Supporting materials for

Significantly Enhanced Energy Density at High Rates in Magnetite/Polypyrrole Nanocomposites under Low Magnetic Field

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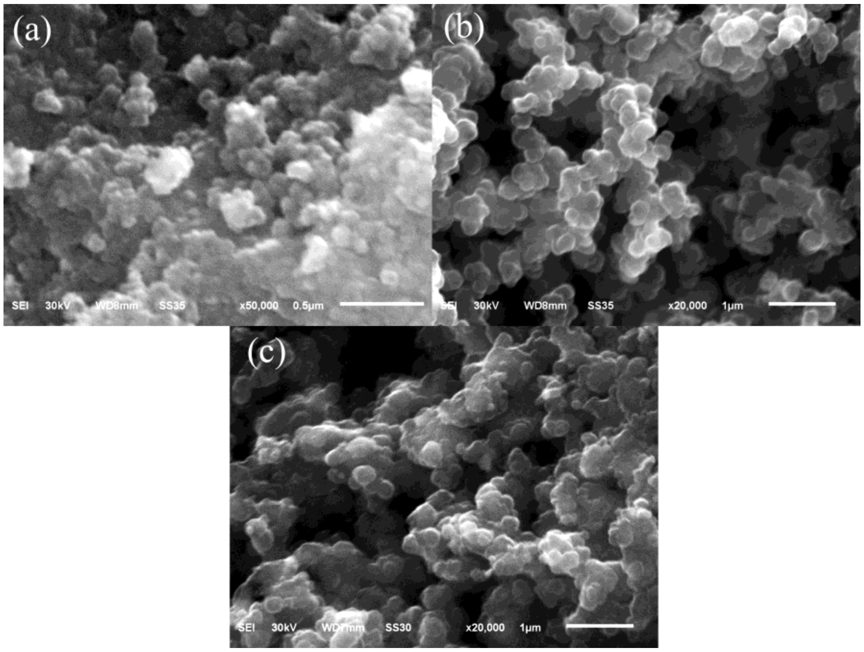

Fig. S1 SEM images of (a) Fe_3O_4, (b) pure PPy, and the Fe_3O_4/PPy nanocomposite with a Fe_3O_4 nanoparticle loading of 20 wt%.

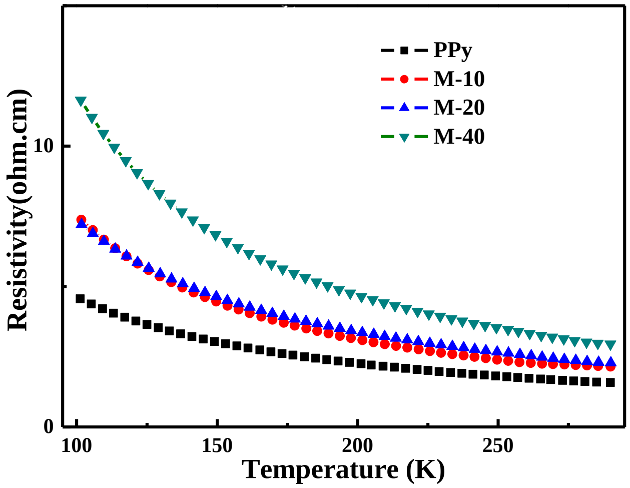

Fig. S2 Resistivity *vs*. temperature of pure PPy and its nanocomposites.

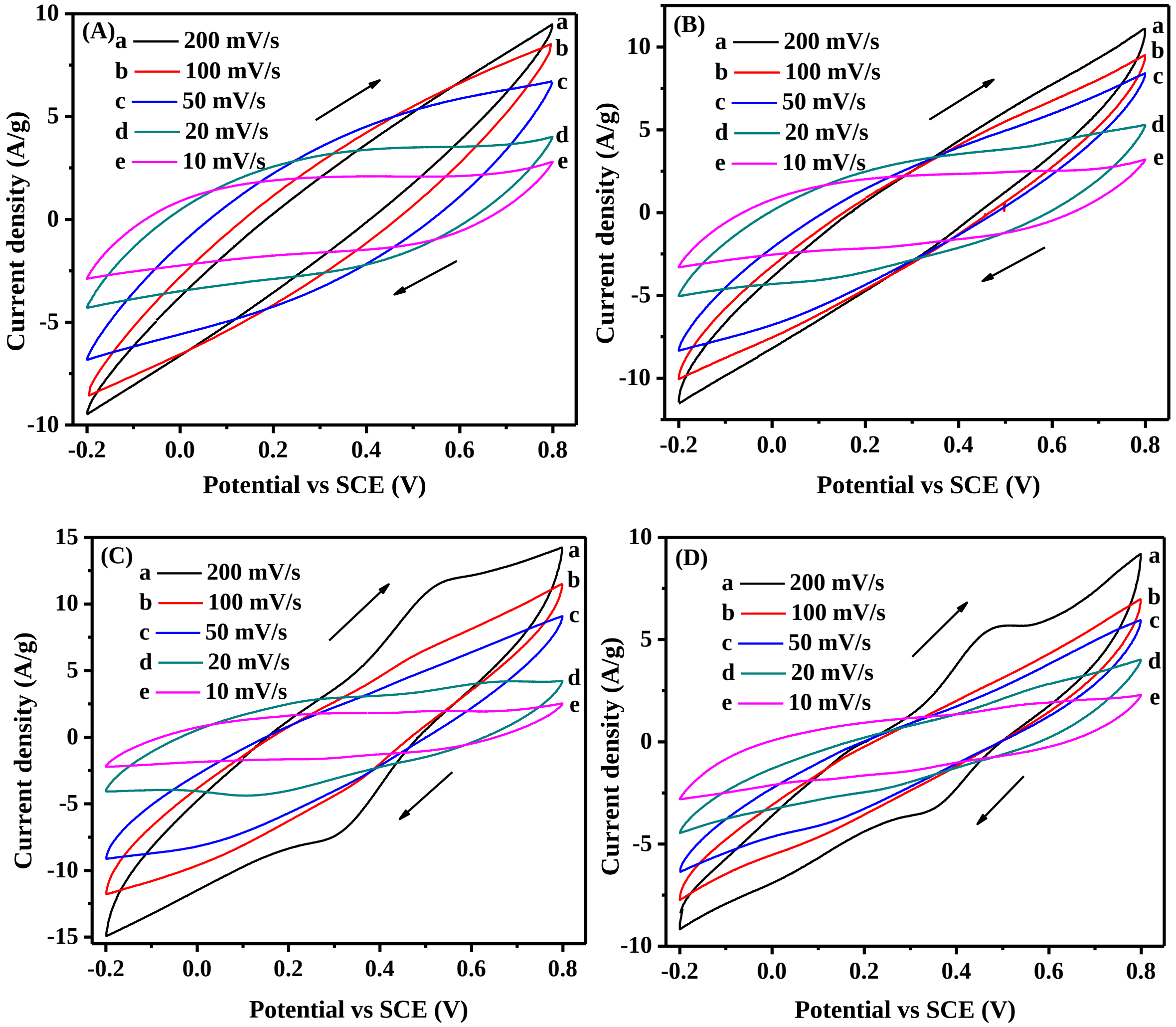

Fig. S3 CV curves of (A) pure PPy, and its magnetite nanocomposites with a magnetite nanoparticle loading of (B) 10.0, (C) 20.0, and (D) 40.0 wt% at different scan rates under a potential range from -0.2 to 0.8 V in 1.0 M H_2SO_4 aqueous solution without the magnetic field.

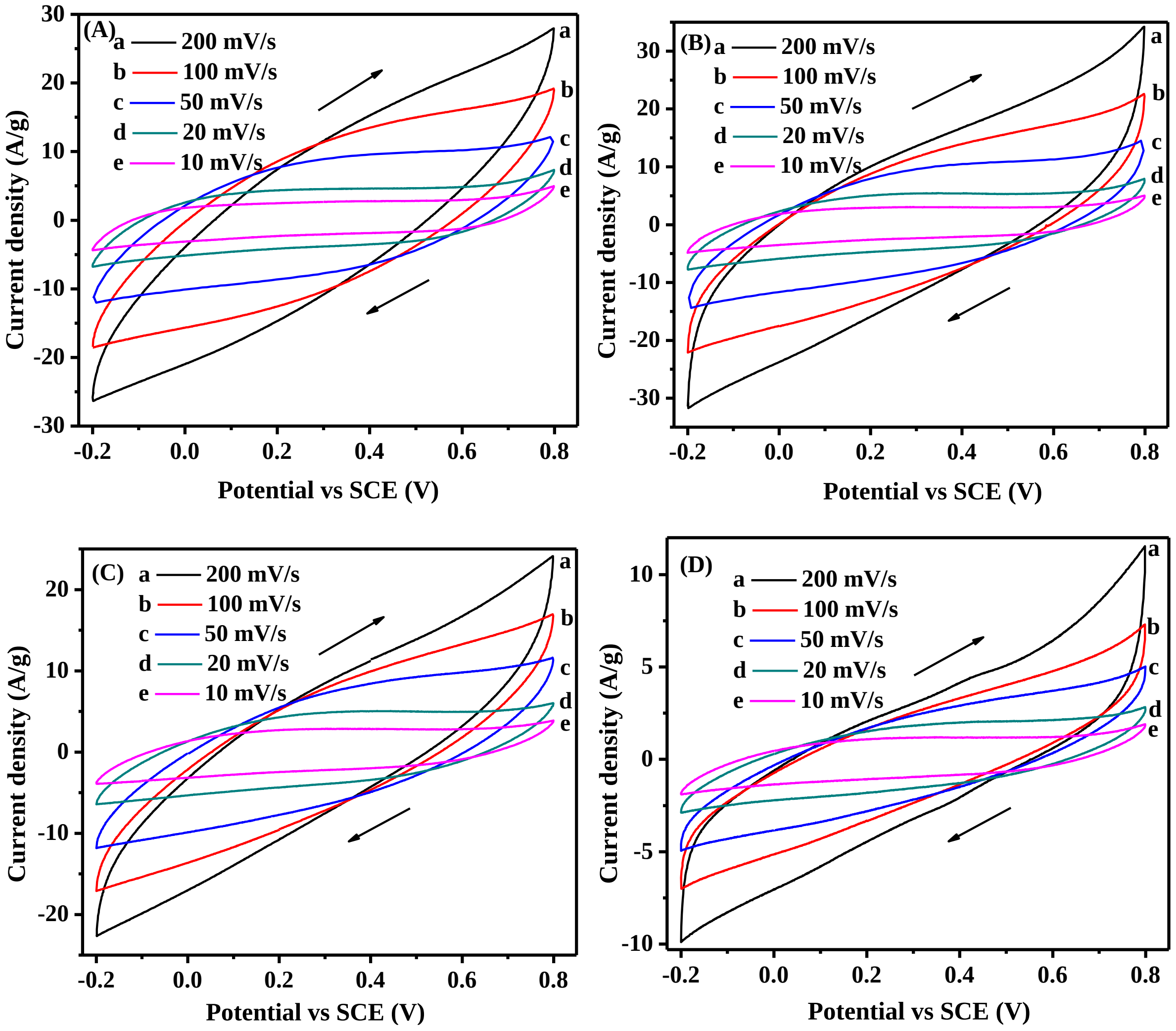

Fig. S4 CV curves of (A) pure PPy, and its magnetite nanocomposites with a magnetite nanoparticle loading of (B) 10.0, (C) 20.0, and (D) 40.0 wt% at different scan rates under a potential range from -0.2 to 0.8 V in 1.0 M H_2SO_4 aqueous solution with the external magnetic field.

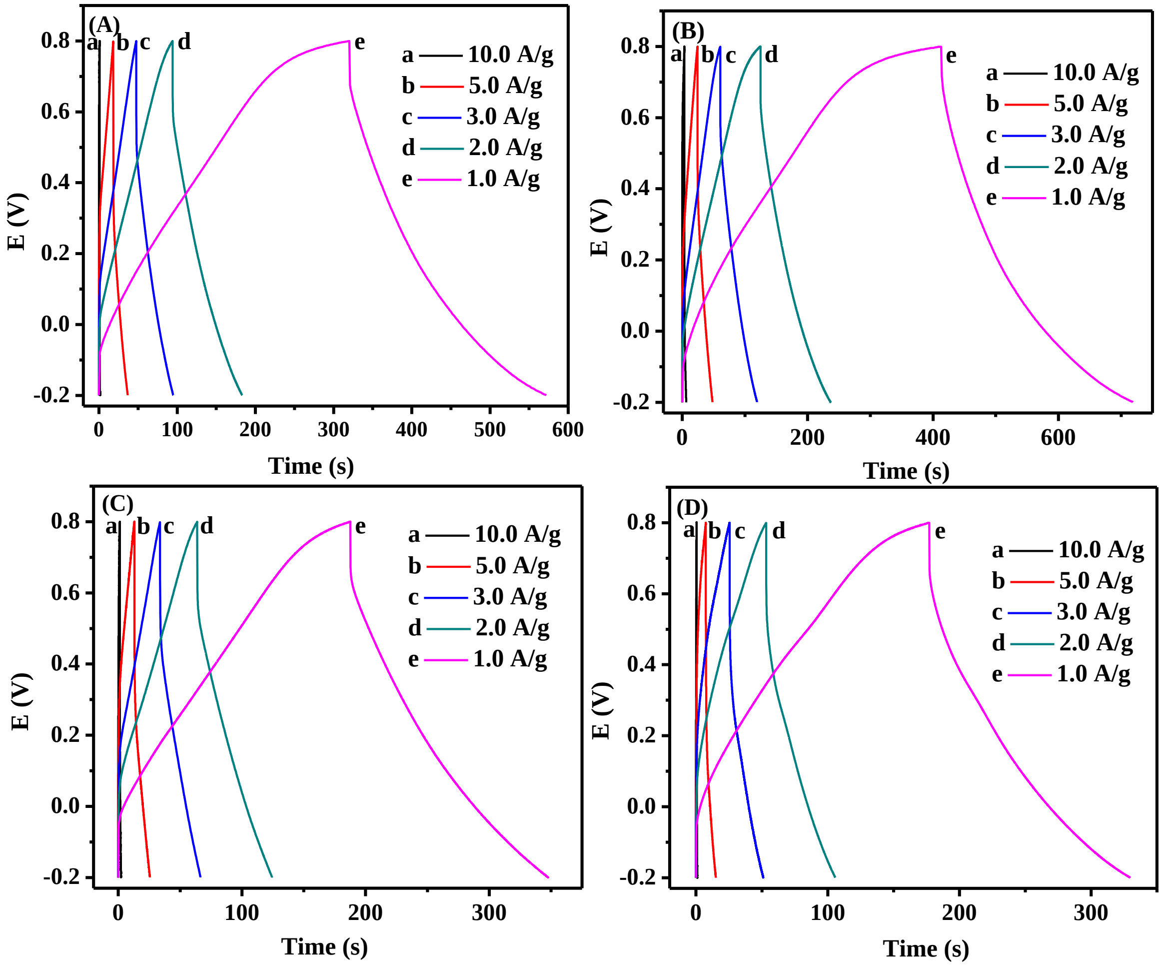

Fig. S5 Charge-discharge curves of (A) pure PPy, and its magnetite nanocomposites with a magnetite nanoparticle loading of (B) 10.0, (C) 20.0, and (D) 40.0 wt% at different current densities under a potential range from -0.2 to 0.8 V in 1.0 M H_2SO_4 aqueous solution without the magnetic field.

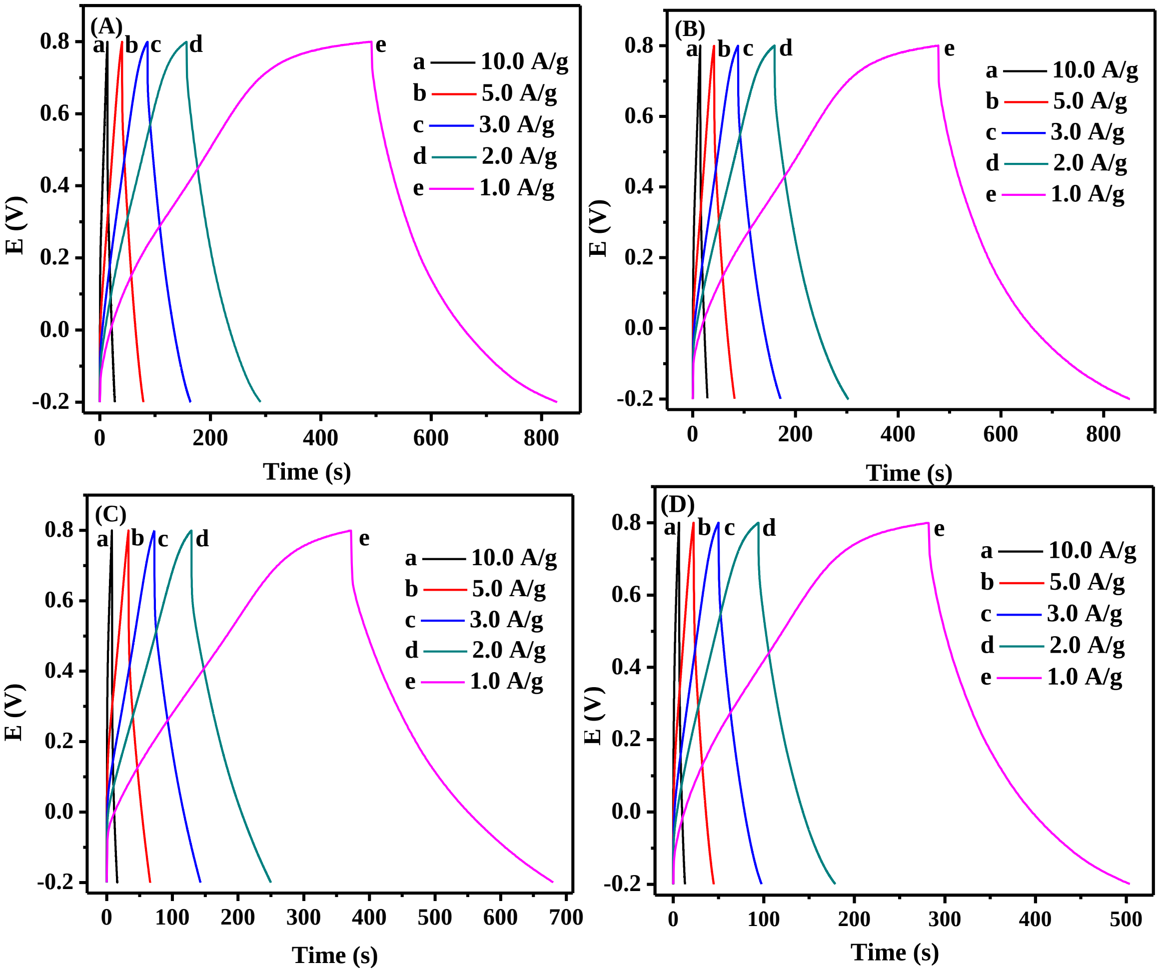

Fig. S6 Charge-discharge curves of (A) pure PPy, and its magnetite nanocomposites with a magnetite nanoparticle loading of (B) 10.0, (C) 20.0, and (D) 40.0 wt% at different scan rates under a potential range from -0.2 to 0.8 V in 1.0 M H_2SO_4 aqueous solution with the magnetic field.

The specific capacitance is calculated using Eq. S1: [1]

$$C_s = (i \times t)/(m \times \Delta V) \qquad (1)$$

where C_s is the specific gravimetric capacitance in F/g, i is the discharge current in A, t is the discharge time in s, m is the mass of the active materials in the electrode in g, and ΔV is the scanned potential window in V (excluding the IR drop at the beginning of the discharge process).

Table S1 Specific capacitances of pure PPy and its magnetite nanocomposites at different current densities with and without an external magnetic field. “W/O M” denotes the experiment conducted without a magnetic field and “W/M” denotes with a magnetic field.

Current density (A/g)			**PPy**	**M-10.0**	**M-20.0**	**M-40.0**
10	$\mathbf{C_s}$ (F/g)	W/O M	14.8	69.4	17.1	8.9
		W/M	**157.7**	**157.4**	**98.3**	**72.5**
5	$\mathbf{C_s}$ (F/g)	W/O M	144.3	158.2	83.2	52.2
		W/M	**215.5**	**218.9**	**189.6**	**120.5**
3	$\mathbf{C_s}$ (F/g)	W/O M	193.6	204.4	116.6	90.9
		W/M	**240.9**	**268.0**	**230.8**	**147.6**
2	$\mathbf{C_s}$ (F/g)	W/O M	210.3	260.1	144.5	126.7
		W/M	**284.7**	**308.4**	**265.2**	**181.5**
1	$\mathbf{C_s}$ (F/g)	W/O M	286.8	332.9	180.0	173.7
		W/M	**361.3**	**413.8**	**338.7**	**242.4**

The specific energy density (E, Wh/kg) and the specific power density (P, W/kg), critical parameters for evaluating the supercapacitor electrode materials, are calculated from Eq. S2&3 in a three-electrode system:[2]

$$E = \frac{\frac{1}{2} C_s \Delta V^2}{3.6} \tag{2}$$

$$P = \frac{3600E}{t} \tag{3}$$

where C_s is the specific capacitance in F/g, ΔV is the scanned potential window (excluding IR drop at the beginning of the discharge process) in V, and t is the discharge time in s.

Table S2 Specific energy densities and power densities of pure PPy and its magnetite nanocomposites at different current densities with and without the magnetic field.

Current density (A/g)			**PPy**	**M-10.0**	**M-20.0**	**M-40.0**
10	**E (Wh/kg)**	W/O M	0.3	1.6	0.8	0.4
		W/M	**16.1**	**17.1**	**9.0**	**8.1**
	P (W/kg)	W/O M	1798.8	2047.3	2916.8	2930.6
		W/M	**4280.1**	**4415.1**	**4054.7**	**4485.6**
5	**E (Wh/kg)**	W/O M	8.1	12.5	6.6	3.8
		W/M	**23.8**	**25.1**	**19.7**	**14.1**
	P (W/kg)	W/O M	1584.9	1884.0	1891.6	1816.5
		W/M	**2227.5**	**2272.7**	**2162.3**	**2297.2**
3	**E (Wh/kg)**	W/O M	15.6	21.1	11.5	9.0
		W/M	**30.6**	**31.8**	**26.6**	**19.0**
	P (W/kg)	W/O M	1191.1	1292.3	1262.4	1268.4
		W/M	**1434.5**	**1378.1**	**1366.8**	**1442.3**
2	**E (Wh/kg)**	W/O M	20.9	26.8	14.1	12.0
		W/M	**34.8**	**36.8**	**30.6**	**22.0**
	P (W/kg)	W/O M	845.6	861.9	837.3	827.5
		W/M	**937.9**	**927.5**	**910.9**	**934.2**
1	**E (Wh/kg)**	W/O M	30.5	38.8	19.8	18.6
		W/M	**43.1**	**46.5**	**38.6**	**28.0**
	P (W/kg)	W/O M	437.5	449.5	444.4	439.2
		W/M	**463.6**	**458.1**	**453.2**	**455.9**

$$Z_{CPE} = T_{CPE}(jw)^{-n} \tag{4}$$

where Z_{CPE} is the complex impedance, T_{CPE} and n are frequency-independent constants, and w is the angular frequency (w=2πf, f is the frequency). T_{CPE} is related to the surface and the electroactive species,[3] and n is related to the roughness of electrode surface in the range from 0 to 1 for a CPE, where *n* is 0 for a pure resistor, 1 for an ideal capacitor, and 0.5 for a Warburg impedance (mass transfer impedance).

Table S3 Fitting values for the equivalent circuit elements from the EIS data of pure PPy and its magnetite nanocomposites without the magnetic field in Fig. 5A.

	PPy	**M-10.0**	**M-20.0**	**M-40.0**
R_e (Ω)	2.074	0.856	2.905	3.239
CPE (F)	0.005383	0.007902	0.007189	0.003938
n_1	0.681	0.692	0.537	0.713
R_{ct} (Ω)	61.9	235.0	240.6	377.6
C_p (F)	0.03355	0.02388	0.03023	0.02733

Table S4 Fitting values for the equivalent circuit elements from the EIS data of pure PPy and its magnetite nanocomposites with the magnetic field in Fig. 5B.

	PPy	**M-10.0**	**M-20.0**	**M-40.0**
R_e (Ω)	2.706	3.020	3.686	2.669
C_{dl} (F)	0.001228	0.002953	0.008810	0.001608
R_{ct} (Ω)	38.8	91.1	82.3	268.5
C_p (F)	0.04020	0.03109	0.03263	0.02439

The anion diffusion coefficient can be calculated from Eq. S5&6:[4]

$$D = R^2T^2/(2A^2n^4F^4C^2\sigma^2) \tag{5}$$

$$Z_{\mathrm{re}} = R_s + R_{ct} + \sigma\omega^{-0.5} \tag{6}$$

where *D* is the diffusion coefficient of the anions, *R* is the gas constant (8.314), *T* is the absolute temperature (294.26 K), A is the surface area of the cathode (0.283 cm^2), n is the number of electrons per molecule during the oxidization (n is 1), F is the Faraday constant (96485 sA/mol), C is the concentration of anions (1.0×10^{-3} mol/cm^3), σ is the Warburg factor which can be obtained from the slopes in the low frequency region (<1 Hz), and w is the angular frequency ($w=2\pi f$, f is the frequency).

Relation between the specific capacitance and the energy denstity:

$$E = 0.5C_s\Delta V^2 \tag{7}$$

where E is the enegy density, C_s is the specific capacitance, ΔV is the working window.

Reference

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