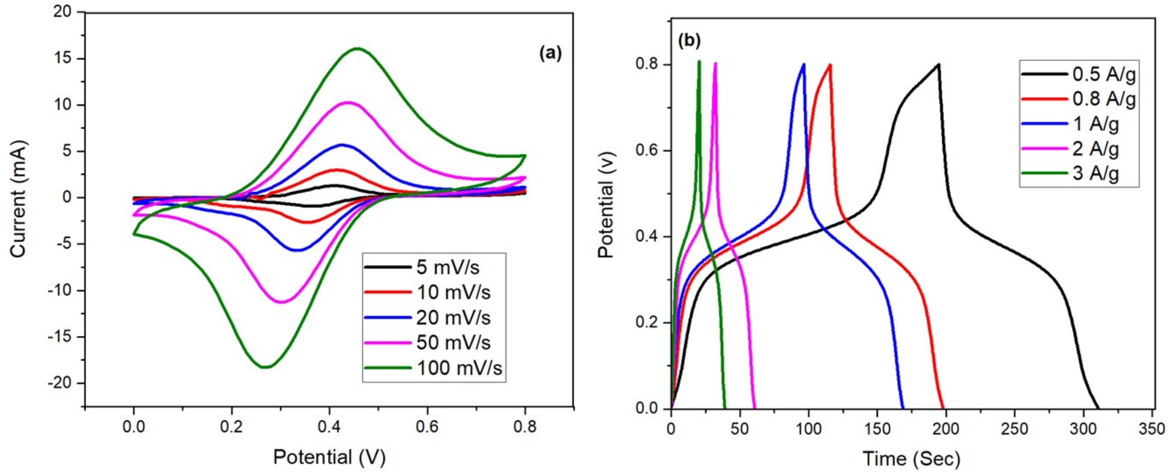


Fig. S6 (a) CV and (b) GCD response of pristine Mo_2VW_9.

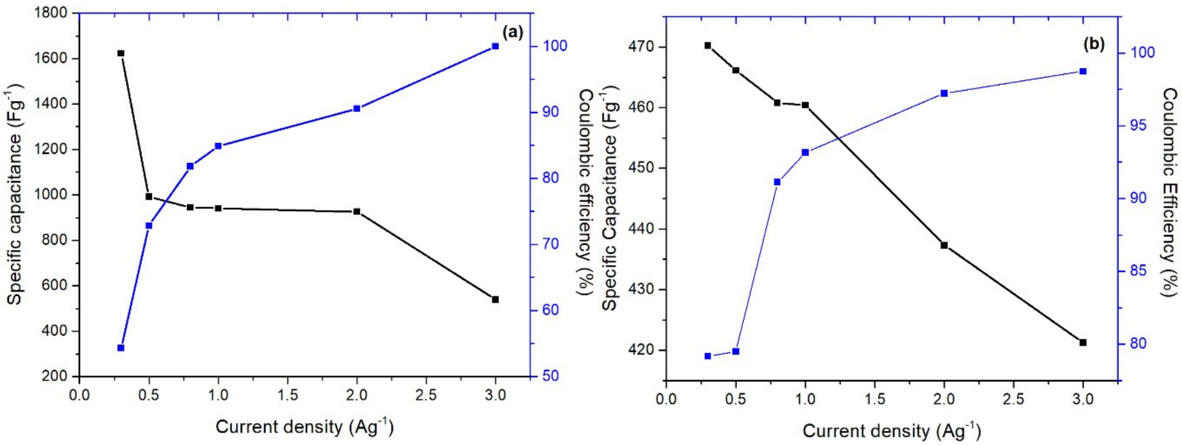


Fig. S7 Coulombic efficiency and specific capacitance variation of (a) prGO-Mo_2VW_9 and (b) crGO-Mo_2VW_9 nanocomposites.

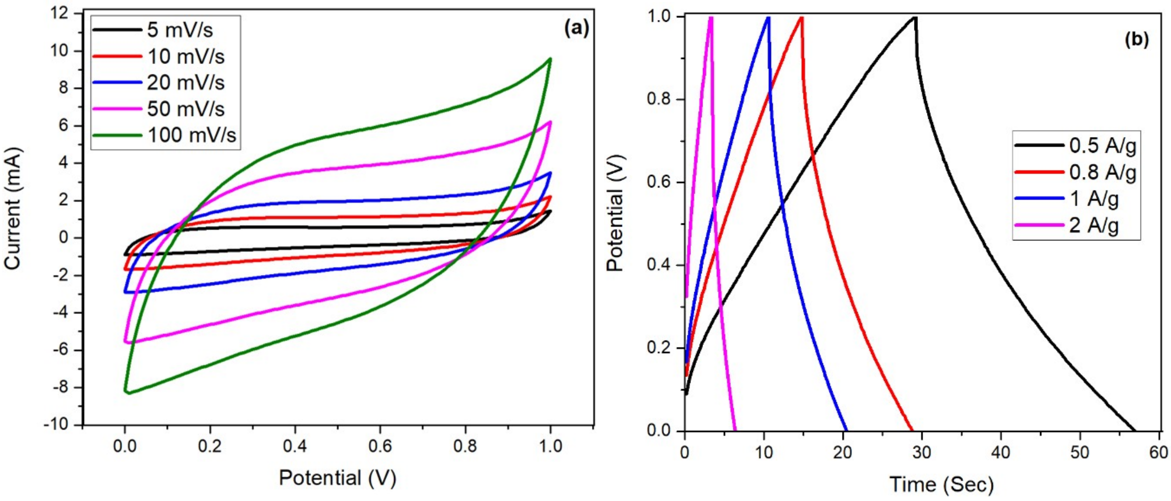


Fig. S8 (a) CV and (b) GCD response of pristine crGO.

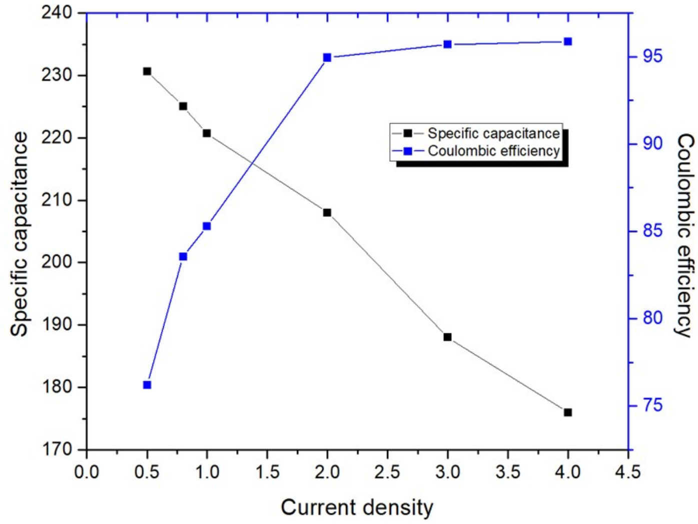


Fig. S9 Coulombic efficiency and specific capacitance variation of the crGO//crGO-Mo_2VW_9 cell.

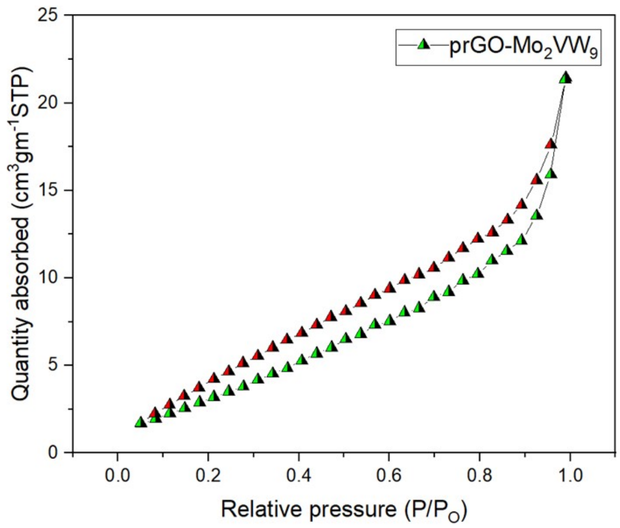


Fig. S10 Repeated BET isotherm of prGO/Mo_2VW_9 nanocomposite.

Table S1. Specific capacitance and energy of prGO-Mo_2VW_9 nanocomposite at different scan rates from CV:

Scan rate (mV/s)	Capacitance (F/g)	Energy density (Wh/kg)
5	97.0361	10.9165
10	98.1652	11.0435
20	92.1861	10.3709
50	78.9094	8.8773
100	65.4347	7.3624

Table S2. Specific capacitance, energy, and power of prGO-Mo_2VW_9 nanocomposite at different current densities from GCD:

Current density (A/g)	Capacitance (F/g)	Energy density (Wh/kg)	Power density (W/kg)	Coulombic efficiency

0.3	1622.7	45.63	1585.59	54.29
0.5	992.29	27.91	2098.28	72.84
0.8	944.55	26.56	3061.17	81.81
1	940.86	26.46	3721.06	84.90
2	925.47	26.02	7135.52	90.54
3	539.40	15.17	10113.75	100

Table S3. The electrical component values of the equivalent series circuit for prGO-Mo_2VW_9 nanocomposite

Equivalent Series Resistance (R_s)	Circuit resistance (R_{ct})	Cell Capacitance (C_T)	Knee frequency (f_k)	Time constant (τ)
0.76 Ω	3.02 Ω	2.69 mF	15.85 Hz	16.2 ms

Table S4. Specific capacitance and energy of crGO-Mo_2VW_9 nanocomposite at different scan rates from CV:

Scan rate (mV/s)	Capacitance (F/g)	Energy density (Wh/kg)
5	252.99	28.46
10	315.17	34.4577
20	304.093	34.2104
50	260.52	29.3094
100	189.87	21.36

Table S5. Specific capacitance, energy, and power of crGO-Mo_2VW_9 nanocomposite at different current densities from GCD:

Current density (A/g)	Capacitance (F/g)	Energy density (Wh/kg)	Power density (W/kg)	Coulombic efficiency
0.3	470.2	52.87	540	79.16
0.5	466.1	52.44	540.71	79.50
0.8	460.8	51.84	1440	91.13
1	460.4	51.79	1800	93.16
2	437.3	49.20	3600	97.23
3	421.3	47.39	5400	98.75

Table S6. The electrical component values of the equivalent series circuit for crGO-Mo_2VW_9 nanocomposite

Equivalent Series Resistance (R_s)	Circuit resistance (R_{ct})	Cell Capacitance (C_T)	Knee frequency (f_k)	Time constant (τ)

0.82 Ω	14.1 Ω	60 mF	0.16 Hz	15.92 ms

Table S7. Specific capacitance, energy, and power of crGO//crGO-Mo_2VW_9 nanocomposite at a different current density from GCD:

Current density (A/g)	Capacitance (F/g)	Energy density (Wh/kg)	Power density (W/kg)	Coulombic efficiency
0.5	230.66	46.13	1194.70	76.21
0.8	225.06	45.01	1929.08	83.56
1	220.66	44.13	2400.00	85.30
2	208	41.60	4800.00	94.94
3	188	37.6	7200	95.70
4	176	35.2	9600	95.85

Table S8. The electrical component values of the equivalent series circuit for crGO-Mo_2VW_9 nanocomposite

Equivalent Series Resistance (R_s)	Circuit resistance (R_{ct})	Cell Capacitance (C_T)	Knee frequency (f_k)	Time constant (τ)
0.468 Ω	3.44 Ω	232.4 mF	0.1 Hz	1.6 ms