Supporting Information

Ultra-Low Cost Supercapacitors from Coal Char: Effect of Electrolyte on Double Layer Capacitance

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Table S1. Literature reports of coal char and carbon-based supercapacitors employing comparable electrolyte concentrations as those used in this work (WIS = water-in-salt; IL = ionic liquid).

	Electrolyte	Concentration (this work)	Comparable Literature References
Aqueous	H_2SO_4	0.5 M	Madhusree *et al.* [1] (0.5 M)
	KOH	6 M	Benoy *et al.* [2] (6 M) Zou *et al.* [3] (6 M) Yaglikci *et al.* [4] (6 M) Bora *et al.* [5] (6 M) Bichat *et al.* [6] (6 M)
	Na_2SO_4	0.5 M	Bichat *et al.* [6] (0.5 M)
	$LiNO_3$	4 M	Jiang *et al.* [7] (4 M)
WIS	$NaClO_4$	13 m	Bu *et al.* [8] (10 m, 17 m) Gharouel and Béguin [9] (10 m, 17 m)
IL	BMIM BF_4/AN	1:1 wt%	Kim *et al.* [10] (1:1 wt%)

Table S2. Ultimate analysis of raw Sufco coal (weight % of total sample).

Component	Weight %
C	63.14
Ash	12.76
O	11.63
H_2O	6.53
H	4.36
N	1.13
S	0.45

Table S3. Ultimate analysis of Sufco coal ash (weight % of ash).

Ash component	Weight %
SiO_2	54.07
CaO	15.25
Al_2O_3	11.03
SO_3	6.35
TiO_2	4.17
Fe_2O_3	4.17
MgO	3.99
Other	0.97

Table S4. Average EDS measurements of coal char (elemental weight % and atomic %).

Element	Weight %	Atomic %
C K	75.0	86.0
O K	12.0	10.1
Si K	4.0	1.9
Ca K	3.0	1.0
Other trace elements	4.9	0.8

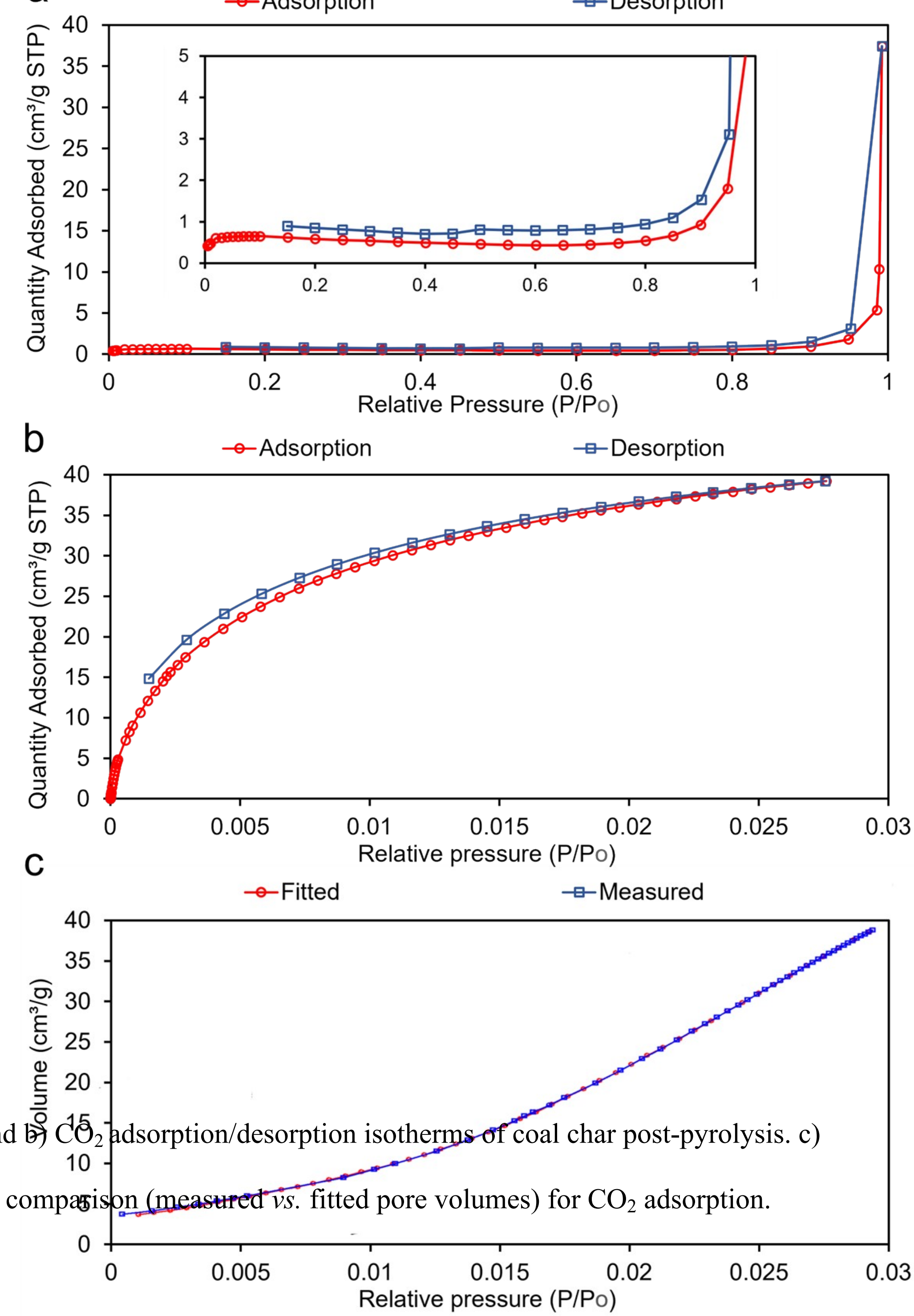

Figure S1. a) N_2 and b) CO_2 adsorption/desorption isotherms of coal char post-pyrolysis. c) Monte Carlo fitting comparison (measured *vs.* fitted pore volumes) for CO_2 adsorption.

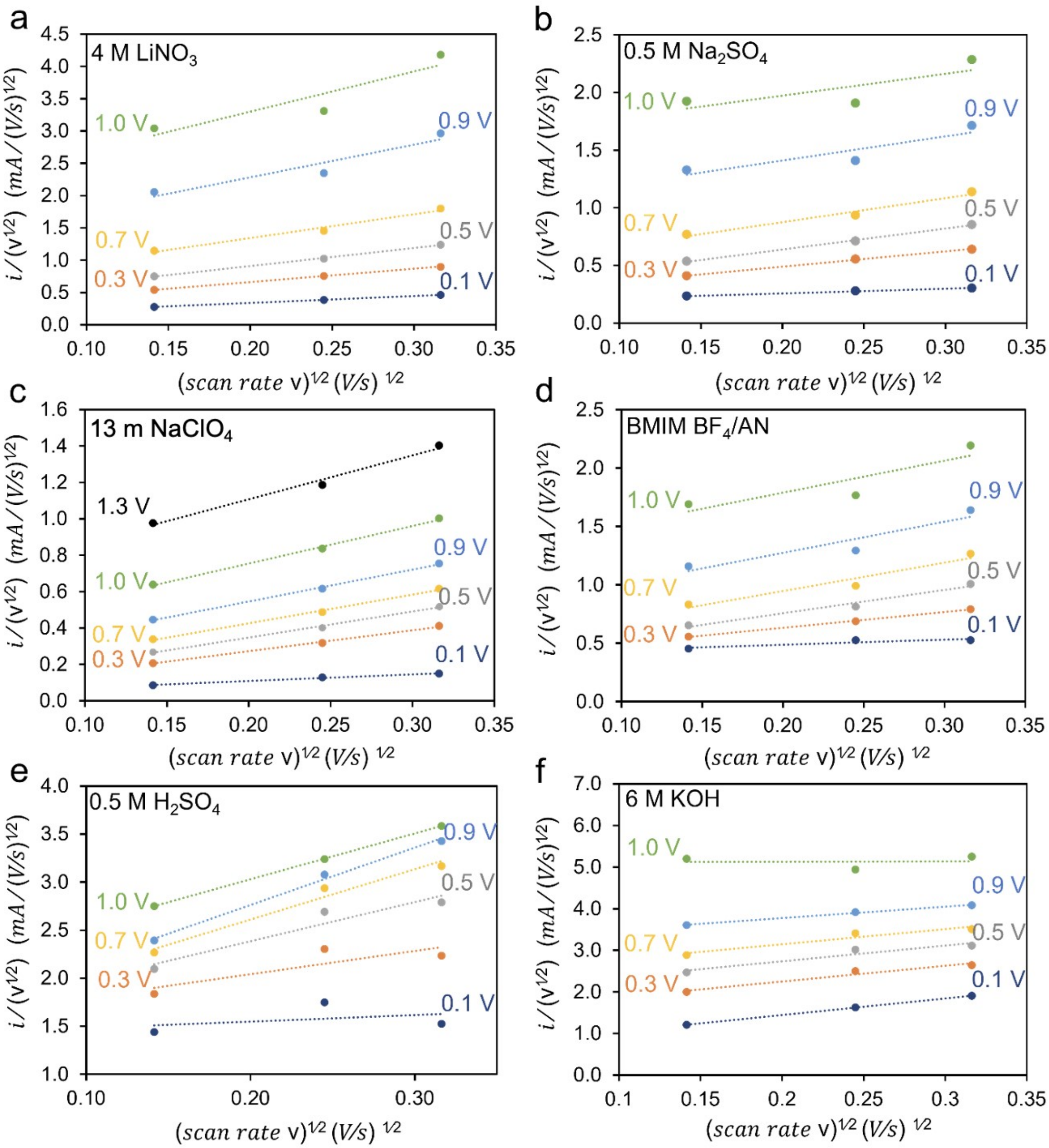

Figure S2. Scan rate dependence of two-electrode CV current at varying cell voltages (charging) for: a) 4 M $LiNO_3$, b) 0.5 M Na_2SO_4, c) 13 m $NaClO_4$, d) BMIM BF_4/AN, e) 0.5 M H_2SO_4 and f) 6 M KOH electrolytes. Slope and intercept values of the linear fits are used to determine k_1 and k_2 (Figure 6).

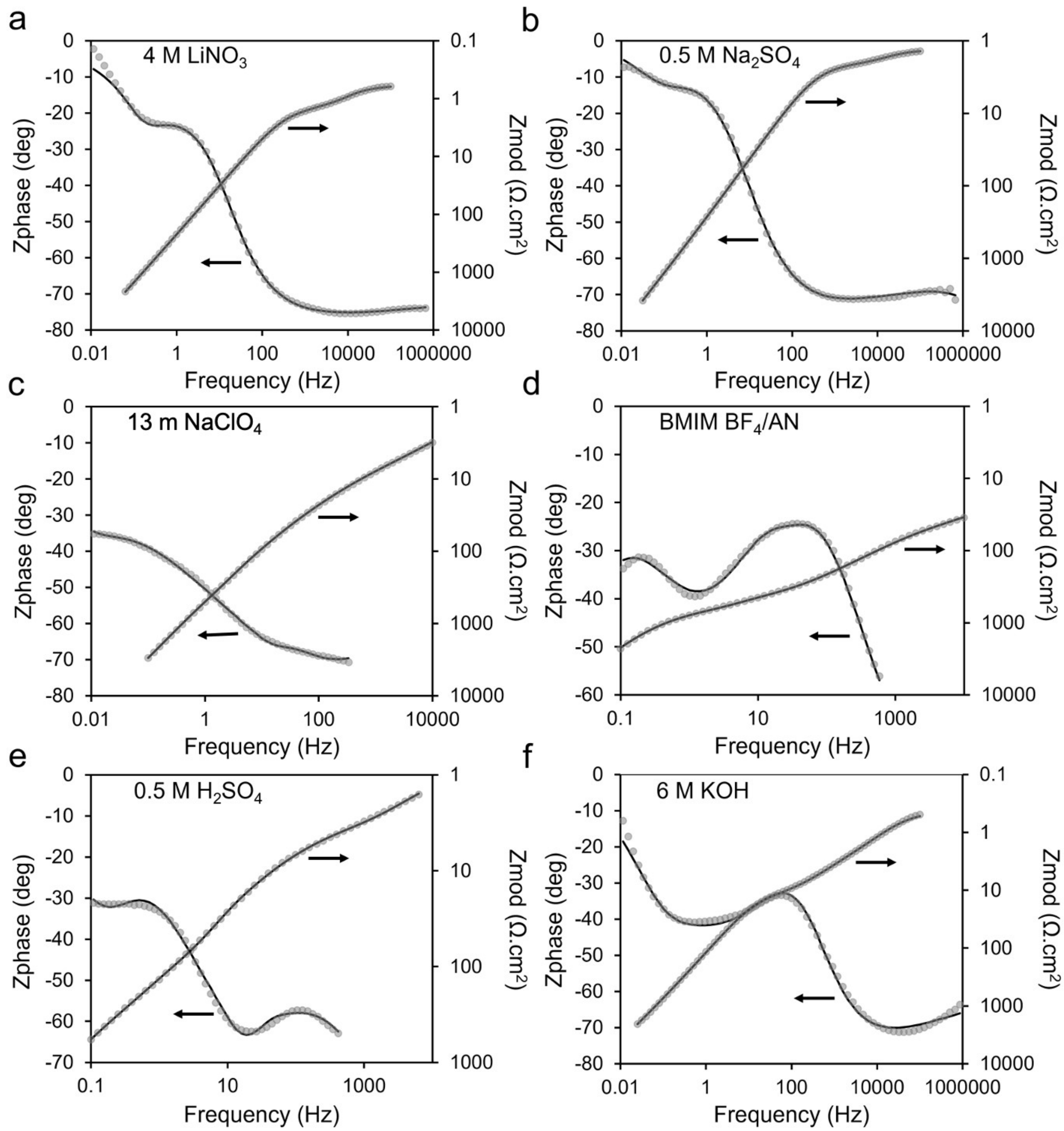

Figure S3. Bode plots of EIS measurements for: a) 4 M $LiNO_3$, b) 0.5 M Na_2SO_4, c) 13 m $NaClO_4$, d) BMIM BF_4/AN, e) 0.5 M H_2SO_4, and f) 6 M KOH electrolytes. Grey circles are measured data points; black lines are Randles equivalent circuit model fits.

Table S5. Equivalent circuit model Bisquert Open (BTO) parameters used to fit EIS measurements.

Electrolyte	BTO				
	L	rm (Ω)	rk (Ω)	Y S^a/Ω (10^{-3})	α (10^{-3})
13 m $NaClO_4$	0.06	477.70	5.88	81.57	703.40
6 M KOH	1.80	3.33	2989.00	4.01	872.70
0.5 M H_2SO_4	12.70	0.28	15.62	0.16	760.50
4 M $LiNO_3$	1.84	74.84	0.01	0.01	944.80
0.5 M Na_2SO_4	3.58	0.13	1446	1.12	758.60
BMIM BF_4/AN	669.70	4256.00	5.88	15.11	934.80

Table S6. Equivalent circuit model parameters used to fit EIS measurements.

Electrolyte	R_s (Ω)	R_{ct} (Ω)	CPE_1 (S^a/Ω) (10^{-3})	CPE_2 (S^a/Ω) (10^{-3})	Goodness of fit (χ^2)(10^{-6})
13 m $NaClO_4$	0.20	44.99	74.62	0.97	35.30
6 M KOH	0.21	2.86	1.76	7.63	728.10
0.5 M H_2SO_4	0.21	43.96	5.35	5.05	24.11
4 M $LiNO_3$	0.31	0.35	0.21	1.94	230.60
0.5 M Na_2SO_4	0.67	0.23	0.25	2.30	173.80
BMIM BF_4/AN	11.70	165.00	0.13	1.40	106.70

References

1. Madhusree J. E., P. R. Chandewar, D. Shee and S. S. Mal, *J. Electroanal. Chem.*, 2023, **936**, 117354.
2. S. M. Benoy, D. Bhattacharjya, M. Bora and B. K. Saikia, *ACS Appl. Electron. Mater.*, 2022, **4**, 6322-6334.
3. Y. Zou, H. Wang, L. Xu, M. Dong, B. Shen, X. Wang and J. Yang, *J. Power Sources*, 2023, **556**, 232509.
4. S. Yaglikci, Y. Gokce, E. Yagmur, A. Banford and Z. Aktas, *Surf. Interfaces*, 2021, **22**, 100899.
5. M. Bora, S. M. Benoy, J. Tamuly and B. K. Saikia, *J. Environ. Chem. Eng.*, 2021, **9**, 104986.
6. M. Bichat, E. Raymundo-Piñero and F. Béguin, *Carbon*, 2010, **48**, 4351-4361.
7. J. Jiang, B. Liu, G. Liu, D. Qian, C. Yang and J. Li, *Electrochim. Acta*, 2018, **274**, 121-130.
8. X. Bu, L. Su, Q. Dou, S. Lei and X. Yan, *J. Mater. Chem. A*, 2019, **7**, 7541.
9. S. Gharouel and F. Béguin, *Electrochim. Acta*, 2023, **450**, 142212.
10. T. Kim, G. Jung, S. Yoo, K.S. Suh and R. S. Ruoff, *ACS Nano*, 2013, **7**, 6899-6905.