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Synthesis and Characterization of Carbon Aerogels as Active Material for Double Layer Capacitors

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Motivation

Supercapacitors (Electrical double layer capacitor)

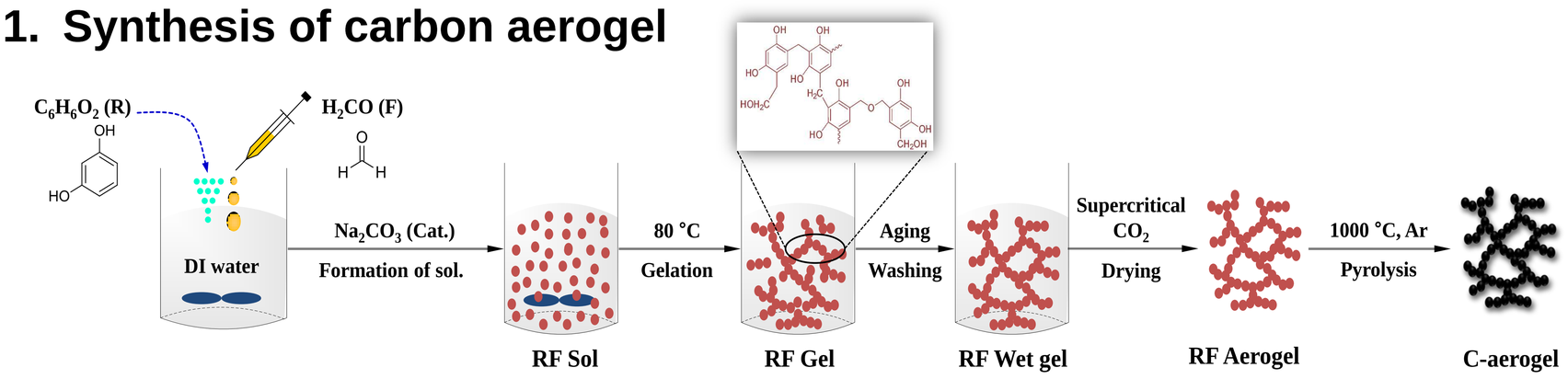
- most significant electrochemical storage systems
- not restricted by the electrochemical charge transfer
- high charge and discharge rates [1]

Carbon Aerogels (CA):

- large specific area
- high electrical conductivity
- chemical stability
- wide operating temperature range [2][3]

Experimental

1. Synthesis of carbon aerogel

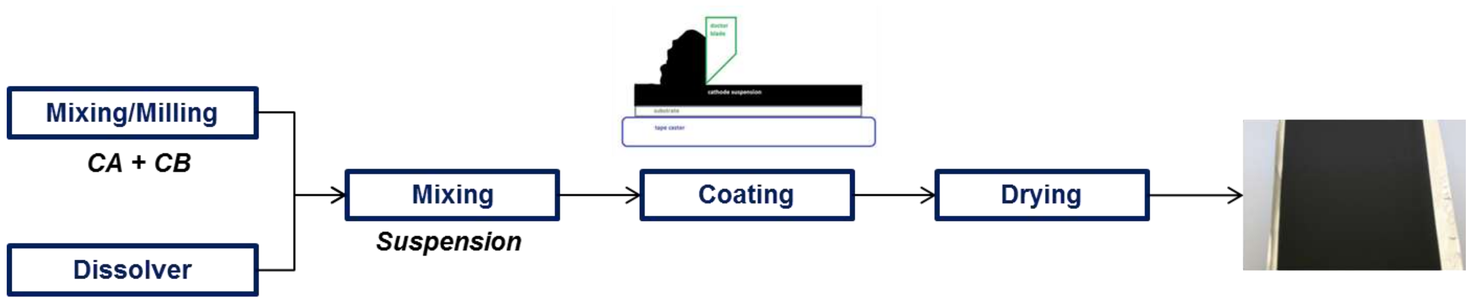


Synthesis Parameter		CA-1	CA-2	CA-3*
Reaction ratio	Resorcinol/ Water	0.044	0.044	0.012
	Resorcinol/ Formaldehyde	0.74	0.74	0.5
	Resorcinol/ Catalyst	1500	1500	50
pH Control	2 N HNO_3	5.5	5.5	N.T
Gelation	@ 80 °C	4 days	4 days	7 days
Drying		subcritical at 80°C	subcritical at 80°C	supercritical CO_2
Carbonization	Pyrolysis	@ 1000 °C for 1 h in Ar		
Pulverization	Ball-milling	Cross beater mill	Ball mill	Ball mill

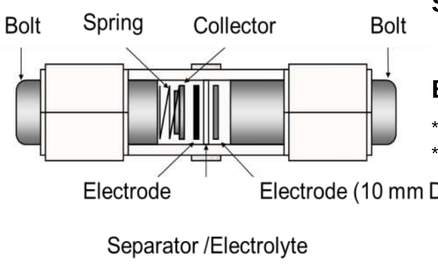
2. Electrode Fabrication

Electrode:

- Active material 90 wt% of C-Aerogel (CA-1, CA-2 or CA-3*)
- Conductive additive 5 wt% of Carbon Black (CB; Super P)
- Binder 5 wt% of CMC (Na-Carboxymethylcellulose)



3. Supercapacitor fabrication & Test



Separator: Whattmann GF/D glass microfiber filter (0.67 mm thick, 12 mm diameter)

Electrolyte: 1 M Et_4NBF_4 in PC

*Et_4NBF_4 : tetraethylammonium tetrafluoroborate

*PC: propylene carbonate

4. Electrochemical characterization

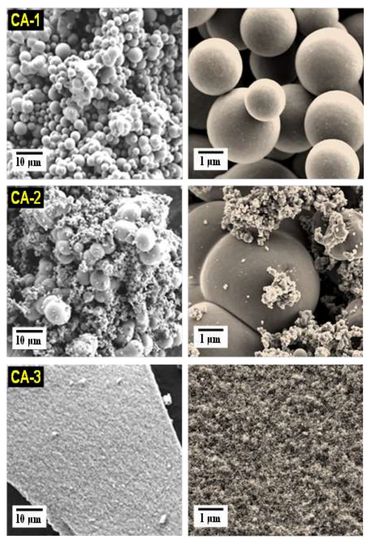
Cyclic Voltammetry (CV)

Galvanostatic Charge/Discharge (GCD) (0–2.7 V range @ RT)

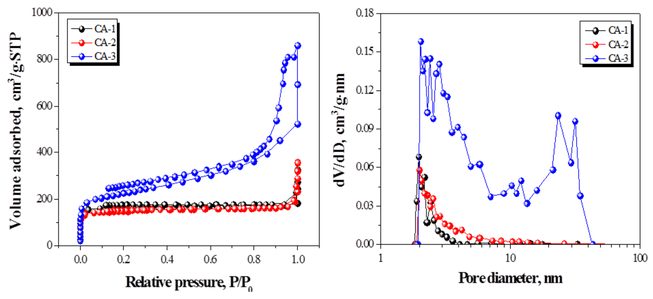
Electrochemical Impedance Spectroscopy (EIS)

Characterization & Results

Morphological & Structural Properties of CA

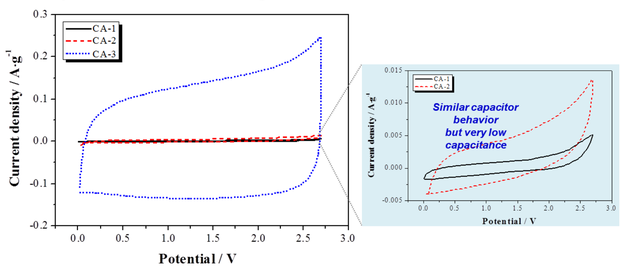


S_{BET} [m^2/g]	V_{total} [cm^3/g]	V_{micro} [cm^3/g]	V_{meso} [cm^3/g]	V_{meso} / V_{total} [%]
532	0.30	0.10	0.20	66.1
478	0.37	0.06	0.31	84.5
758	2.32	0.16	2.17	93.2

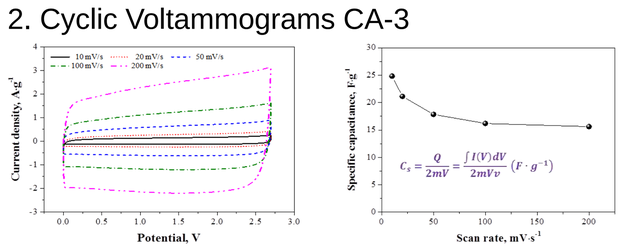


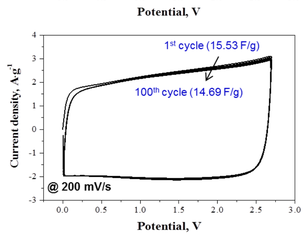
Electrochemical Characteristics

1. Cyclic Voltammograms @10 mV/s



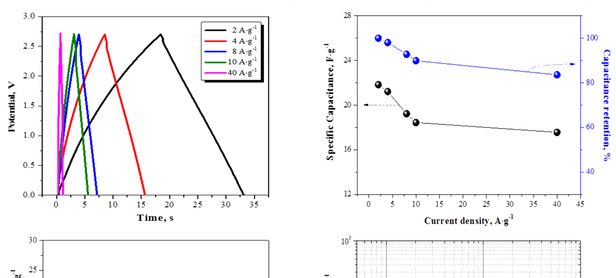
2. Cyclic Voltammograms CA-3



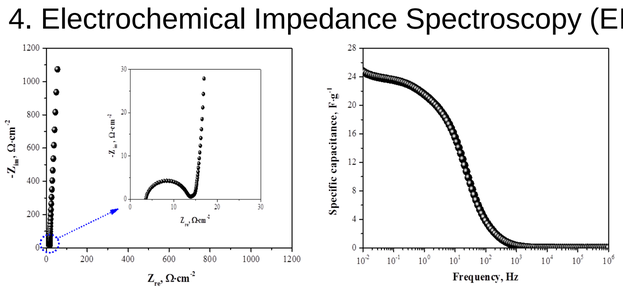


After 100 cycles, the CV curve still maintains a rectangular shape and retains 95% of the initial capacitance (scan rate: 200 mV·s^{-1})

3. Galvanostatic Charge/Discharge



4. Electrochemical Impedance Spectroscopy (EIS)



- As the frequency increases, the capacitance decreases for the C-Aerogel electrode
- At high frequencies, SCs behave like a pure resistor
- It shows higher capacitance at low frequencies, but also maintains 50% of capacitance up to 10 Hz

Summary

Development of carbon aerogels with bimodal mesoporous structure and 3-D networked morphology:

- **more accessible active sites** and
- **efficient transport of electrolyte ions**

during electrochemical reactions

Superior performance in terms of specific energy (22.1 Wh·kg^{-1}) and power density (2.4 kW·kg^{-1}) at 2 A·g^{-1}

Cycle durability of 87% over 10,000 cycles

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[3] A.G. Pandolfo, A.F. Hollenkamp, J. Power Sources 157 (2006) 11.
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