

Supporting information

Enhancing capacitance of supercapacitor with both organic electrolyte and ionic liquid on a biomass-derived carbon

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Table S1 capacitance vs current density/scan rate calculated based on both GCD curve and CV curve

APN-IMPREG-HCl		Capacitance (F/g)									
Method	electrolyte	Current density (A/g)/Scan rate (mV/s)									
		1	2	3	4	5	6	7	8	9	10
GCD*	TEABF4/AN	133	141		137	135		129			130
	EMIMBF4	185	166	160	153			149			
CV**		50	100	200	300	500					
	TEABF4/AN	129	129	123	119	114	110				
	EMIMBF4	174	176	153	138	123	100				
APN-IMPREG		Current density (A/g)									
Method	electrolyte	1	2	3	4	5	6	7	8	9	10
GCD	TEABF4/AN	105	105	104	109	106	104				104
	EMIMBF4	141	110		90			75			
APN-KOH		Current density (A/g)									
Method	electrolyte	1	2	3	4	5	6	7	8	9	10
GCD	TEABF4/AN	65		67		66		64			63
	EMIMBF4	130	81	73		71	69	68			

* GCD: The capacitance retention at current density of 10 A/g is 97% of the capacitance at 1 A/g for organic electrolyte, and 81 % (7A/g vs. 1A/g) in neat IL electrolyte.

** CV: The capacitance retention at current density of 500 mV/s is 77% of the capacitance at 1 A/g for organic electrolyte, and 57 % (7A/g vs. 1A/g) in neat IL electrolyte. The rate capability based on CV is worse than the one calculated based GCD, as the voltage drop is taken into consideration when calculating the capacitance using GCD curve. The exact voltage drop is reported in Figure 2b and 2e.

Table S2 Comparison of properties of carbon materials synthesized from plant and their use in SCs

Material	Activating Agent	BET Surface Area (m ² /g)	Electrolyte	Capacitance (F/g) (recording conditions)	Operating Voltage Window (V)	Maximum Energy (Wh/kg)	Ref.
Dead leave	no	1230	Organic	0.5A/g	2.5	28	1
peanut shell	ZnCl ₂	1552	1M TEABF ₄ /PC	106 (50mA/g)	2.5	26.6	2
rice husk	ZnCl ₂	1527	1M TEABF ₄ /PC	94 (50mA/g)	2.5	23.4	2
seaweeds	no	1307	1M TEABF ₄ /AN	94 (2mV/s)	2.3	17.5	3
Coconut shell	KOH	1500-1600	1M TEABF ₄ /AN neat EMIMBF ₄	118/127 (N/A)	2.7/3.5	29/54	4
Commercial AC	no	~1500	1M TEABF ₄ /AN	80-120 (N/A)	2.5-2.7		5
pollen	KOH	3037	1M TEABF ₄ /AN neat EMIMBF ₄	185/207 (1A/g)	2.7/3.5	46/88	6
Pine tree	KOH	1018	1M TEABF ₄ /AN neat EMIMBF ₄	77/130 (1A/g)	2.5/4	18/46	APN-KOH
Pine tree	H ₃ PO ₄ +NH ₃	2029	1M TEABF ₄ /AN neat EMIMBF ₄	105/140 (1A/g)	2.5/4	21/47	APN-IMPREG
Pine tree	H ₃ PO ₄ +NH ₃	2207	1M TEABF ₄ /AN neat EMIMBF ₄	134/184 (1A/g)	2.5/4	26/92	APN-IMPREG-HCl

Model used in this work

The original model deviation is reported in our previous work⁷, We summary the capacitance estimation process.

Firstly, the cumulative pore volume curve of the material derived from the N₂-isotherm is converted based on:

$$l(D_i) = \frac{4[V_C(D_i) - V_C(D_{i-1})]}{\pi(D_i)^2} \quad (i = 1, 2, 3, \dots n, \text{ and } D_0 = d_{\text{ion}})$$

where VC is the cumulative pore volume. Thus, l(D_i) represents the pore lengths for the pores with same pore diameter (as D_i is very close to D_{i-1}). In this work, the d_{ion}=0.95 nm based on the size of EMIM⁺.

The number of adsorbed ions N in the pore with pore size D and pore length l can be solved as:

$$N = \frac{3D^2 \cdot l \cdot \varphi}{16d_{\text{ion}}^3}$$

Here φ is the volume fraction (φ = the total volume of the adsorbed ions/the volume of the pore) and d_{ion} is the effective ion size for IL. The deviation of the volume fraction is based on the geometrically close packing structure of the spherical ions inside the cylindrical pores.⁷⁻¹⁰

The number of ions adsorbed on the total surface area of the porous material (or N⁺) can be calculated by summing up the number of ions stored in all the ion-accessible pores (D₁ to D_i from the PSD) on the sample:

$$N_{\text{total}} = \sum_{d_{\text{ion}}}^{D_i} N(D_i, d_{\text{ion}}) \quad (i = 1, 2, 3, 4 \dots \text{ and } D_0 = d_{\text{ion}})$$

As the discharge curve at room temperature is very close to linear, the estimated gravimetric capacitance of a single electrode can be expressed as:

$$C'_{sp, electrode} = \frac{Q}{U} = \frac{2e \cdot N_{\text{total}}}{U}$$

where Q is the total charge on the electrode, U is the potential absolute value of the single electrode, which is approximately 2 V, and e is one electron charge equals to 1.6×10⁻¹⁹ C.

References

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