Synthesis and electrochemical properties of polybenzoxazine-derived nanoporous carbon electrode materials for supercapacitors

Phornphatch Hiranpattanakul[1], Sujitra Wongkasemjit[1,2] Thanyalak Chaisuwan[1,2] *

[1]The Petroleum and Petrochemical College, Chulalongkorn University, Bangkok, Thailand.
[2]Center of Excellence on Petrochemical and Materials Technology, Bangkok, Thailand.

Introduction

Supercapacitors

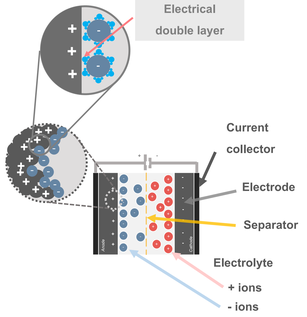
Advantages

- High specific power
- Quick charging time
- Long life cycle
- Wide working temperature
- Eco-friendly
- safety

Application :

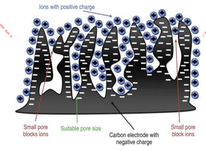
Regenerative braking
Uninterruptible Power Supply systems (UPS)
Light weight power supplies for small aircraft
Buses, racing cars, elevators

Electrical double layer



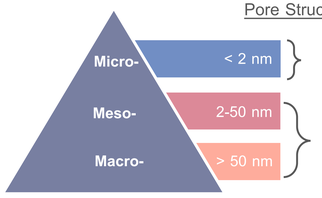
Electrode

- Specific surface area
- Conductivity
- Suitable pore structure for rapid ion motion



" Porous carbon "

Pore Structure



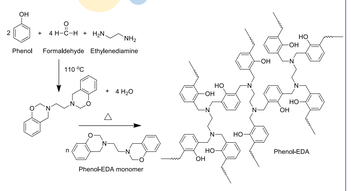
For charge accumulations

For facilitate the kinetics of electrical double layer formation and transportation of the electrolyte ions

Polybenzoxazine

a high performance thermosetting resin

- ✓ Molecular design flexibility
- ✓ Tunable pore structure
- ✓ High dimensional stability
- ✓ Low shrinkage
- ✓ High Tg

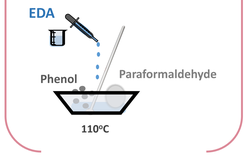


Objectives

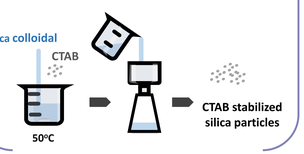
1. To enhance the electrochemical performance of polybenzoxazine-based nanoporous carbon for electrodes of supercapacitors by using ethylene diamine (EDA) as amine and increase the pore structure with activation process.
2. To improve the surface area and pore structure by adding silica nanoparticles as hard templates to create uniform mesoporous structure as well as hexadecyltrimethylammonium bromide (CTAB) as a surfactant and soft templates of the EDA-based template nanoporous carbon electrodes.
3. To study the electrochemical performance of polybenzoxazine-based nanoporous carbon and the effect of template by using silica nanoparticles as hard templates to create uniform mesopore size and compare the result with the non-template materials from PBZ-EDA based nanoporous carbon.

Experimental

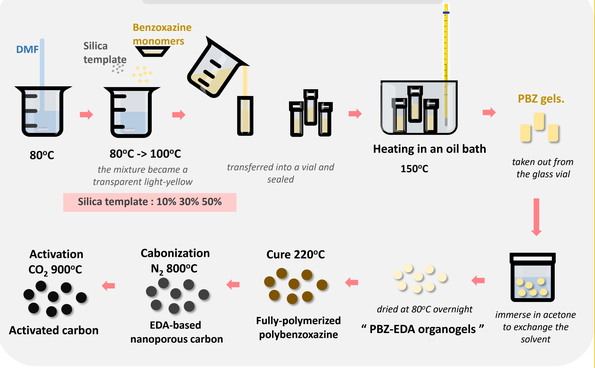
Synthesis of EDA-based benzoxazine monomer



Preparation of the CTAB stabilized silica particles as template



Synthesis of EDA-based Polybenzoxazine



Electrochemical measurements

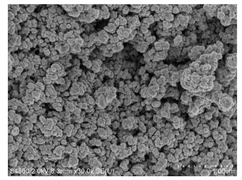
Coin-type EDLC cell

- Graphite rod(current collector)
- Nanoporous carbon (electrode)
- Porous polyester sheet (separator)

Using 1.0 M of H_2SO_4 as aqueous electrolyte

Results and discussion

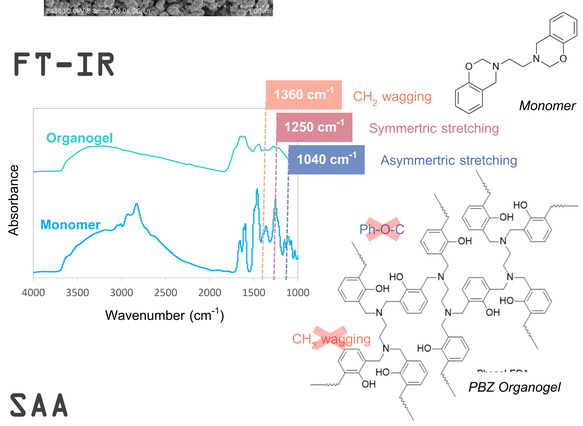
SEM



Morphology of activated carbon

- Loose packaging
- Small particles

FT-IR



SAA

EDA-based non-template nanoporous carbon

Sample	S_{BET} (m^2/g)	S_{micro} (m^2/g)	S_{meso} (m^2/g)	V_{micro} (cm^3/g)	V_{meso} (cm^3/g)	Microporosity (%)	Mesoporosity (%)
BA_blank	**305**	111	155	0.06	0.65	**8.45**	91.55
AC_blank	**680**	412	316	0.21	0.94	**18.26**	81.74

Effect of CO_2 activation

- ✓ S_{BET} ↑
- ✓ Microporosity ↑

In response to the increment of charge accumulation resulting in high C_{sp} of electrode materials

EDA-based template nanoporous carbon

Sample	S_{BET} (m^2/g)	S_{micro} (m^2/g)	S_{meso} (m^2/g)	V_{micro} (cm^3/g)	V_{meso} (cm^3/g)	Microporosity (%)	Mesoporosity (%)
AC_10%	**761**	405	**392**	0.21	0.76	21.65	73.25
AC_30%	**912**	356	**601**	0.19	1.26	27.55	86.90
AC_50%	**810**	268	**511**	0.15	1.25	10.71	89.29

When silica nanoparticles template is loaded at 50%, they were slightly aggregated to form macro- structure resulting in lower surface area.

Effect of Silica colloidal + CTAB surfactant

- ✓ S_{BET} ↑
- ✓ S_{meso} ↑

with the increasing amount of the CTAB stabilized silica particles loading 10% and 30% respectively.

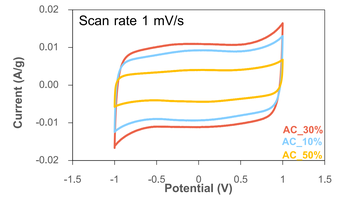
CV

Specific capacitance (C_{sp}, F/g)

Scan rate (mV/s)	1	2	5
AC_blank	149	140	125
AC_10%	170	171	150
AC_30%	186	179	162
AC_50%	156	154	147

$$C_{sp} = \frac{\int IdE}{[S \times m \times (E_2 - E_1)]}$$

C_{sp} (F/g) is the specific capacitance
$\int IdE$ (A·V) is the total voltammetric charge
S (V/s) is the scan rate
m (g) is the mass of two carbon electrodes
$E_2 - E_1$ (V) is the range of potential scan.



Rectangular, symmetric, and reversible shape with less deviation

General and ideal electrochemical properties

Conclusion

- Polybenzoxaxine was successfully synthesized by using sol gel method
- Improvement the surface area and pore structure by adding silica nanoparticles and CTAB as the template was successful.
- The S_{BET} of the nanoporous carbon materials increased after activated with CO_2 at 900°C due to the development of the micropores in the materials during the activation process.
- The higher surface area of activated carbon resulting in the higher specific capacitance.
- The activated nanoporous carbon material derived from EDA-based PBZ and adding 30%template showed the highest C_{sp} of 186 F/g at scan rated 1 mV/s in 1.0 M H2SO4 due to its high surface area and proper mesopore size for electrolyte ions mobility and ions accumutions.

Acknowledgement

This thesis is funded by the Petroleum and Petrochemical College, the Ratchadapisek Sompote Endowment Fund of Chulalongkorn University and the Center of Excellence on Petrochemical and Materials Technology.

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