Development of Carbon Materials from Biomass for Energy Storage Applications

Dr. Sumittra Charojrochkul

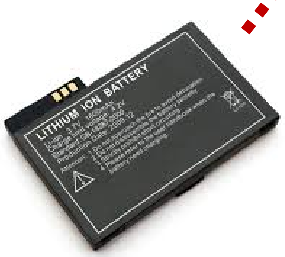
Materials for Energy Research Unit
National Metal and Materials Technology Center (MTEC)
National Science and Technology Development Agency (NSTDA)

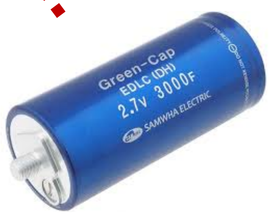
Members of Research Group

• Dr. Sumittra Charojrochkul	MTEC/NSTDA
• Prof. Dr. Takeshi Abe	Kyoto University
• Dr. Yatika Somrang	MTEC/NSTDA
• Dr. Korakot Sombatmankong	MTEC/NSTDA
• Mr. Thanathon Sesuk	MTEC/NSTDA

Research target

- To develop activated carbon derived from palm empty fruit bunches for energy storage devices





Typical characteristics of Capacitor and Battery

Characteristic	Electrolytic capacitor	Carbon supercapacitor	Battery
Specific energy (Wh/kg)	<0.1	1-10	10-100
Specific power (W/kg)	>>10,000	500-10,000	<1000
Discharge time	10^{-6} to 10^{-3} s	s to min	0.3-3 h
Charging time	10^{-6} to 10^{-3} s	s to min	1-5 h
Charge/discharge efficiency (%)	~100	85-98	70-85
Cycle-life (cycles)	Infinite	>500,000	~1,000
Max. voltage (V_{max}) determinants	Dielectric thickness and strength	Electrode and electrolyte stability window	Thermodynamics of phase reactions
Charge stored determinants	Electrode area and dielectric	Electrode microstructure and electrolyte	Active mass and thermodynamics

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

Properties of carbon-based materials as a supercapacitor component

Table 1 Properties and characteristics of various carbon and carbon-based materials as supercapacitors electrode materials

			Aqueous electrolyte		Organic electrolyte	
Materials	Specific surface area/$m^2\ g^{-1}$	Density/$g\ cm^{-3}$	/$F\ g^{-1}$	/$F\ cm^{-3}$	/$F\ g^{-1}$	/$F\ cm^{-3}$
Carbon materials						
Commercial activated carbons (ACs)	1000–3500	0.4–0.7	< 200	< 80	< 100	< 50
Particulate carbon from SiC/TiC	1000–2000	0.5–0.7	170–220	< 120	100–120	< 70
Functionalized porous carbons	300–2200	0.5–0.9	150–300	< 180	100–150	< 90
Carbon nanotube (CNT)	120–500	0.6	50–100	< 60	< 60	< 30
Templated porous carbons (TC)	500–3000	0.5–1	120–350	< 200	60–140	< 100
Activated carbon fibers (ACF)	1000–3000	0.3–0.8	120–370	< 150	80–200	< 120
Carbon cloth	2500	0.4	100–200	40–80	60–100	24–40
Carbon aerogels	400–1000	0.5–0.7	100–125	< 80	< 80	< 40
Carbon-based composite materials						
TC–RuO_2 composite	600	1	630	630	—	—
CNT–MnO_2 composite	234	1.5	199	300	—	—
AC–polyaniline composite	1000	—	300	—	—	—

Zhang, L.L., Zhao, X.S., Chem. Soc. Rev. 38 (2009) 2520.

Properties of Commercial Negative Electrode Materials for Li-ion Battery

Material Property	Hard Carbon (Pitch-Derived)	Graphitized Mesocarbon (MCMB 25-28)	Coated Natural Graphite	Synthetic Graphite (TIMREX SLG5)
Xylene density (g cm^{-3})	1.60	2.10	2.21	2.26
L_c(002) (nm)	1	70	150	150
$c/2$(002) (nm)	0.377	0.338	0.336	0.336
BET SSA (m^2 g^{-1})	4.3	1	1.5	1.5
Average particle size (μm)	9	25	18	22
Bulk density (Scott density) (g cm^{-3})	0.35	0.90	0.83	0.60
Typical reversible charge capacity (mAh g^{-1})	400	335	360	360

Beguin, F., Frackowiak, E., Carbons for Electrochemical Energy Storage and Conversion Systems (2010)

Schematic of Proposed Research

Char

Carbonisation → Activation

- Carbonisation of washed biomass
- Hydrothermal carbonisation

- Physical activation (CO_2, steam)
- Chemical activation ($ZnCl_2$, H_3PO_4, KOH)

Project Duration and Budget

- Project duration
  - 5 years
- Estimated budget
  - 4,800,000 Baht
- Expected output
  - 5 international conference papers
  - 5 international journals (ISI)

Research Plan

Year	MTEC/NSTDA	Kyoto University
1 (less than 12 months)	Characterisation of PEFB • To obtain properties of PEFB – PEFB with steam pretreatment (from oil extraction industry) – PEFB with no pretreatment	Suggestion of carbon properties required for energy storage application
2	Carbonisation of washed PFEB to obtain char • To study the effect of carbonisation temperature on properties of PFEB char • To compare the char properties obtained from PEFB with and without steam pretreatment	Evaluation of char prepared by MTEC as a component in a Lithium-ion battery and a supercapacitor

Research Plan (cont.)

Year	MTEC/NSTDA	Kyoto University
3	Hydrothermal carbonisation of PFEB to obtain hydrochar • To study the effect of carbonisation temperature and pressure on properties of PFEB hydrochar • To compare the hydrochar properties obtained from PEFB with and without steam pretreatment • To compare the properties of hydrochar and char obtained from HTC and carbonisation, respectively	Evaluation of hydrochar prepared by MTEC as a component in a Lithium-ion battery and a supercapacitor

Research Plan (cont.)

Year	MTEC/NSTDA	Kyoto University
4	Physical activation of hydrochar to produce good qualities of activated carbon • To study the role of CO_2 in enhancement of porosity • To study the role of steam in enhancement of porosity	Evaluation of activated carbon prepared by MTEC as a component in a Lithium-ion battery and a supercapacitor
5	Chemical activation of hydrochar to produce good qualities of activated carbon • To study the role of $ZnCl_2$ in enhancement of porosity • To study the role of H_3PO_4 in enhancement of porosity • To study the role of KOH in enhancement of porosity	Evaluation of activated carbon prepared by MTEC as a component in a Lithium-ion battery and a supercapacitor