


CHEMISTRY
CHIANG MAI UNIVERSITY

FACULTY OF SCIENCE
CHIANG MAI UNIVERSITY

BE FUN TO THE FRONTIER
FUN FUNCTIONAL FUNDAMENTAL

CMU CHIANG MAI UNIVERSITY

EGAT

MR CENTER
Faculty of Science Chiang Mai University

สร้างคนข้ามพรมแดน

PERCH-CIC PERDO

PMUC
Program Management Unit for Competitiveness

Energy Policy and Planning Office
MINISTRY OF ENERGY

STEP CMU
SCIENCE AND TECHNOLOGY PARK
CHIANG MAI UNIVERSITY

สกสว

# From Biomass to Battery Materials



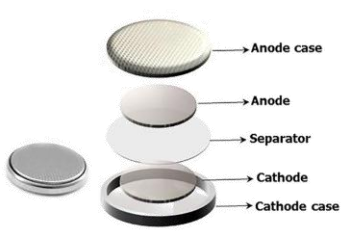
RENEWABLE ENERGY LABORATORY

Speaker:
Assoc. Prof. Dr. Thapanee Sarakonsri
Department of Chemistry, Faculty of Science
Chiang Mai University (CMU)

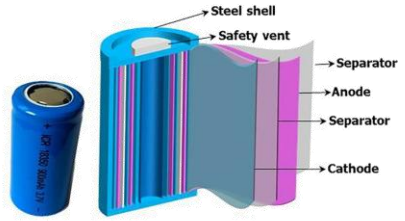
12 November 2026

RENEWABLE ENERGY LABORATORY

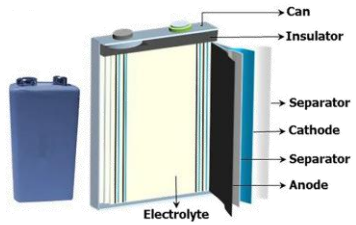
# Lithium-ion batteries (LIBs)



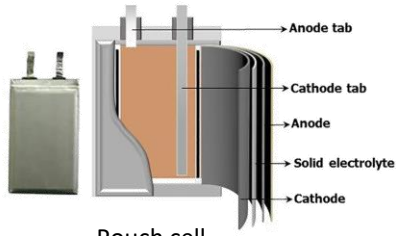
Coin cell



Cylindrical cell

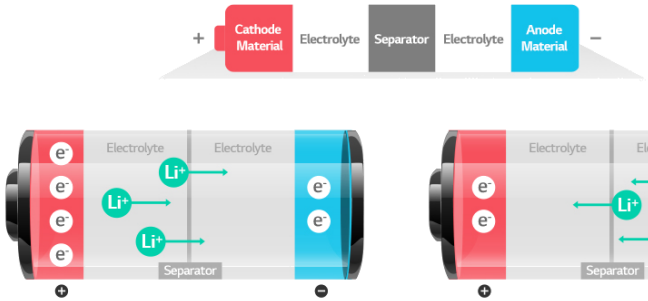


Prismatic cell



Pouch cell

*Structure of LIBs*




https://inside.lgensol.com/en/2022/07/lithium-ion-batterys-structure-and-how-it-works/

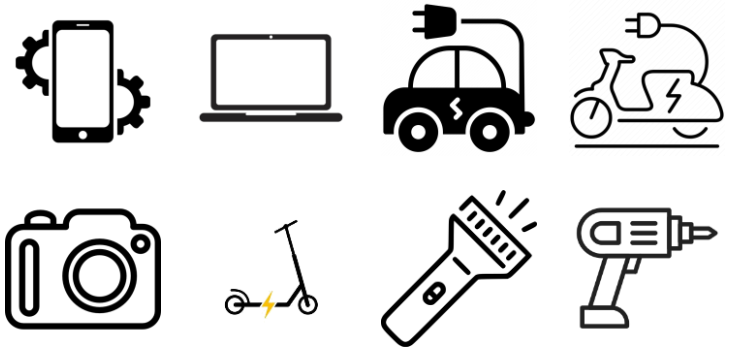
## Advantages

- High energy density
- Longer lifecycle
- Fast Charging
- Lower self-discharge rate
- Low maintenance
- Lightweight and compact

## Disadvantages

- High initial cost
- Sensitive to High Temperatures
- Charging Limitations

## Applications



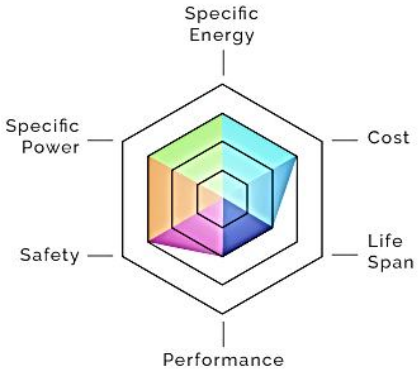


Liang YR, Zhao CZ, Yuan H *et al*. A review of rechargeable batteries for portable electronic devices. *Info Mat* **2019**, 1, 6–32

2

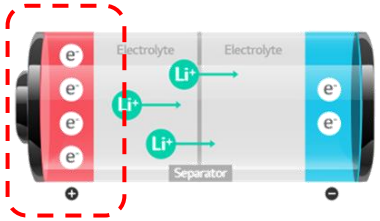
RENEWABLE ENERGY LABORATORY

# Types of LIBs



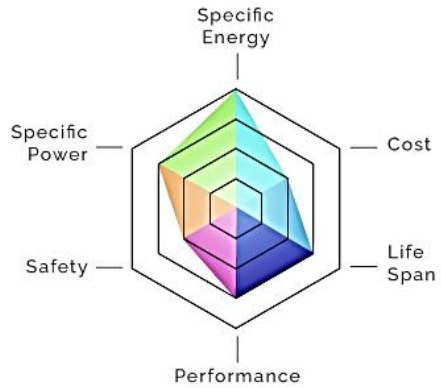

## Lithium Manganese Oxide: LMO

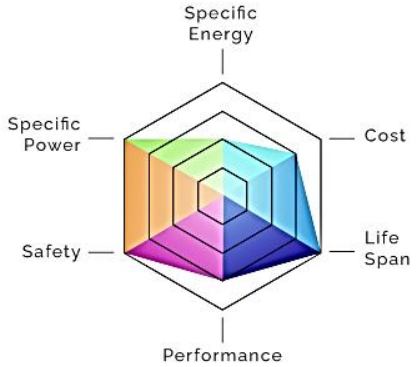





## Lithium Nickel Cobalt Aluminum Oxide: NCA





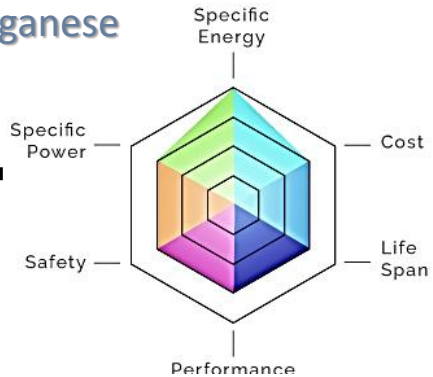

## Lithium Iron Phosphate: LFP

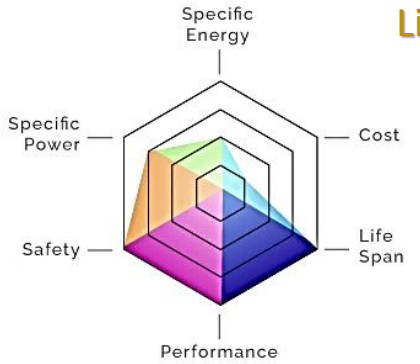





## Lithium Nickel Manganese Cobalt Oxide: NMC





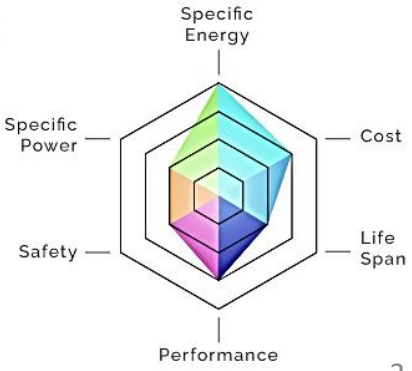




## Lithium Titanate: LTO



## Lithium Cobalt Oxide: LCO



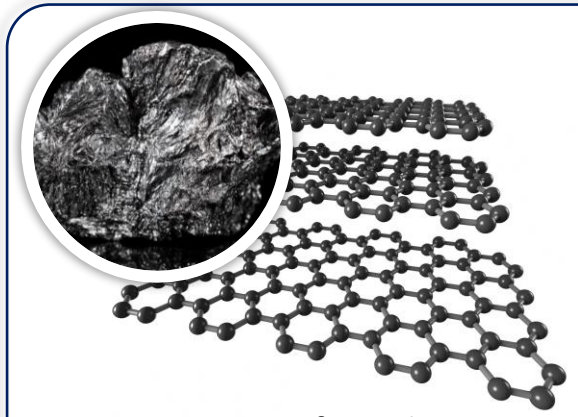



*https://www.lisocl2-battery.com/quality-11061844-limno2-lithium-manganese-oxide-battery-3v-cr17450*
*https://batteryswapcabinet.com/nca-battery/*
*https://www.walmart.com/ip/BtrPower-12V-50Ah-LiFePO4-Lithium-Iron-Phosphate-Battery-Pack-for-RV-Marine-Solar-System/1979049949*
*https://lightning-energy.cn/product/catl-3-7v-7ah-lithium-ion-nmc-battery-cells/*
*https://www.evlithium.com/Lithium-Titanate-Battery-LTO/18650-lto-battery-cell.html*
*https://szaspower.en.made-in-china.com/product/cyrQhTIDgSVR/China-Lipo-Battery-603450-Pouch-Cell-3-7V-1050mAh-Polymer-Battery-with-Wires-and-Connector.html*
*https://www.flaticon.com*
*https://www.freepik.com/*

https://batteryuniversity.com/article/bu-205-types-of-lithium-ion


3

# Commercial anode: Graphite



*Structure of Graphite*

## 1 *Natural Graphite*

- It boasts a purity level exceeding 99% carbon.
- The production involves graphitizing at temperatures exceeding 2,500°C.
- It exhibits high density, low porosity, and remarkable thermal and electrical conductivity and excellent resistance to chemical corrosion.

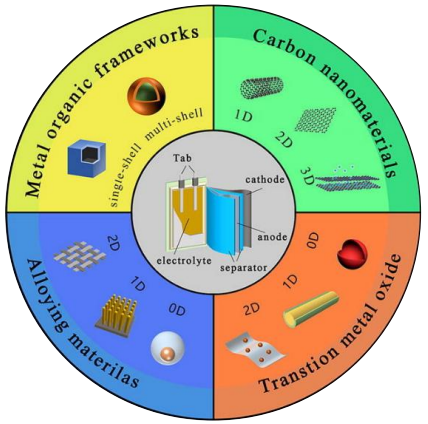
## 2 *Synthetic Graphite*

- It consists of varying carbon content, typically ranging from 15% to 95%
- natural graphite undergoes several mechanical and chemical treatments to enhance its quality.
- Natural graphite exhibits lower density, higher porosity, and moderate thermal and electrical conductivity.

- Inexpensive
- Intercalation materials (Lithiated form = $LiC_6$)
- High thermal stability
- High electrical conductivity

- Low theoretical capacity (372 mAh $g^{-1}$)
- Low operating voltage (0.05 V vs Li/Li+)
- Lithium dendrite formation
- Combustible & Explodable
- Temperature restriction (-30 to 60ºC)

## *Anode material development*




*Cheng, H. et al. J. Energy Chem.* ***2020.***

- Increase capacity
- Enhance stability of electrodes
- Improve battery life
- Improve safety in using
- Decrease production cost
- Support fast charge technologies
- Improve ICE
- Reduce SEI layer
- Improve environmentally friendliness

https://graphel.com/natural-vs-synthetic-graphite/


4

RENEWABLE ENERGY LABORATORY

# Pain points of LIBs industry in Thailand

**High LIBs retail price in Thailand**

Limited raw materials & technologies
(Li, Cu, anode, cathode, etc.)

- Dependency on imported batteries
- Expensive import tax rate

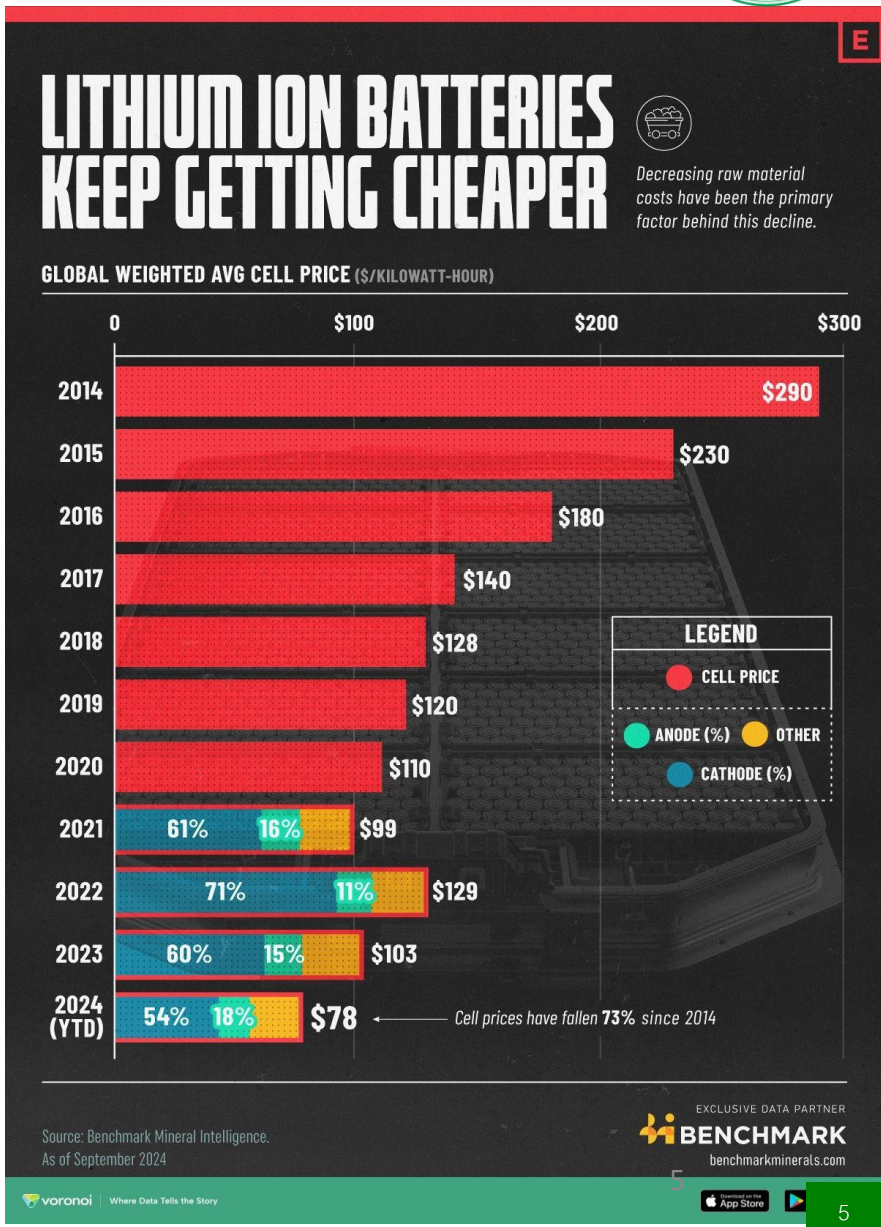
Safety concerns
(Overcharging, thermal runaway, fire & explosion)

- High-risk shipping & transportation
- High shipping & insurance fee

## Reducing retail price of LIBs

- Development of material production from low cost, easily accessible local materials
- Collaboration with raw material manufacturer in Thailand
- Reduce raw material imports

Full in-house LIBs production in Thailand

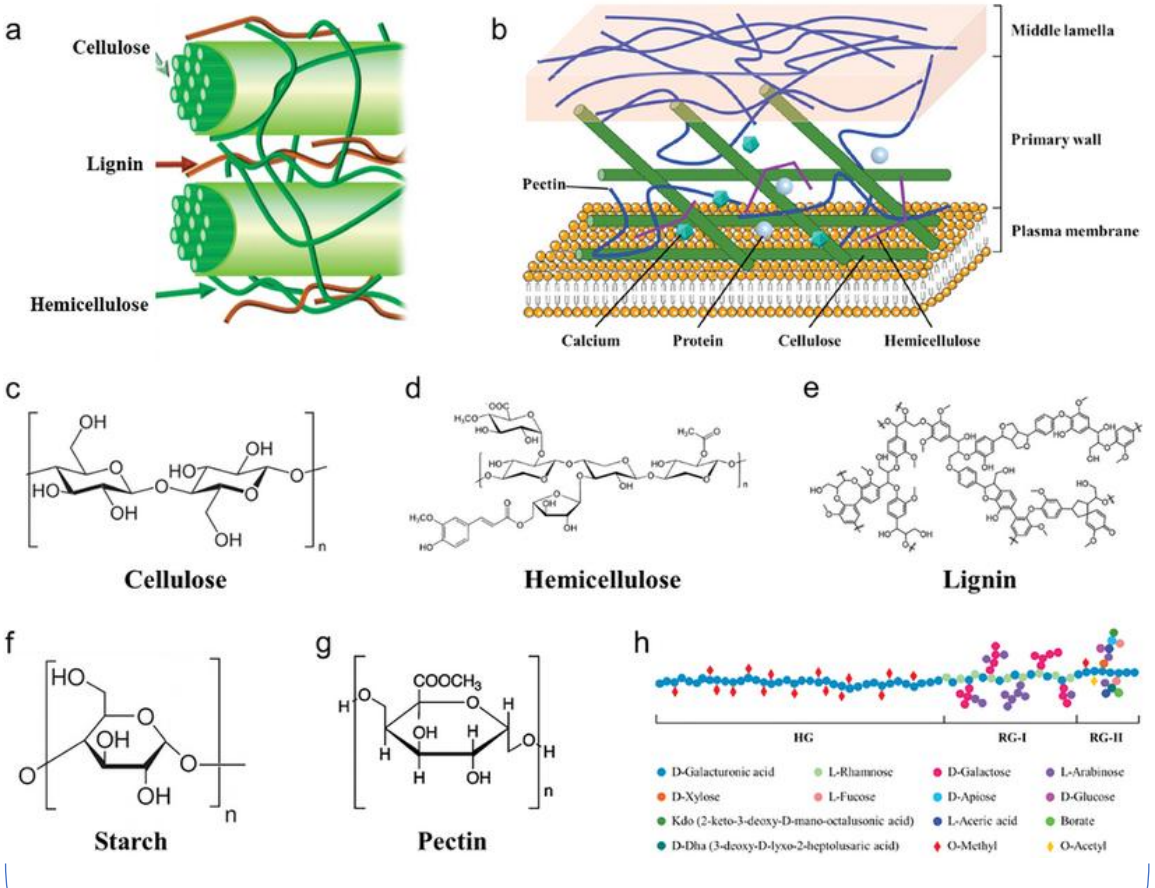



*Ref: https://www.riege.com/resources/blog/dangerous-goods-with-a-growing-transportation-volume-lithium-ion-battery-and-lithium-metal-battery-shipments*

# Silicon and Carbon anode can be derived from plant biomass



## Main components of biomass




**Source of carbon**

Other key components:
inorganic mineral content such as $SiO_2$

Shijie Yu et al., Advanced Materials, 36(18):e2307412, 2024

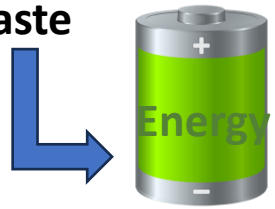
## Silica content in some plants



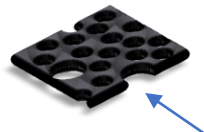

Soundharraj, Prabha et al., (2020). Environmental Chemistry Letters. 19. 10.1007/s10311-020-01123-5.



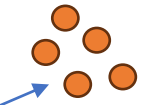

43 million ton/year
**Waste**

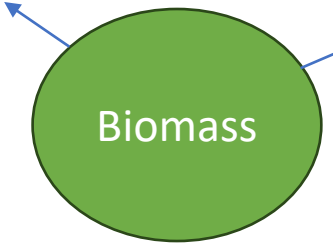



Porous carbon



Nano $SiO_2$ and Si



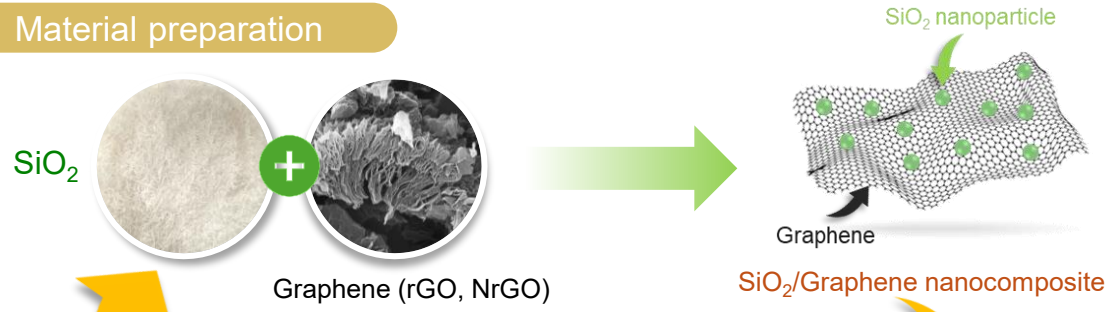



## Challenges

- Volume changes
- Low conductivity
- Need to be composited with supporter

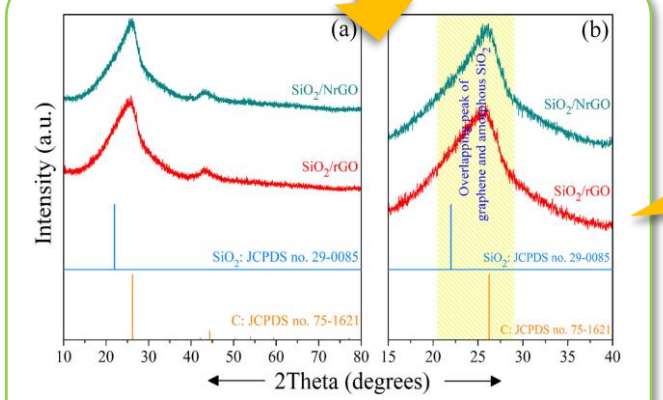
# $SiO_2$/Graphene-based nanocomposites

## Material preparation

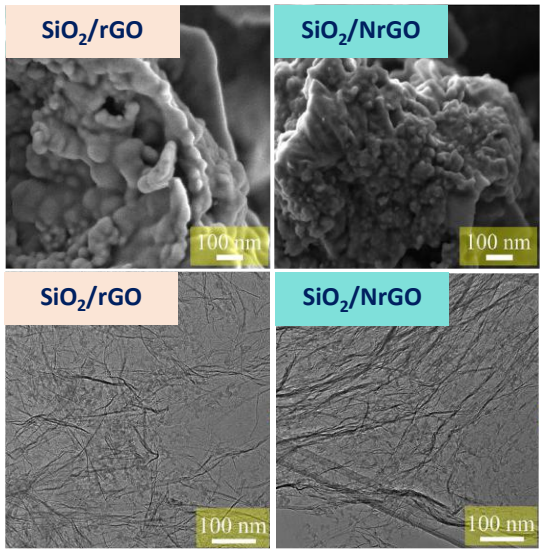




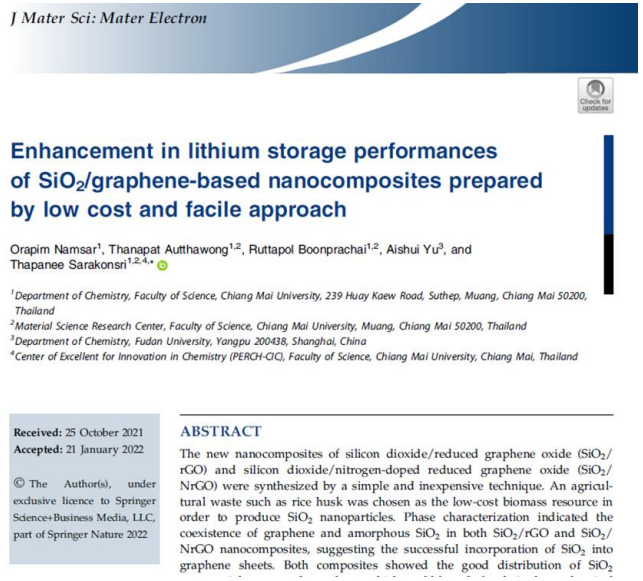





XRD patterns of $SiO_2$/rGO and $SiO_2$/NrGO composites.




SEM and TEM images of the obtained composites.



J Mater Sci: Mater Electron

**Enhancement in lithium storage performances of $SiO_2$/graphene-based nanocomposites prepared by low cost and facile approach**

Orapim Namsar[1], Thanapat Autthawong[1,2], Ruttapol Boonprachai[1,2], Aishui Yu[3], and Thapanee Sarakonsri[1,2,4,*]

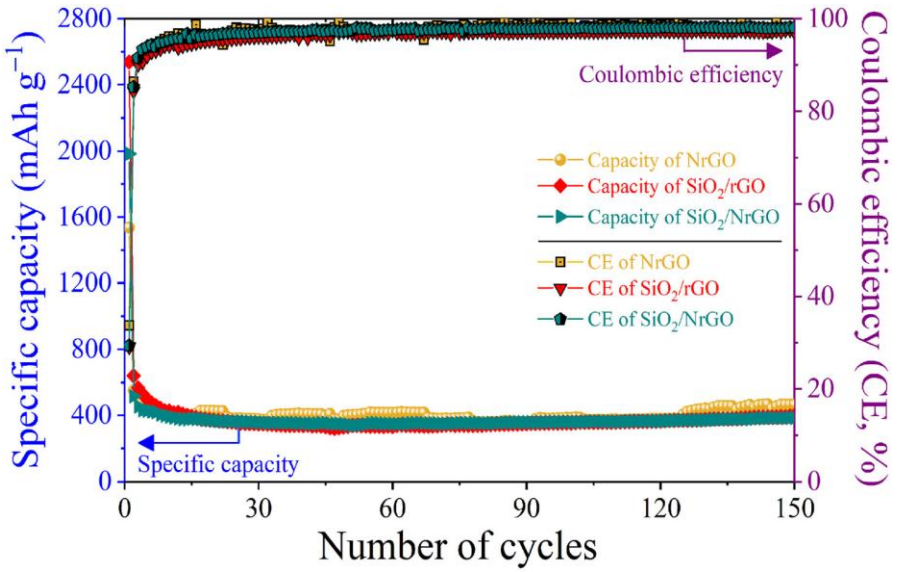
[1]Department of Chemistry, Faculty of Science, Chiang Mai University, 239 Huay Kaew Road, Suthep, Muang, Chiang Mai 50200, Thailand
[2]Material Science Research Center, Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand
[3]Department of Chemistry, Fudan University, Yangpu 200438, Shanghai, China
[4]Center of Excellent for Innovation in Chemistry (PERCH-CIC), Faculty of Science, Chiang Mai University, Chiang Mai, Thailand

**Received:** 25 October 2021
**Accepted:** 21 January 2022

© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature 2022

ABSTRACT

The new nanocomposites of silicon dioxide/reduced graphene oxide ($SiO_2$/rGO) and silicon dioxide/nitrogen-doped reduced graphene oxide ($SiO_2$/NrGO) were synthesized by a simple and inexpensive technique. An agricultural waste such as rice husk was chosen as the low-cost biomass resource in order to produce $SiO_2$ nanoparticles. Phase characterization indicated the coexistence of graphene and amorphous $SiO_2$ in both $SiO_2$/rGO and $SiO_2$/NrGO nanocomposites, suggesting the successful incorporation of $SiO_2$ into graphene sheets. Both composites showed the good distribution of $SiO_2$




Cycle stability of $SiO_2$/rGO and $SiO_2$/NrGO nanocomposites as compared to NrGO.

Ref: https://www.freepik.com/free-psd/lush-green-rice-paddy-field-with-rice-plants-grains-ready-harvest-beautiful-agricultural-scene_410859845.htm#fromView=search&page=1&position=2&uuid=7322eebc-77bc-4516-be8e-8da05a8ead2f&query=rice+field

# $Sn(SnO_2)$-$SiO_2$/Graphene-based nanocomposites


Sustainable Energy & Fuels

ROYAL SOCIETY OF CHEMISTRY

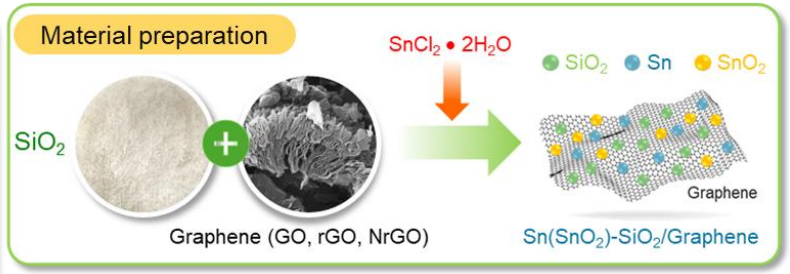
PAPER

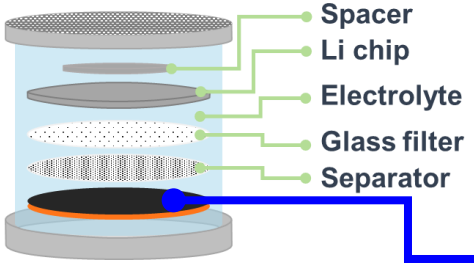
View Article Online

Check for updates

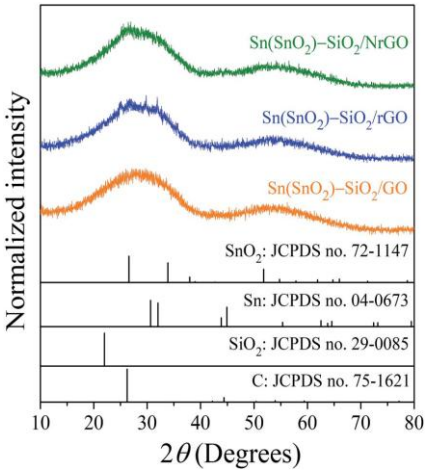
Improved electrochemical performance of anode materials for high energy density lithium-ion batteries through $Sn(SnO_2)$–$SiO_2$/graphene-based nanocomposites prepared by a facile and low-cost approach

Orapim Namsar,[a] Thanaphat Autthawong,[a] Viratchara Laokawee,[a] Ruttapol Boonprachai,[ab] Mitsutaka Haruta,[c] Hiroki Kurata,[c] Aishui Yu,[d] Torranin Chairuangsri[e] and Thapanee Sarakonsri[a]

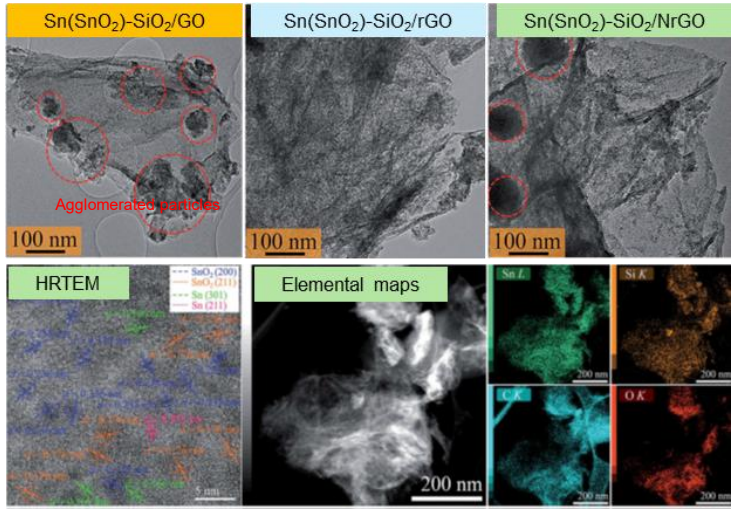



***Half-coin cell structure***




XRD patterns of all prepared nanocomposites.




TEM images of all prepared nanocomposites, High Resolution TEM, and EDS mapping of $Sn(SnO_2)$-$SiO_2$/NrGO nanocomposite.

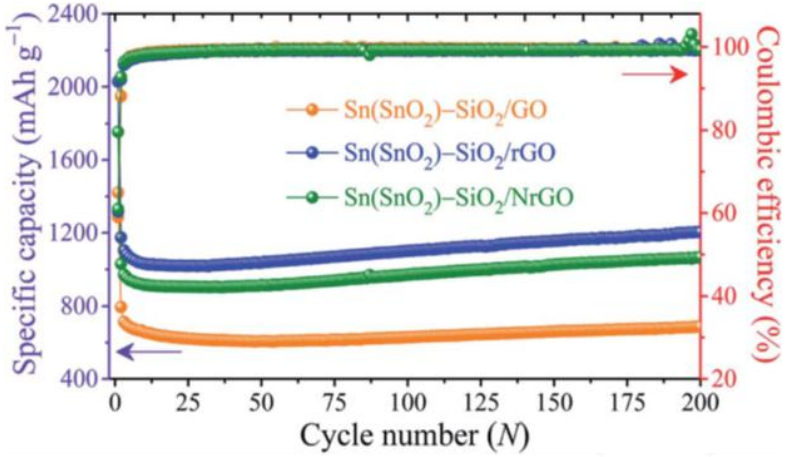




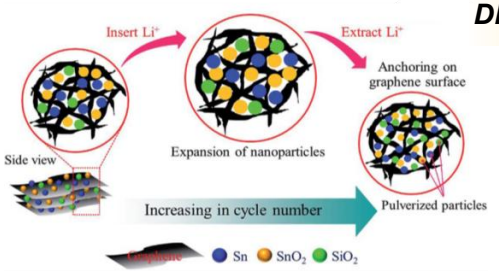

Ref: https://www.freepik.com/free-psd/lush-green-rice-paddy-field-with-rice-plants-grains-ready-harvest-beautiful-agricultural-scene_410859845.htm#fromView=search&page=1&position=2&uuid=7322eebc-77bc-4516-be8e-8da05a8ead2f&query=rice+field

## Developed ANODE

## Electrochemical performance




*The increased capacity with increasing cycle numbers may be due to the effect of pulverization.*




***ADVANTAGES of DEVELOPED NANOCOMPOSITES***

- High capacity
- Excellent cycle stability
- Cost effective
- Sustainable raw materials

Cycle stability of $Sn(SnO_2)$-$SiO_2$/graphene-based nanocomposites and the pulverization effect.

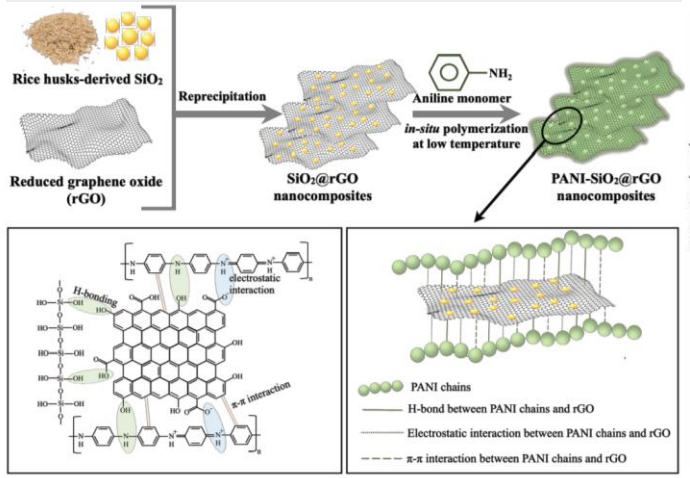
# *Polyaniline-coated rice husk-derived $SiO_2$@rGO nanocomposites*

**Polyaniline (conductive polymer)**

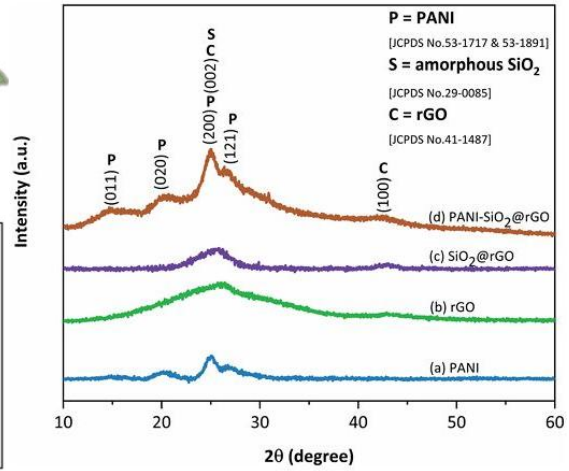
- Low-cost
- ease of synthesis from readily available monomers
- Relatively high electrical conductivity
- good environmental stability



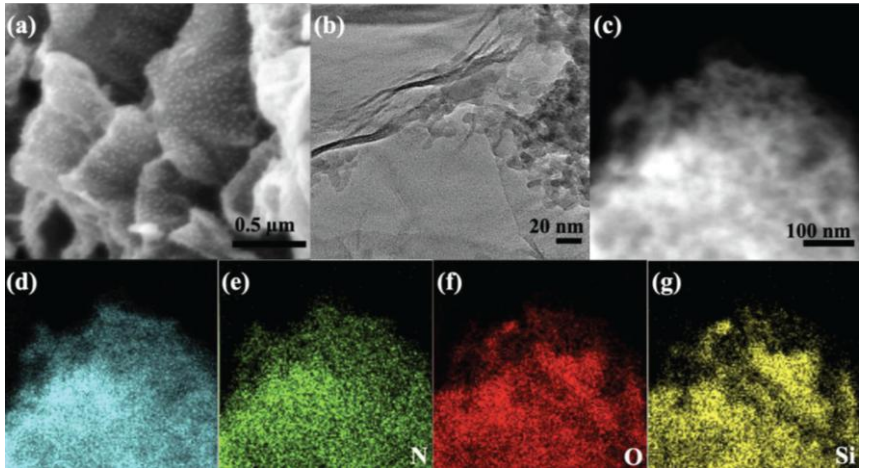
## Schematic diagram of the synthesis route




## XRD of all nanocomposites



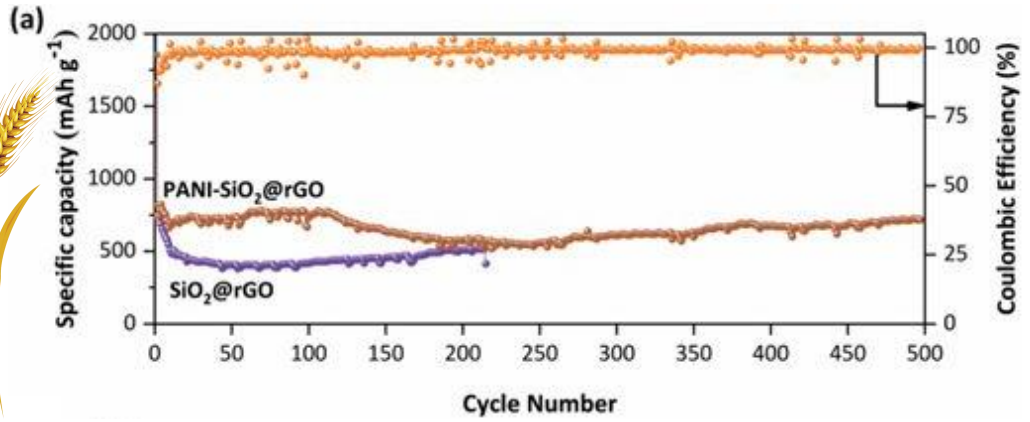

## Microstructure investigation of all nanocomposites




## Rice husk-raw material source



## Cycle stability of all nanocomposites




## Paper publication



RSC Advances

PAPER

Check for updates

Cite this: *RSC Adv.*, 2022, 12, 14621

**Rice husk-derived nano-$SiO_2$ assembled on reduced graphene oxide distributed on conductive flexible polyaniline frameworks towards high-performance lithium-ion batteries**

Natthakan Ratsameetammajak, Thanapat Autthawong, Torranin Chairuangsri, Hiroki Kurata, Ai-shui Yu and Thapanee Sarakonsri

By combining rice husk-derived nano-silica and reduced graphene oxide and then polymerizing PANI by *in situ* polymerization, we created polyaniline-coated rice husk-derived nano-silica@reduced graphene oxide (PANI-$SiO_2$@rGO) composites with excellent electrochemical performance. ATR-FTIR and XRD analyses confirm the formation of PANI-$SiO_2$@rGO, implying that $SiO_2$@rGO served as a template in the formation of composites. The morphology of PANI-$SiO_2$@rGO was characterized by SEM, HRTEM, and STEM, in which $SiO_2$ nanoparticles were homogeneously loaded on graphene sheets and the PANI fibrous network uniformly covers the $SiO_2$@rGO composites. The structure can withstand the large volume change as well as retain electronic conductivity during Li-ion insertion/extraction. Over 400 cycles, the assembled composite retains a high reversible specific capacity of 680 mA h g$^{-1}$ at a current density of 0.4 A g$^{-1}$, whereas the $SiO_2$@rGO retains only 414 mA h g$^{-1}$ at 0.4 A g$^{-1}$ after 215 cycles. The enhanced electrochemical performance of PANI-$SiO_2$@rGO was a result of the dual protection provided by the PANI flexible layer and graphene sheets. PANI-$SiO_2$@rGO composites may pave the way for the development of advanced anode materials for high-performance lithium-ion batteries.

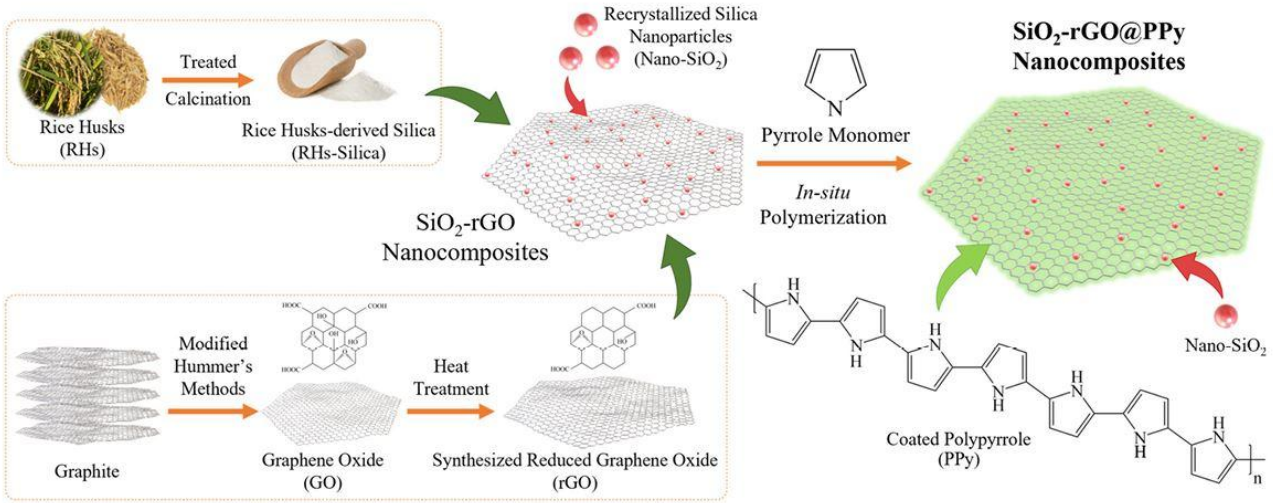
Received 25th January 2022
Accepted 7th May 2022
DOI: 10.1039/d2ra00526c
rsc.li/rsc-advances

# *Polypyrrole-coated rice husk-derived $SiO_2$@rGO nanocomposites*

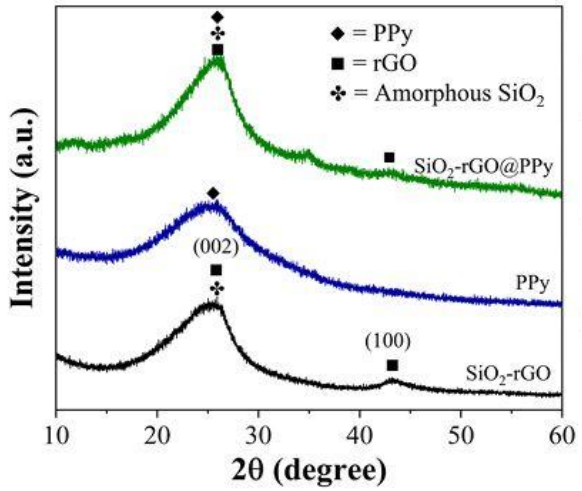
**Polypyrrole (conductive polymer)**

- Affordable cost
- remarkable redox capabilities
- commendable electrical conductivity
- biocompatibility
- chemical stability

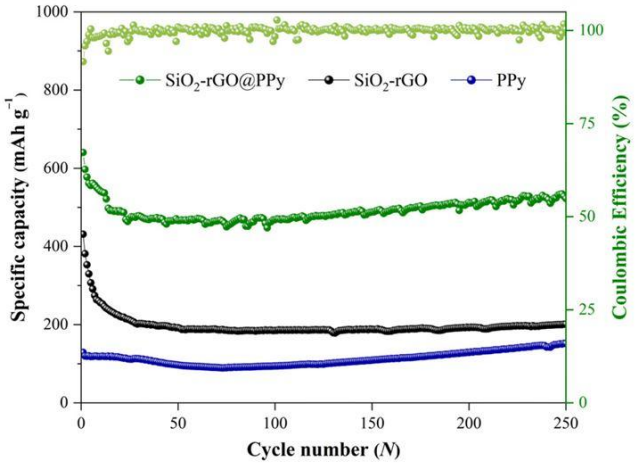
## Schematic illustration of the synthesis of nanocomposites



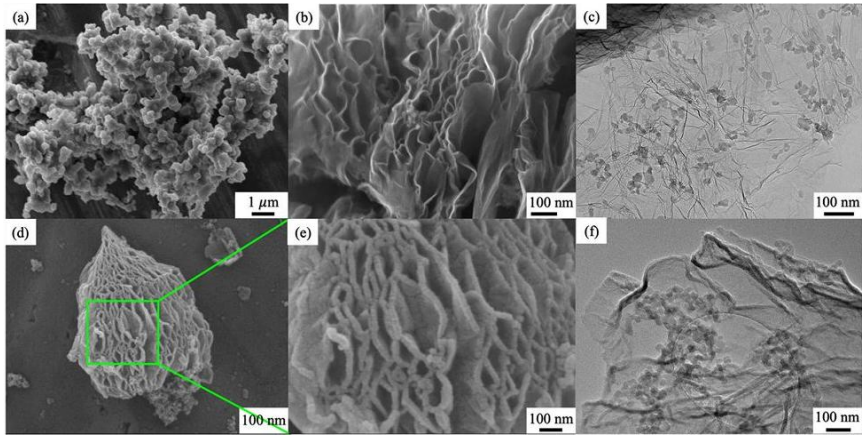

## XRD of all nanocomposites



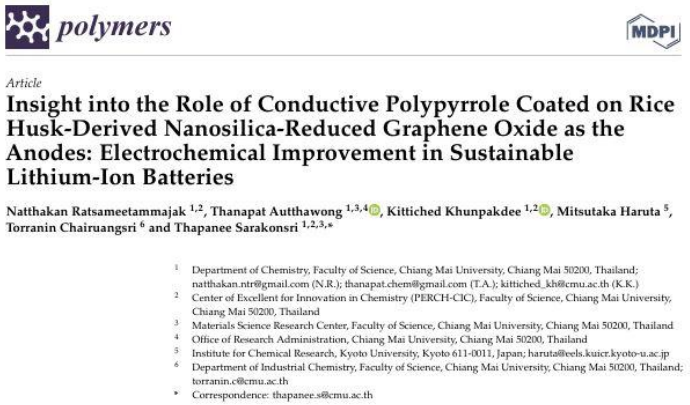

## Cycle stability of all nanocomposites




## SEM of all nanocomposites




## Paper publication



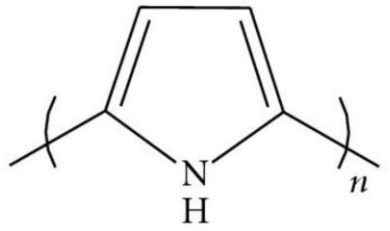
*polymers* MDPI

*Article*

**Insight into the Role of Conductive Polypyrrole Coated on Rice Husk-Derived Nanosilica-Reduced Graphene Oxide as the Anodes: Electrochemical Improvement in Sustainable Lithium-Ion Batteries**

Natthakan Ratsameetammajak [1,2], Thanapat Autthawong [1,3,4], Kitticheed Khunpakdee [1,2], Mitsutaka Haruta [5], Torranin Chairuangsri [6] and Thapanee Sarakonsri [1,2,3,*]

[1] Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand; natthakan.ntr@gmail.com (N.R.); thanapat.chem@gmail.com (T.A.); kitticheed_kh@cmu.ac.th (K.K.)
[2] Center of Excellent for Innovation in Chemistry (PERCH-CIC), Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand
[3] Materials Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand
[4] Office of Research Administration, Chiang Mai University, Chiang Mai 50200, Thailand
[5] Institute for Chemical Research, Kyoto University, Kyoto 611-0011, Japan; haruta@eels.kuicr.kyoto-u.ac.jp
[6] Department of Industrial Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand; torranin.c@cmu.ac.th
* Correspondence: thapanee.s@cmu.ac.th




Polypyrrole

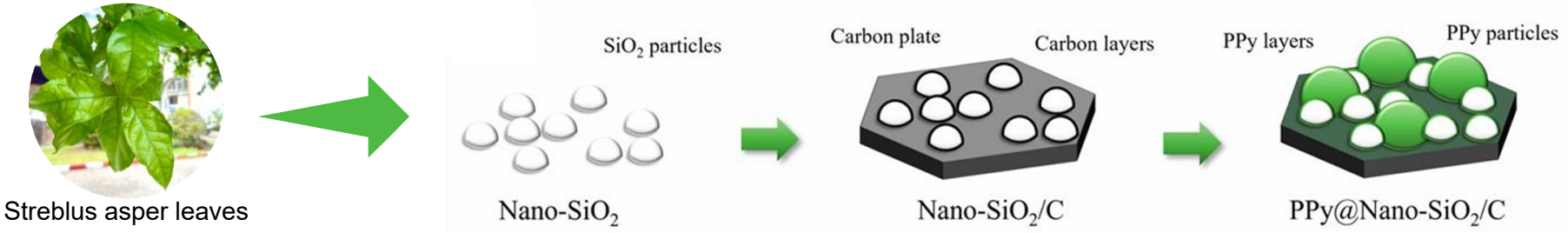


Rice husk-raw biomass

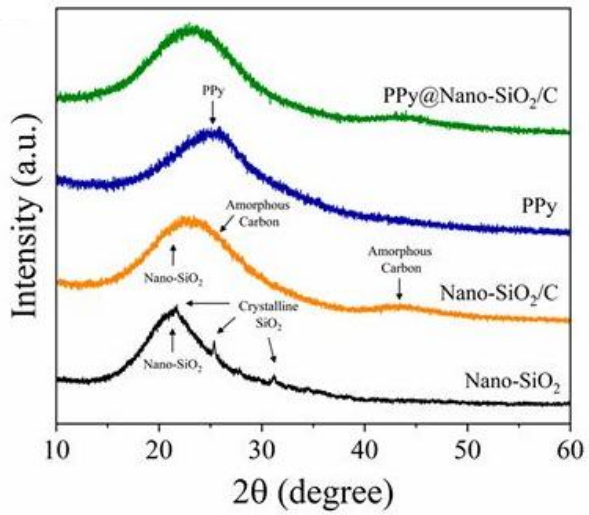
## *Conductive polymers strengthened $SiO_2$/C composites from Streblus asper leaves*

- Sodium alginate-Polyprrole@*Streblus asper Lour.* Leaves-derived nano-$SiO_2$/C composites

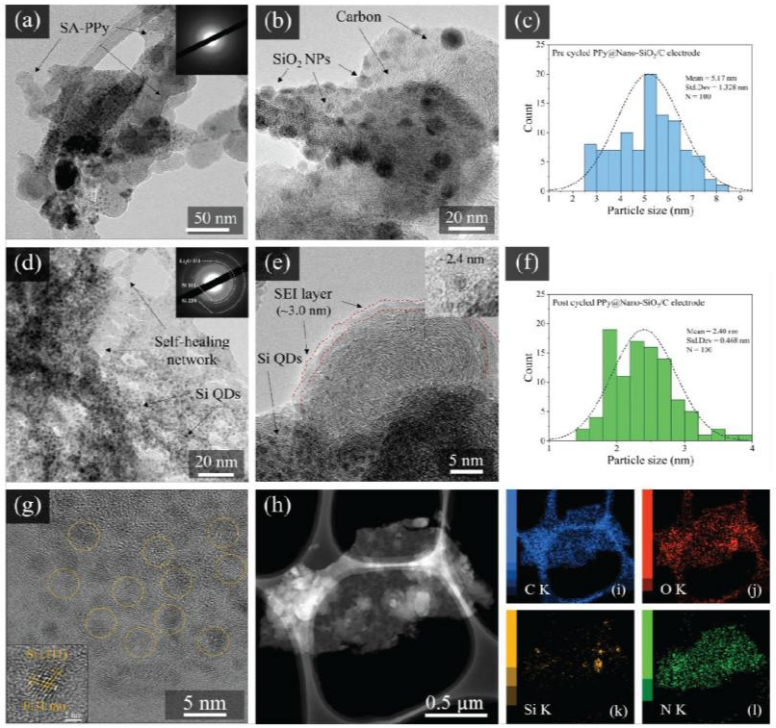
### Schematic diagram of morphology in as-synthesized materials



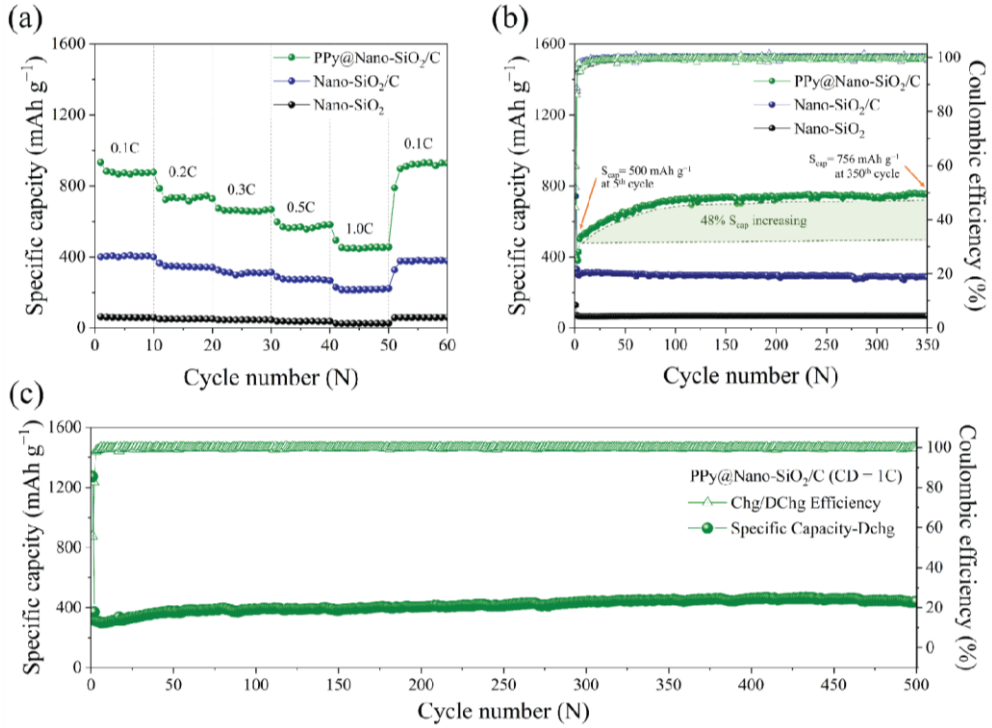

### XRD of all synthesized materials



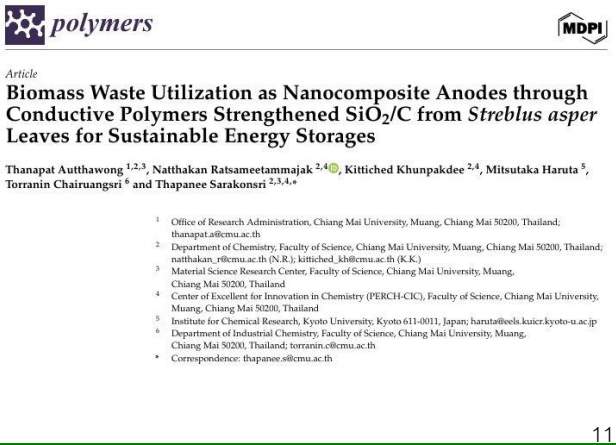

### Microstructure characterization of synthesized materials




### Electrochemical performances of synthesized materials




### Paper publication


polymers
MDPI

Article

**Biomass Waste Utilization as Nanocomposite Anodes through Conductive Polymers Strengthened $SiO_2$/C from *Streblus asper* Leaves for Sustainable Energy Storages**

Thanapat Autthawong [1,2,3], Natthakan Ratsameetammajak [2,4], Kittiched Khunpakdee [2,4], Mitsutaka Haruta [5], Torranin Chairuangsri [6] and Thapanee Sarakonsri [2,3,4,*]

1 Office of Research Administration, Chiang Mai University, Muang, Chiang Mai 50200, Thailand; thanapat.a@cmu.ac.th
2 Department of Chemistry, Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand; natthakan_r@cmu.ac.th (N.R.); kittiched_kh@cmu.ac.th (K.K.)
3 Material Science Research Center, Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand
4 Center of Excellent for Innovation in Chemistry (PERCH-CIC), Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand
5 Institute for Chemical Research, Kyoto University, Kyoto 611-0011, Japan; haruta@eels.kuicr.kyoto-u.ac.jp
6 Department of Industrial Chemistry, Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand; torranin.c@cmu.ac.th
* Correspondence: thapanee.s@cmu.ac.th

# *Sustainable materials* – *Silicon-based materials from biomass wastes*

Dry teak leaves (TL)

Dry mahogany-based biomass (MB)



BIOMASS



Napier grass (NG)

Dry palm-based biomass (PB)

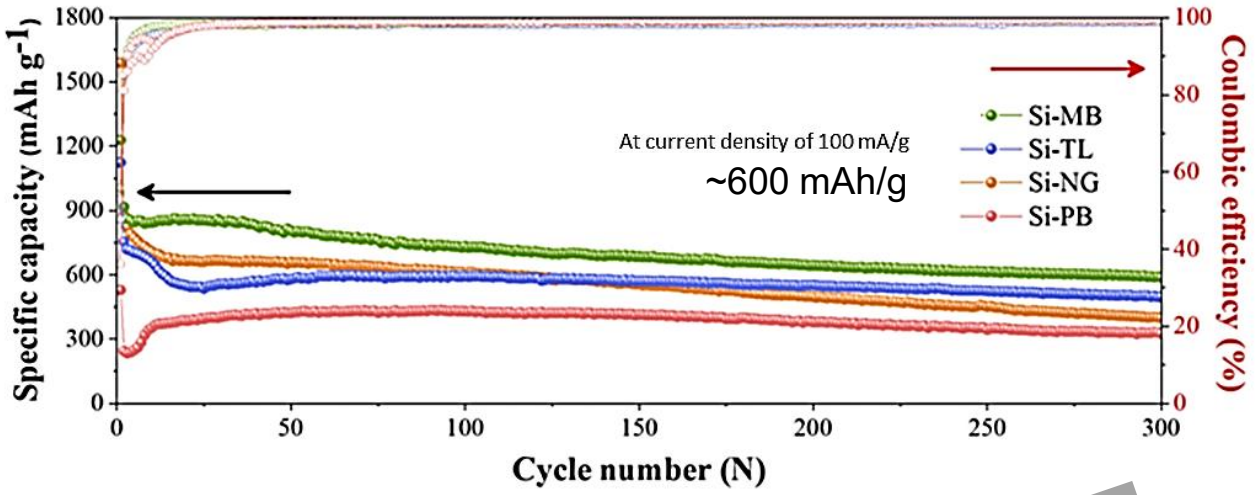


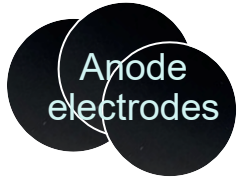
***Si-based materials***

**Advantages**

- Non-toxic precursor
- Natural abundant & biomass waste recycling
- Reducing air pollution from open burning

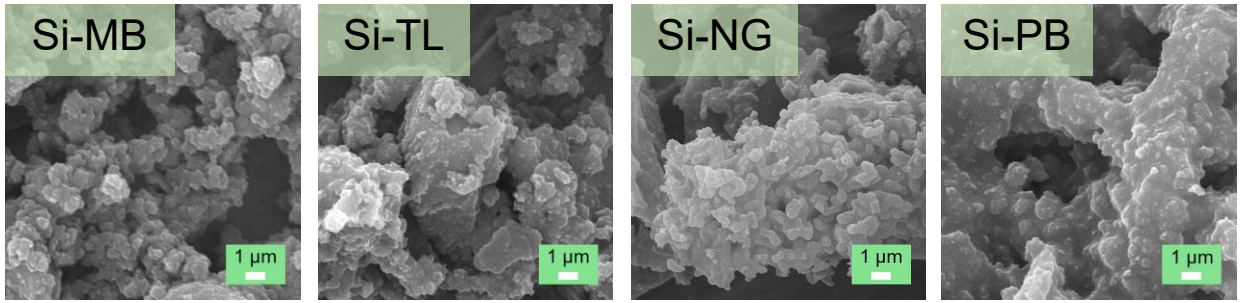
***Cycle performance test at 100 mA/g***






Half-coin cells




SEM images of all Si-based nanocomposites

Diverse morphologies depending on biomass precursor

# SILICON-BASED ANODES DERIVED FROM AGRICULTURAL WASTES



*This research has received funding support from the NSRF via the Program Management Unit for Human Resources & Institutional Development, Research and Innovation [grant number B13F670056].*

## OUTPUT: PAPER PUBLICATION (Q1, ISI/SCOPUS, IF = 5.8)

Biomass and Bioenergy 215 (2026) 109516

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: www.elsevier.com/locate/biombioe

### Agricultural waste upcycling into silicon-based anodes with strategically engineered dual protection of introduced carbon and native silicon dioxide for sustainable lithium-ion batteries

Orapim Namsar [a,b], Chawin Yodbunork [a,b,c], Waewwow Yodying [a], Kittiputh Kunniyom [a,d], Thanapat Autthawong [b,d,e], Mitsutaka Haruta [f], Thapanee Sarakonsri [a,b,d,*]

[a] Department of Chemistry, Faculty of Science, Chiang Mai University, Muang, Chiang Mai, 50200, Thailand
[b] Materials Science Research Center, Faculty of Science, Chiang Mai University, Muang, Chiang Mai, 50200, Thailand
[c] Office of Research Administration, Office of the University, Chiang Mai University, Muang, Chiang Mai, 50200, Thailand
[d] Center of Excellence for Innovation in Chemistry (PERCH-CIC), Faculty of Science, Chiang Mai University, Muang, Chiang Mai, 50200, Thailand
[e] Department of Industrial Chemistry, Faculty of Science, Chiang Mai University, Muang, Chiang Mai, 50200, Thailand
[f] Institute for Chemical Research, Kyoto University, Uji, Kyoto, 611-0011, Japan

ARTICLE INFO

*Keywords:*
Lithium-ion batteries
Anodes
Silicon
Silicon dioxide
Carbon
Agricultural waste

ABSTRACT

The sustainable utilization of agricultural waste is essential for mitigating environmental pollution advancing energy technologies. In this research, corn leaves were selected as raw material due to their abu dance and common disposal by open burning, which significantly contributes to PM2.5 emissions. This researc reported the successful upcycling of corn leaves into Si-based anode materials for lithium-ion batteries (LIBs) via magnesiothermic reduction, which offered dual benefits of waste management and air pollution mitigation. Despite the high theoretical capacity of Si, its severe volume expansion during lithiation and delithiation leads to rapid capacity decay and poor cycling stability. To address this issue, dual protective architecture was rationally designed by integrating an introduced carbon confinement with intrinsically formed native $SiO_2$ in Si nano-structures. Glucose was used as a low-cost carbon precursor to form carbon confinement. The engineered structure enabled native $SiO_2$ to react with lithium ions ($Li^+$) during the initial cycle, forming lithium oxide and lithium silicates that buffer mechanical stress. Simultaneously, the carbon confinement enhanced electrical contact, maintained structural integrity, and stabilized the electrode/electrolyte interface. As a result, the optimized anode delivered a high reversible capacity of 845 mAh $g^{-1}$ at 500 mA $g^{-1}$ after 1001 cycles, which was 14 times higher than that of the Si/$SiO_2$ without carbon confinement (60 mAh $g^{-1}$) and 11 times greater than that of commercial Si (80 mAh $g^{-1}$). This research demonstrated an effective strategy to mitigate Si degradation and highlighted a sustainable route for converting agricultural waste into high-performance anode materials for advanced LIBs.






Corn leaves



$SiO_2$



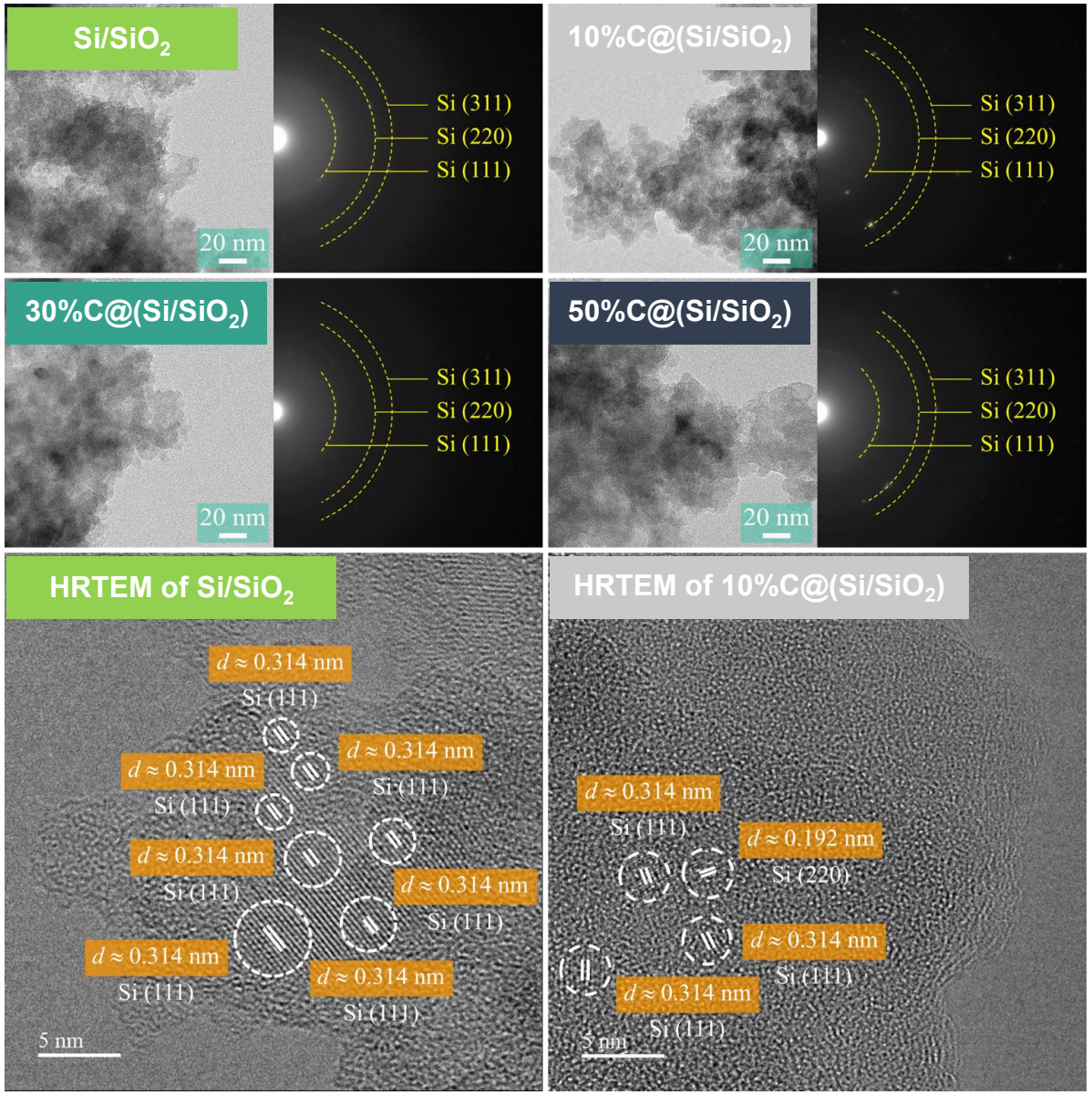
Si/$SiO_2$

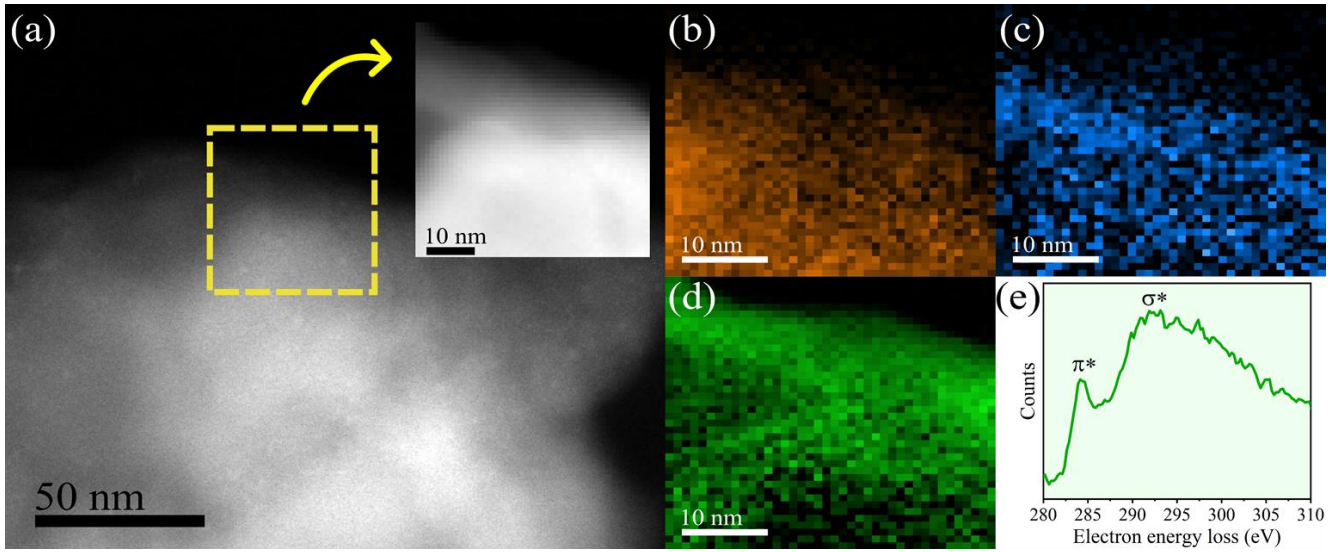


C@(Si/$SiO_2$)

**NANOCOMPOSITE SYNTHESIS**

Namsar et al., Biomass and Bioenergy, 215(2026) 109516.

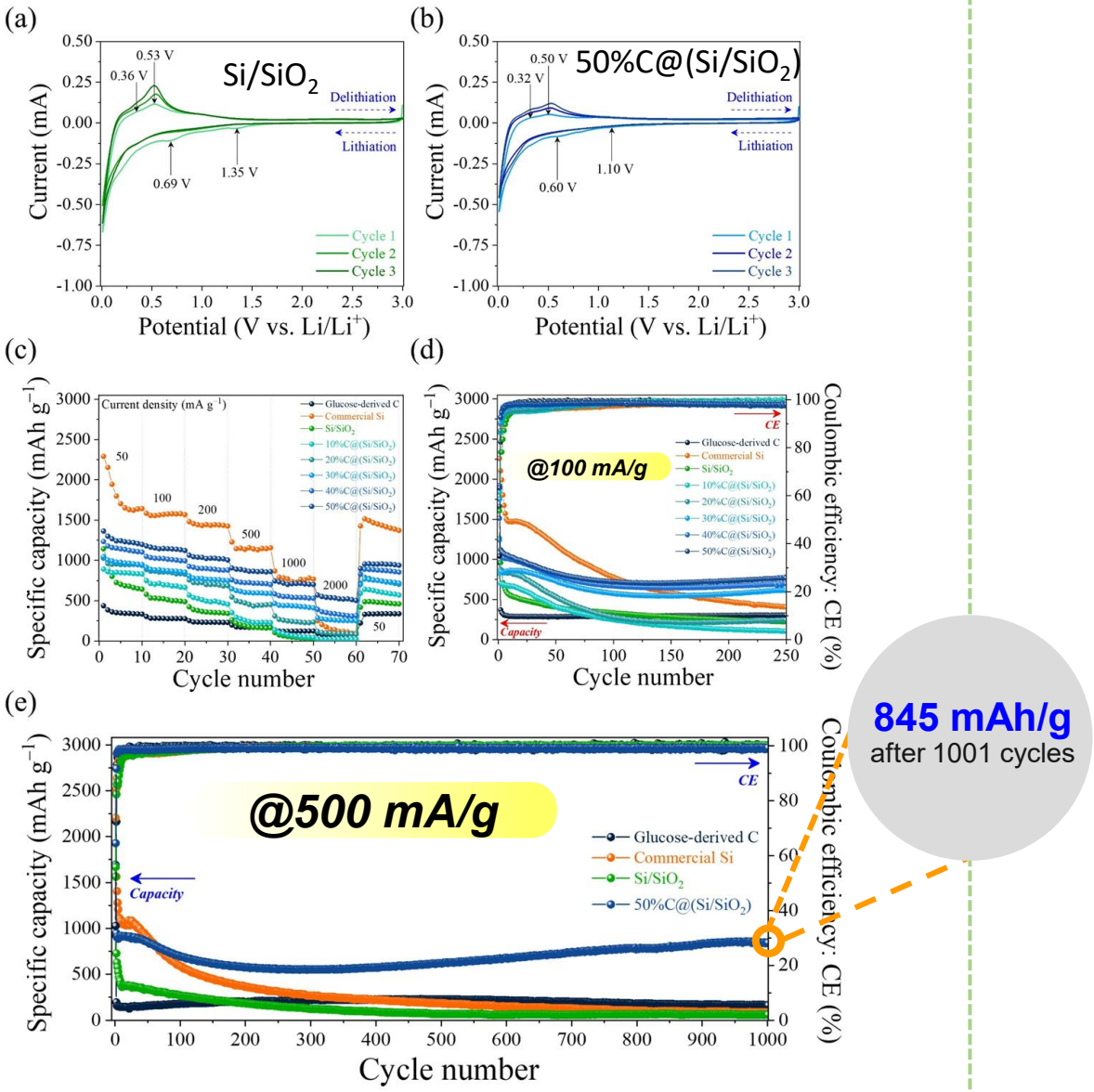



*(a) Overall TEM image and EELS mapping of (b) Si, (c) O, (d) C and (e) EEL spectrum of carbon in 10%C@(Si/SiO$_2$).*

- ***TEM investigation:*** Interconnected nanoparticle network observed in both uncoated and carbon-coated samples
- ***HRTEM investigation:*** Crystalline Si nanoparticles embedded in the amorphous matrix
- ***EELS mapping:*** A uniform distribution of Si and O, with C covering the surface
- ***EELS spectra of C:*** Amorphous phase of carbon coating

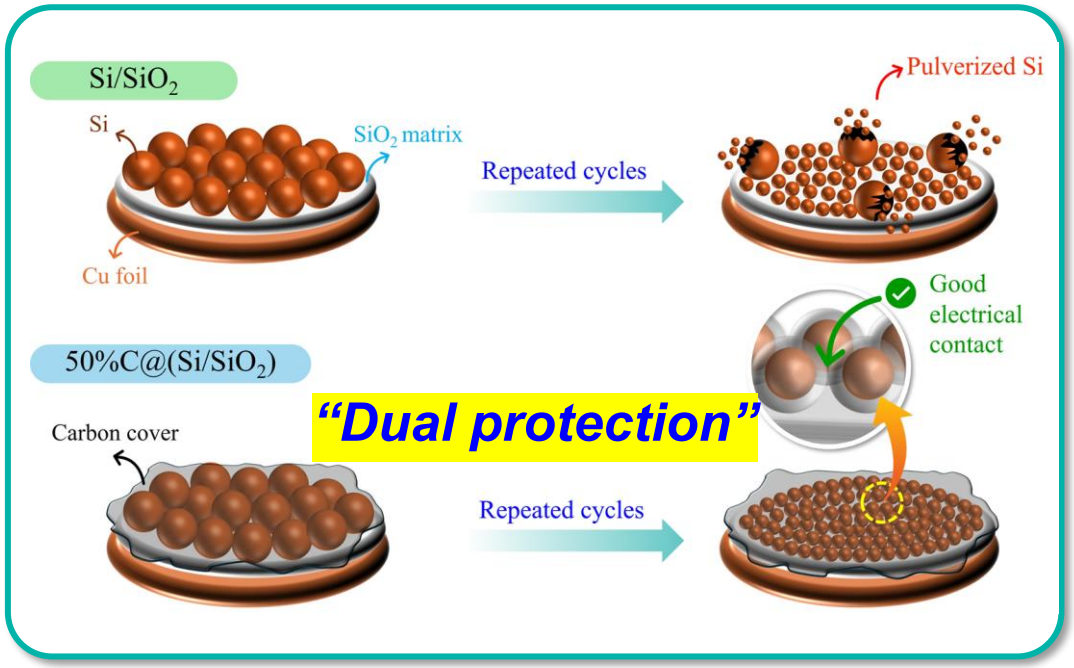
## Electrochemical performances of all electrodes




**845 mAh/g**
after 1001 cycles

*Namsar et al., Biomass and Bioenergy, 215(2026) 109516.*

## *"Possible mechanism during cycles"*




The ***$SiO_2$ matrix*** helped alleviate volume expansion, while the ***carbon coating*** confined pulverized Si particles, maintained electrical contact, and preserved stable electrochemical activity, resulting in enhanced electrochemical performances.

# POROUS CARBON MATERIALS from BIOMASS

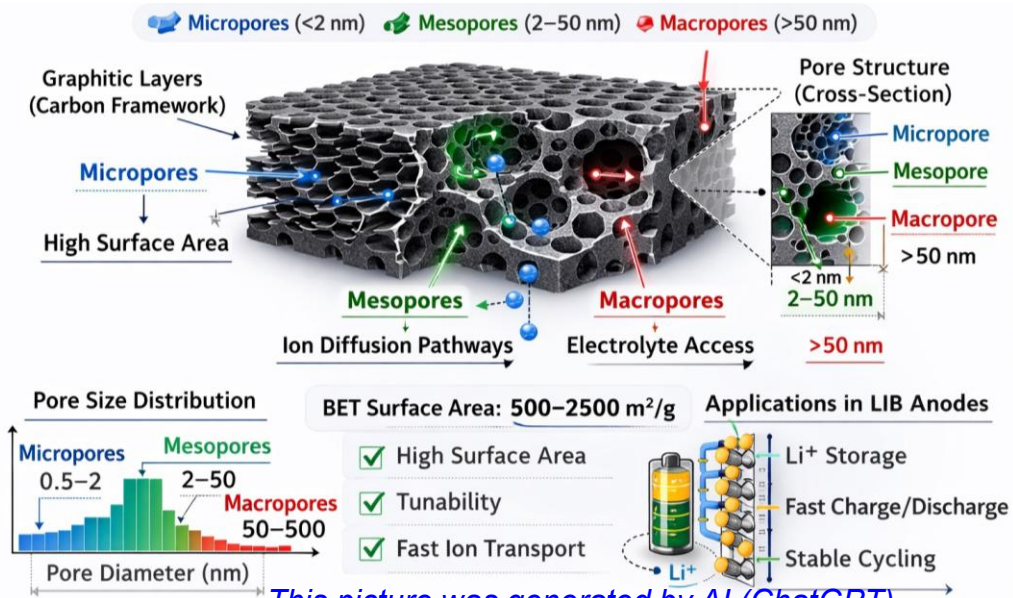
*Manuscript in progress.*

## Unused biomass in Thailand

- ✓ Sustainable
- ✓ Abundant
- ✓ Low-cost



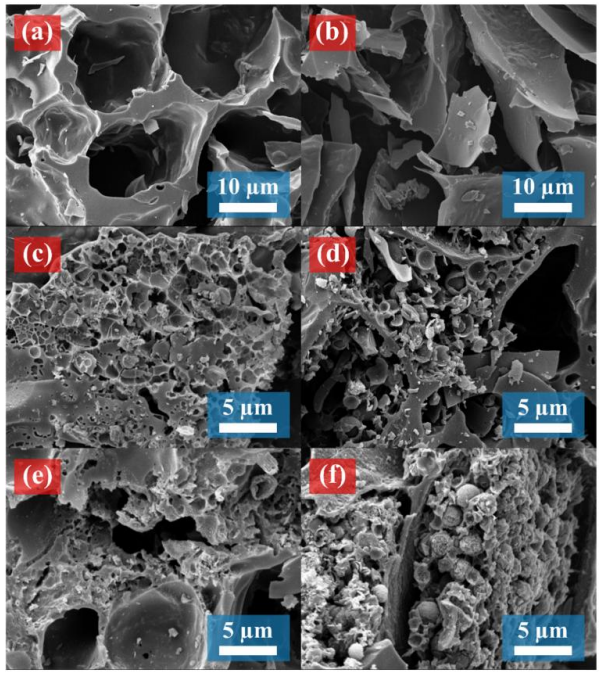

Chemical activation

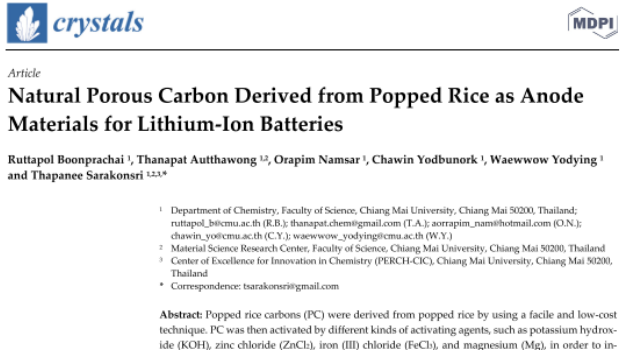



*This picture was generated by AI (ChatGPT).*

Porous carbon is a type of carbon material deliberately engineered to have **large, open, and highly accessible pore structures**. These pores allow ions ($Li^+$, $Na^+$, $K^+$, etc.) to move quickly, making porous carbon useful for **fast-charging batteries, supercapacitors, catalysts, and adsorption applications**.

# POPPED RICE-derived porous carbon



crystals

MDPI

Article

**Natural Porous Carbon Derived from Popped Rice as Anode Materials for Lithium-Ion Batteries**

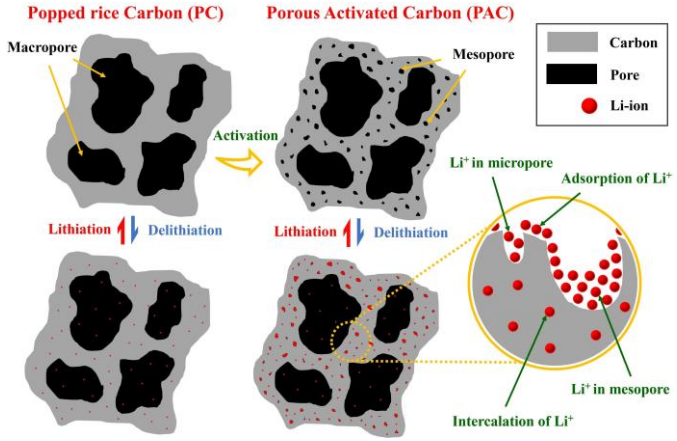
Ruttapol Boonprachai [1], Thanapat Autthawong [1,2], Orapim Namsar [1], Chawin Yodbunork [1], Waewwow Yodying [3] and Thapanee Sarakonsri [1,2,3,*]

[1] Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand; ruttapol_b@cmu.ac.th (R.B.); thanapat.chem@gmail.com (T.A.); aorrapim_nami@hotmail.com (O.N.); chawin_yo@cmu.ac.th (C.Y.); waewwow_yodying@cmu.ac.th (W.Y.)
[2] Material Science Research Center, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand
[3] Center of Excellence for Innovation in Chemistry (PERCH-CIC), Chiang Mai University, Chiang Mai 50200, Thailand
* Correspondence: tsarakonsri@gmail.com

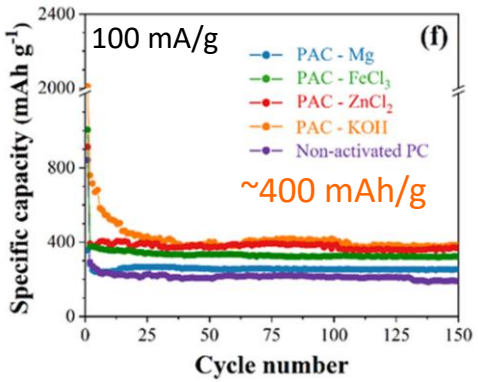
**Abstract:** Popped rice carbons (PC) were derived from popped rice by using a facile and low-cost technique. PC was then activated by different kinds of activating agents, such as potassium hydroxide (KOH), zinc chloride ($ZnCl_2$), iron (III) chloride ($FeCl_3$), and magnesium (Mg), in order to in-

- Low-cost method with various activating agents
- PAC-KOH has the largest surface area (1696 $m^2/g$) and best electrochemical performance.

SEM images of (a, b) non-activated PC and PAC samples with different activating agents of (c) KOH, (d) $ZnCl_2$, (e) $FeCl_3$, and (f) Mg



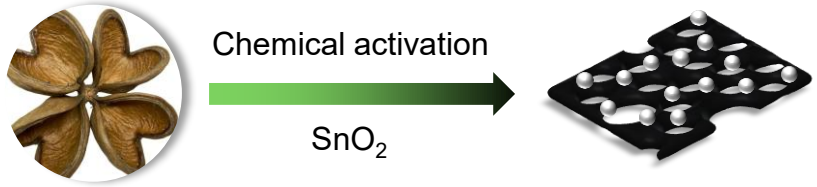

Possible lithiation-delithiation mechanism of PAC.



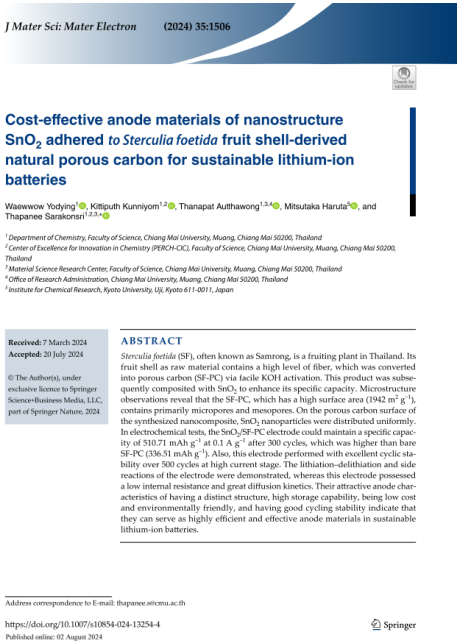

Cycle performance tests of PAC from different activating agents.

# Porous Carbon-based materials from Sterculia foetida (SF) as anode for Lithium-ion batteries

- Porous carbon has a high surface area and good stability
- $SnO_2$ has a high theoretical capacity (1494 mAh/g)




***Sterculia foetida*** **SFPC/$SnO_2$**



J Mater Sci: Mater Electron (2024) 35:1506

**Cost-effective anode materials of nanostructure $SnO_2$ adhered *to Sterculia foetida* fruit shell-derived natural porous carbon for sustainable lithium-ion batteries**

Waewwow Yodying[1], Kittiputh Kunniyom[1,2], Thanapat Autthawong[1,3,4], Mitsutaka Haruta[5], and Thapanee Sarakonsri[1,2,3,4]

[1] Department of Chemistry, Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand
[2] Center of Excellence for Innovation in Chemistry (PERCH-CIC), Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand
[3] Material Science Research Center, Faculty of Science, Chiang Mai University, Muang, Chiang Mai 50200, Thailand
[4] Office of Research Administration, Chiang Mai University, Muang, Chiang Mai 50200, Thailand
[5] Institute for Chemical Research, Kyoto University, Uji, Kyoto 611-0011, Japan

**Received:** 7 March 2024
**Accepted:** 20 July 2024

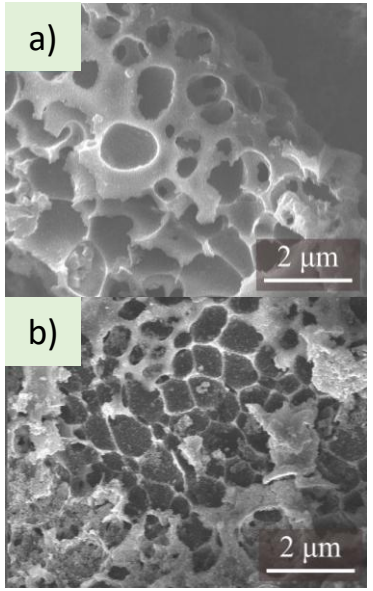
© The Author(s), under exclusive licence to Springer Science+Business Media, LLC, part of Springer Nature, 2024

ABSTRACT

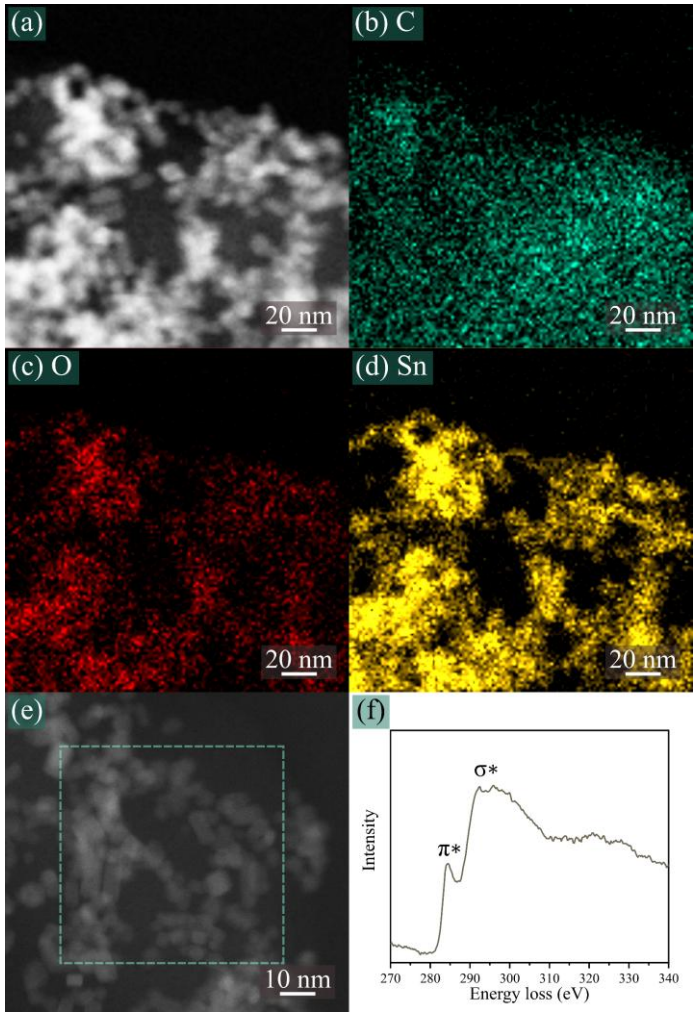
*Sterculia foetida* (SF), often known as Samrong, is a fruiting plant in Thailand. Its fruit shell as raw material contains a high level of fiber, which was converted into porous carbon (SF-PC) via facile KOH activation. This product was subsequently composited with $SnO_2$ to enhance its specific capacity. Microstructure observations reveal that the SF-PC, which has a high surface area (1942 $m^2 g^{-1}$), contains primarily micropores and mesopores. On the porous carbon surface of the synthesized nanocomposite, $SnO_2$ nanoparticles were distributed uniformly. In electrochemical tests, the $SnO_2$/SF-PC electrode could maintain a specific capacity of 510.71 mAh $g^{-1}$ at 0.1 A $g^{-1}$ after 300 cycles, which was higher than bare SF-PC (336.51 mAh $g^{-1}$). Also, this electrode performed with excellent cyclic stability over 500 cycles at high current stage. The lithiation–delithiation and side reactions of the electrode were demonstrated, whereas this electrode possessed a low internal resistance and great diffusion kinetics. Their attractive anode characteristics of having a distinct structure, high storage capability, being low cost and environmentally friendly, and having good cycling stability indicate that they can serve as highly efficient and effective anode materials in sustainable lithium-ion batteries.

Address correspondence to E-mail: thapanee.s@cmu.ac.th

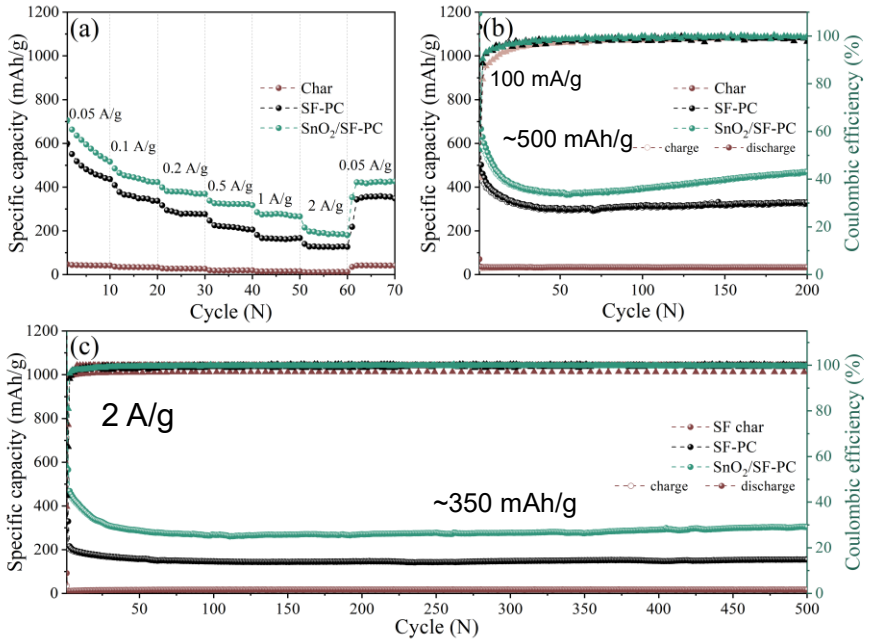
https://doi.org/10.1007/s10854-024-13254-4
Published online: 02 August 2024
Springer




SEM images of (a) SFPC and (b) SFPC/$SnO_2$ in BSE




(a-d) EDS mapping and (e-f) EELS spectra of SFPC/$SnO_2$




(a) Rate performance test and (b-c) cycle stability test

- $SnO_2$ nanoparticles were uniformly distributed on the surface of SFPC.
- SFPC/$SnO_2$ achieved 510.71 mAh/g at 0.1 A/g after 300 cycles, higher than bare SFPC (336.51 mAh/g).
- The electrode exhibited excellent cycling stability over 500 cycles at high current.

# POROUS CARBON MATERIALS from BIOMASS

*PC-WH = Porous carbon derived from water hyacinth stem*
*PC-BL = Porous carbon derived form lotus stem*
*PC-NG = Porous carbon derived from nippier grass root*

Lotus stem

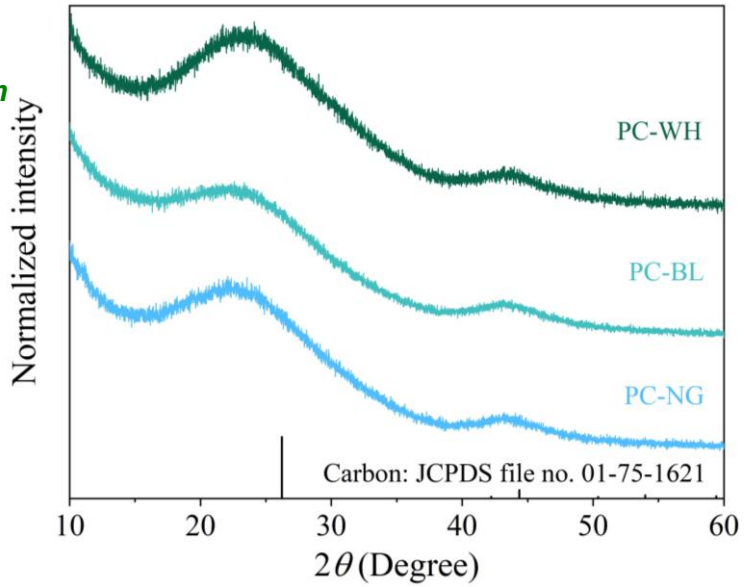


Water hyacinth stem

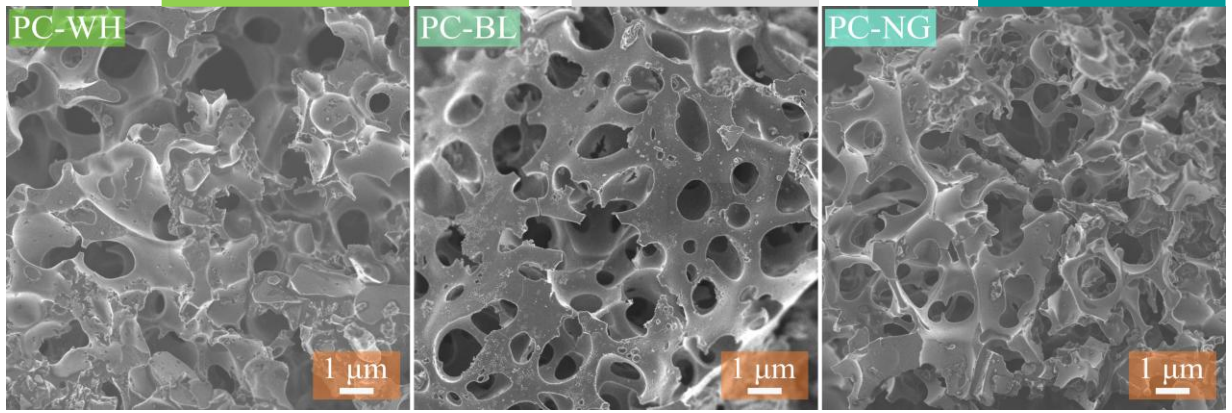




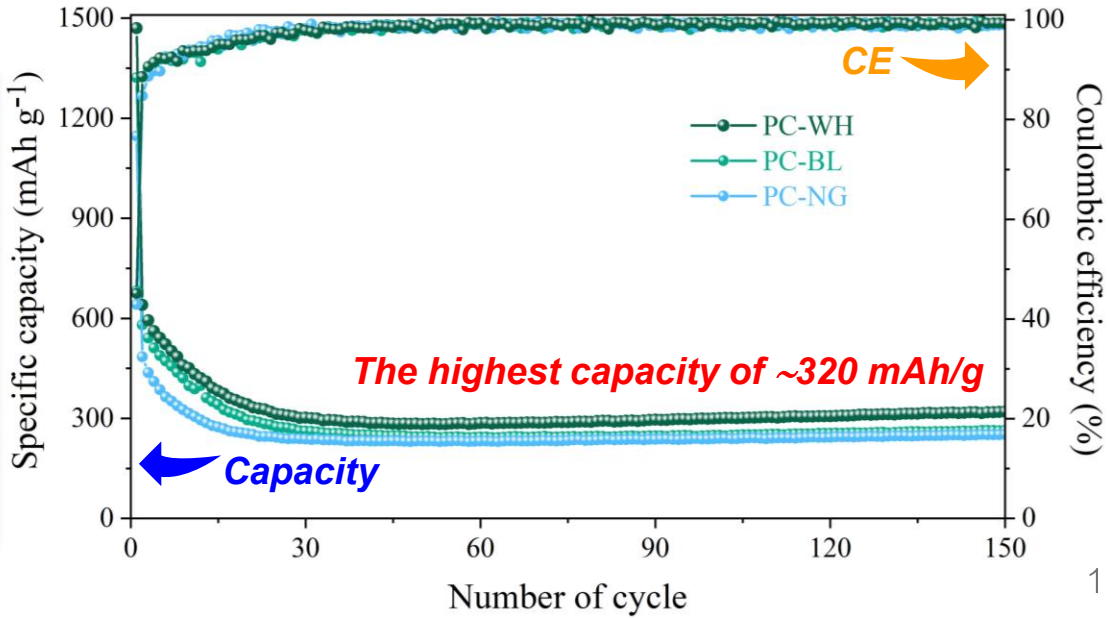
Napier grass root



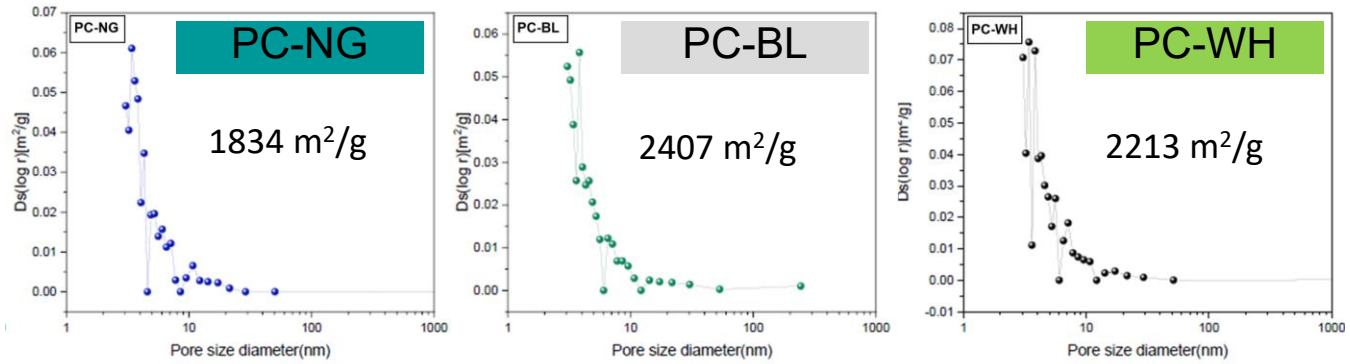

2213 $m^2/g$ | 2408 $m^2/g$ | 1834 $m^2/g$




***Cycle stability of porous carbons derived from biomass at 100 mA/g.***




## PORE SIZE DISTRIBUTIONS:




***"Pore sizes are predominantly within the mesoporous range."***

# Fast-growing flowering aquatic plant, *Wolffia*-derived porous biochar as a sustainable anode material for lithium-ion batteries

RENEWABLE ENERGY LABORATORY

CMU CHIANG MAI UNIVERSITY | FACULTY OF SCIENCE CHIANG MAI UNIVERSITY | BE FUN FUNCTIONAL FUNDAMENTAL TO THE FRONTIER

Biomass and Bioenergy 212 (2026) 109325

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: www.elsevier.com/locate/biombioe

Fast-growing flowering aquatic plant, *Wolffia*-derived porous biochar as a sustainable anode material for lithium-ion batteries

Thammanoon Kapanya [a], Chanchana Thanachayanont [b], Thapanee Sarakonsri [a,c,d,*]

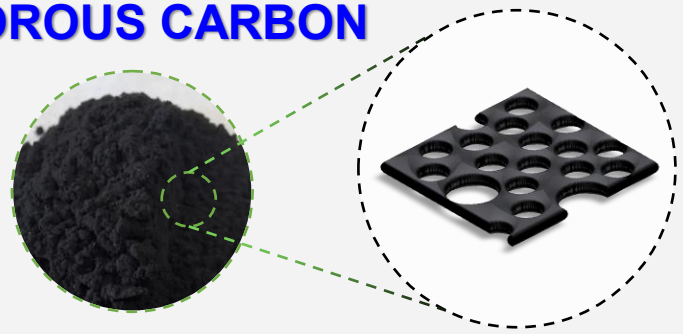
*Wolffia*






*"Chemical activation"*

**POROUS CARBON**



High surface area for reactions

Better battery performance

Stable support

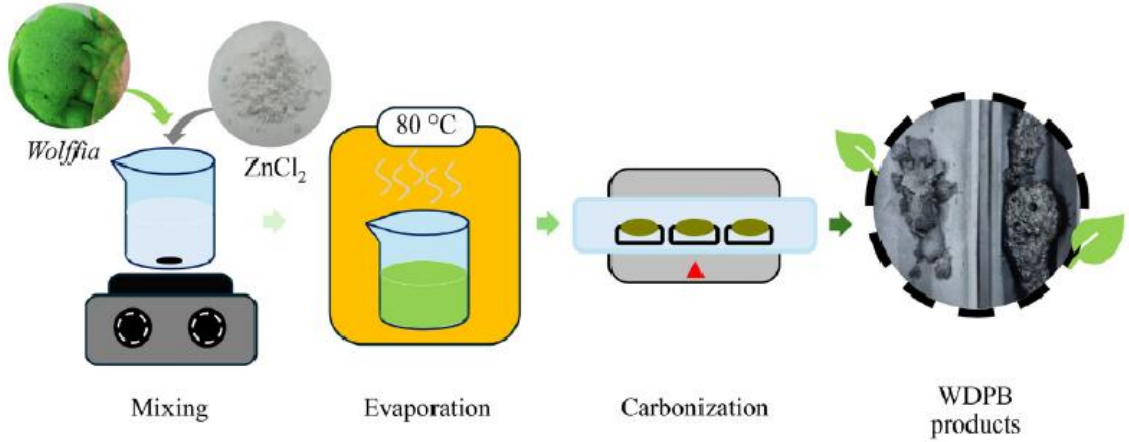
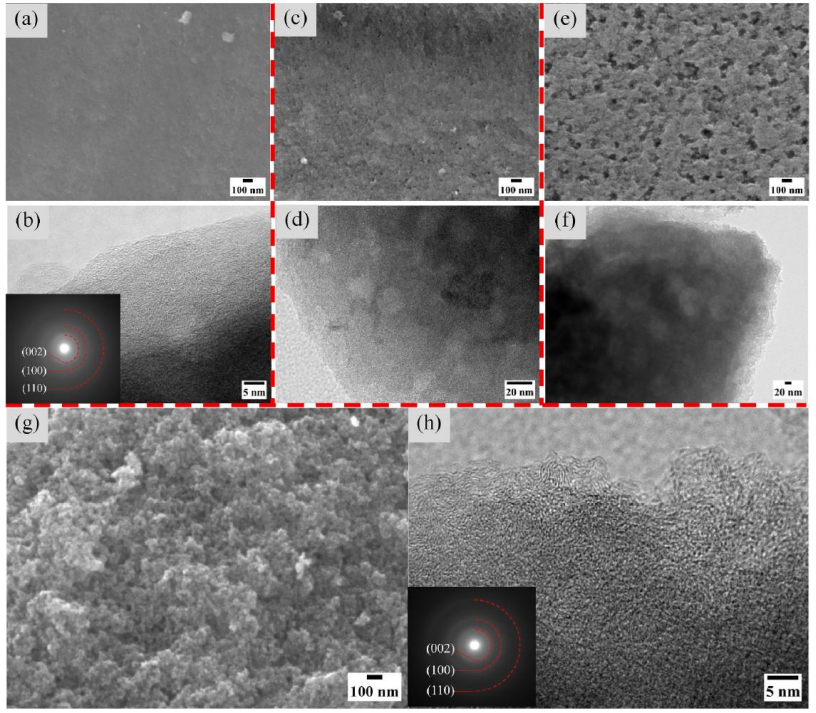
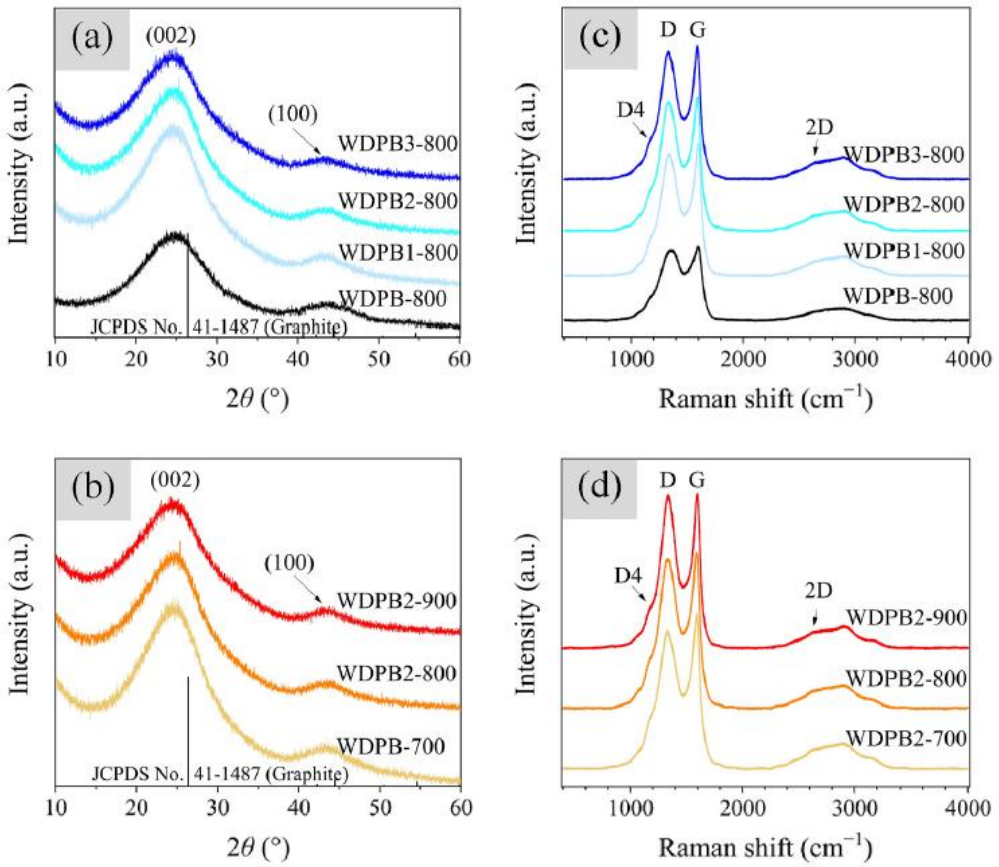


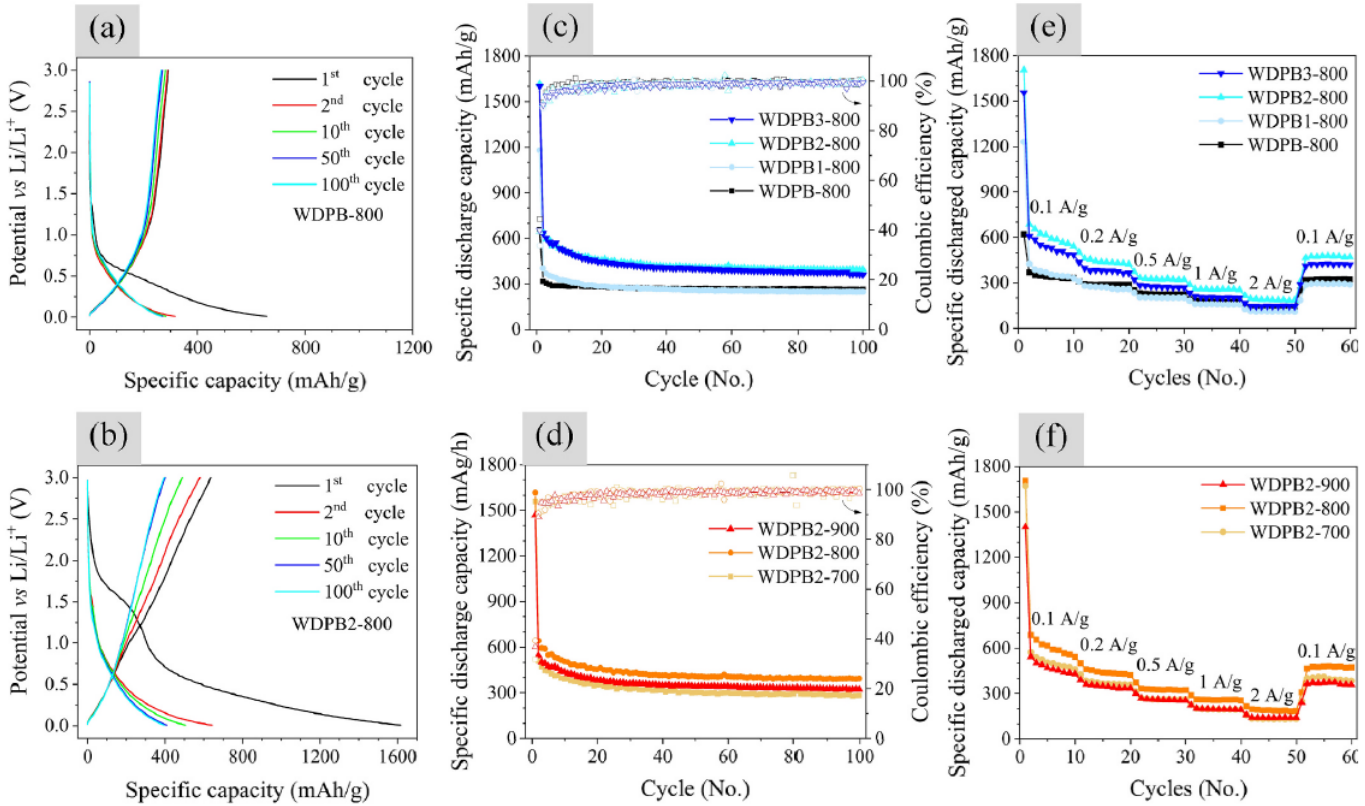

**Fig. 1.** Schematic diagram of WDPB product preparation.




FESEM and TEM images of (a,b) WDPB-800, (c,d) WDPB1-800, (e,f) WDPB2-800, and (g,h) WDPB3-800.

# Fast-growing flowering aquatic plant, *Wolffia*-derived porous biochar as a sustainable anode material for lithium-ion batteries

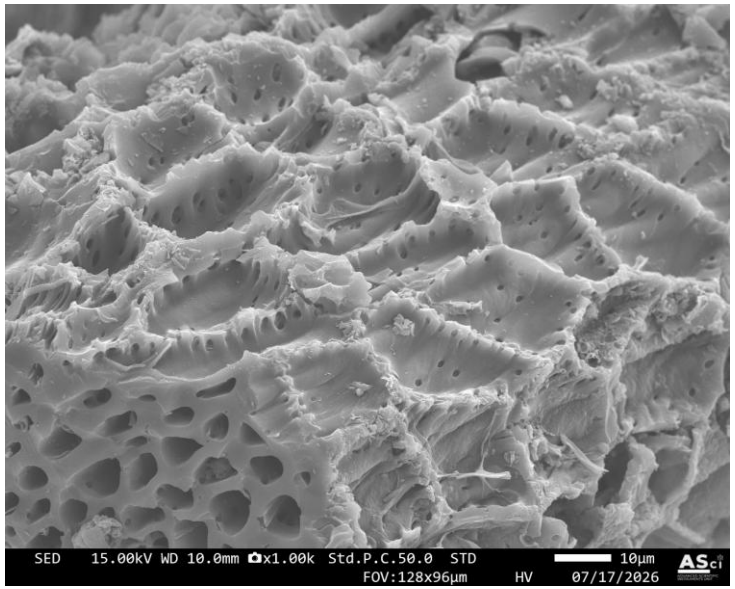


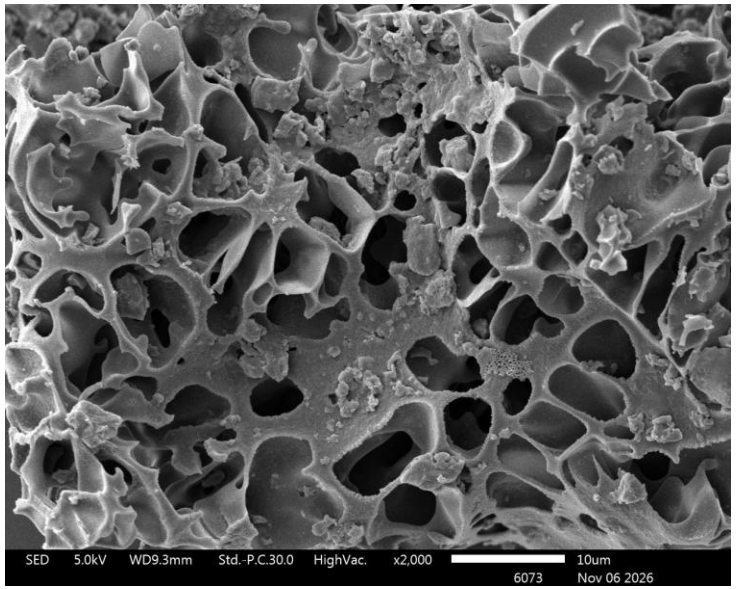



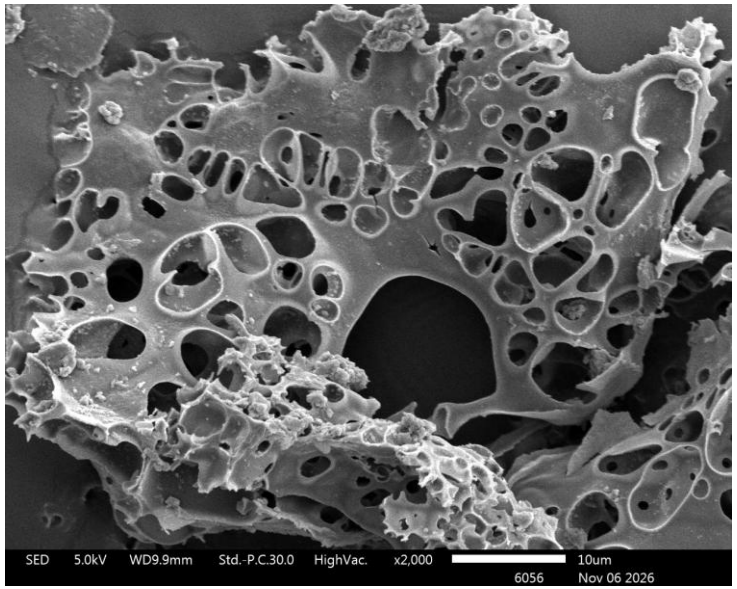

- XRD; All samples exhibit two consistent broad peaks at 2$\theta$ angles of approximately 25 and 44degree suggesting that the WDPBs may be carbon materials with a low degree of graphitization and an irregularly arranged carbon layer.
- Raman; WDPBs are composed of carbon materials possessing both disordered and ordered graphitic structures, along with defects.

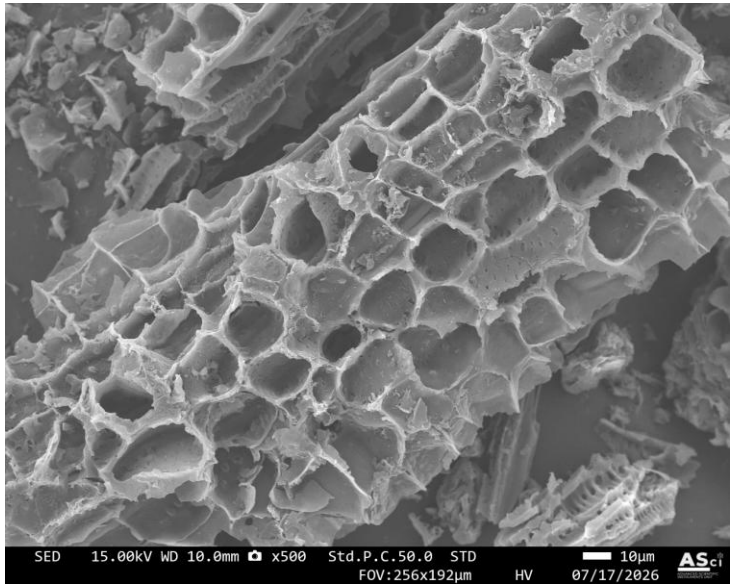
Charge-discharge profiles of (a) WDPB-800 and (b) WDPB2-800. (c,d) Cycle and (e,f) rate performance of WDPBs with different ZnCl2: *Wolffia* ratios and activation temperatures.

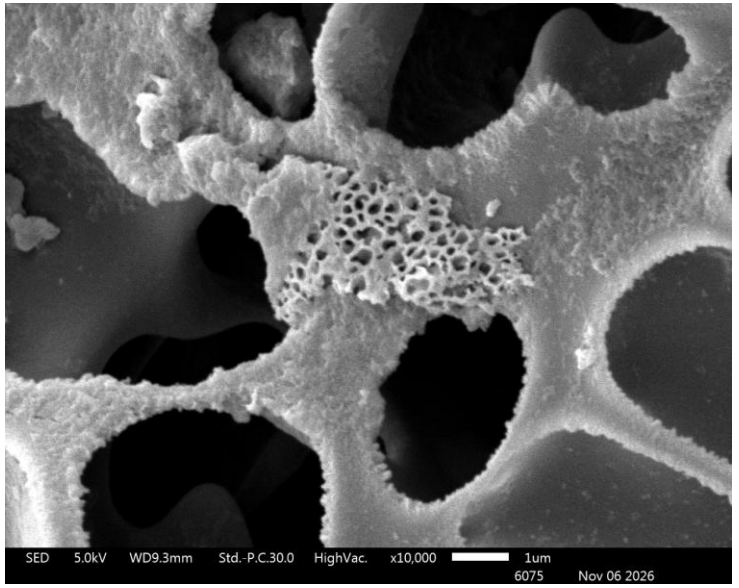
# ON GOING RESEARCH

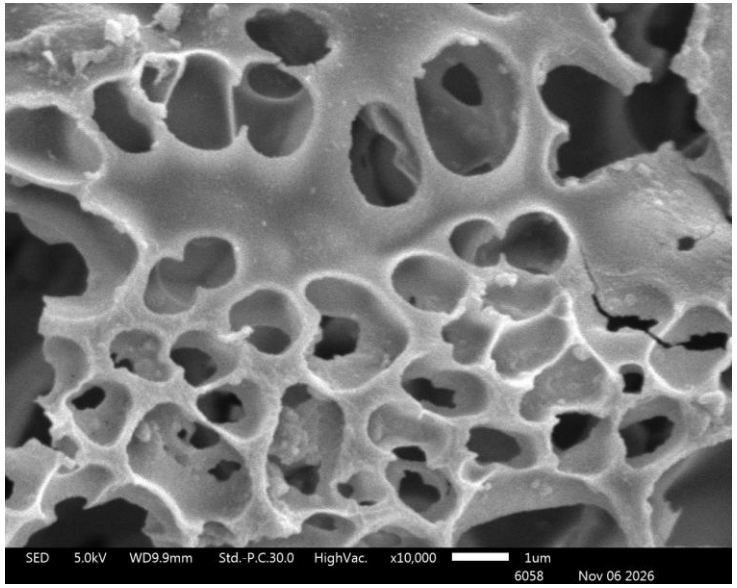


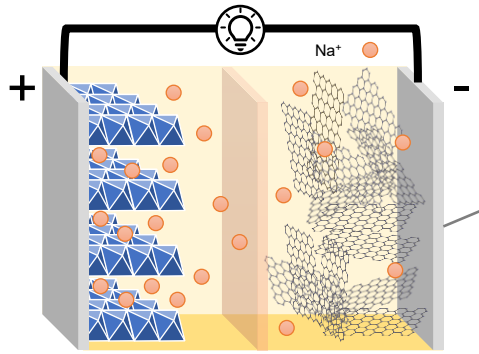



# ANODE MATERIALS FOR SODIUM-ION BATTERIES




Hard carbon (commercial)
+ Stable
+ Various precursor
- Low specific capacity

***New anode materials***

- ✓ Increase capacity
- ✓ Enhance stability
- ✓ Improve safety
- ✓ Decrease production cost

**Discharge reactions**

Anode: $Na_xC_6 \rightleftharpoons xNa^+ + xe^- + 6C$

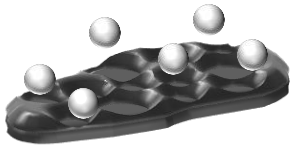
Cathode: $xNa^+ + xe^- + Na_{1-x}MO_2 \rightleftharpoons NaMO_2$

Overall: $Na_xC_6 + Na_{1-x}MO_2 \rightleftharpoons 6C + NaMO_2$



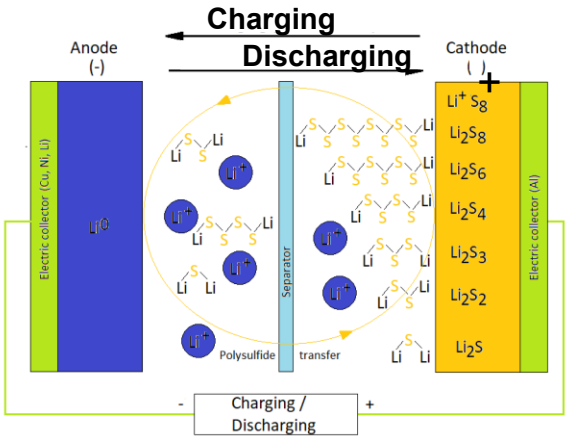
**Biomass waste**
+ Renewable
+ Abundant
+ Heteroatom (N, P, S, etc.)

*Carbonization*



**Carbon materials**
+ Renewable
+ Low cost
+ Decent performance

# CATHODE MATERIALS FOR LITHIUM-SULFUR BATTERIES




Anode : Lithium metal
Cathode : Sulfur element
Electrolyte: 1 M LiTFSI and 0.2 M $LiNO_3$ in DOL/DME

**Discharge reactions**

Cathode: $S_8 + 16Li^+ + 16e^- \rightarrow 8Li_2S$

Anode: $16Li \rightarrow 16Li^+ + 16e^-$

Overall: $S_8 + 16Li \rightarrow 8Li_2S$

**Advantages**
- Environmental friendliness
- Low-cost
- High-energy density (2,600 wh/kg)
- High theoretical specific capacity of 1673 mAh/g

**Pain point**
- Low conductivity of sulfur
- Volume expansion of sulfur
- Polysulfide shuttle effect

**Sulfur host cathode design**
- Conductive matrix
- Absorbed or trapped polysulfide

*Improvement*

**Porous materials**
- High surface area
- Synthesis from biomass
- Composite with polymers

# POTENTIAL FOR SCALE-UP FROM "LABORATORY" TO "PILOT PLANT"

*The potential of carbon and silicon-based materials for increasing production capacity*



**Biomass**

*Chemical synthesis from lab scale*

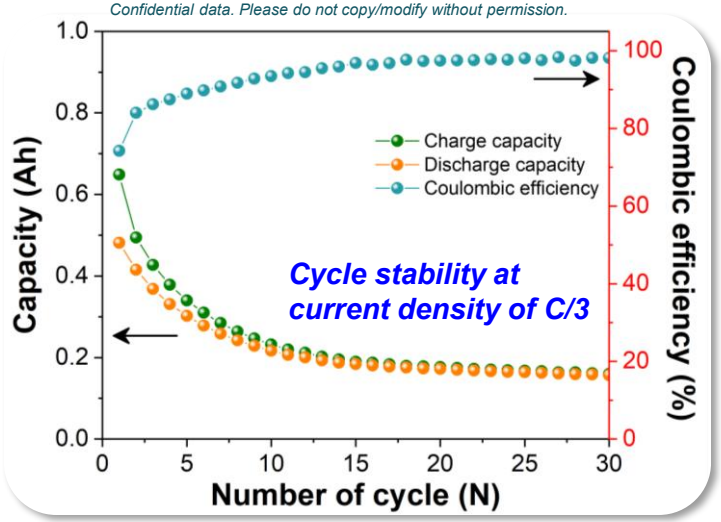



***Carbon- and silicon-based materials derived from biomass***

**Previous work**

**Funded by STEP, CMU**

STEP CMU SCIENCE AND TECHNOLOGY PARK CHIANG MAI UNIVERSITY




***Anode:***
*$Sn(SnO_2)$-$SiO_2$/rGO*

***Cathode:***
*Lithium Nickel Manganese Cobalt Oxide (NMC 811)*

***Capacity:***
*0.16 Ah at 30$^{th}$ cycle*






*78650 cell fabrication*




***Supported by:***

PMUC Program Management Unit for Competitiveness

Energy Policy and Planning Office MINISTRY OF ENERGY

MR CENTER Faculty of Science Chiang Mai University

KNP KNP Marketing Co., Ltd.

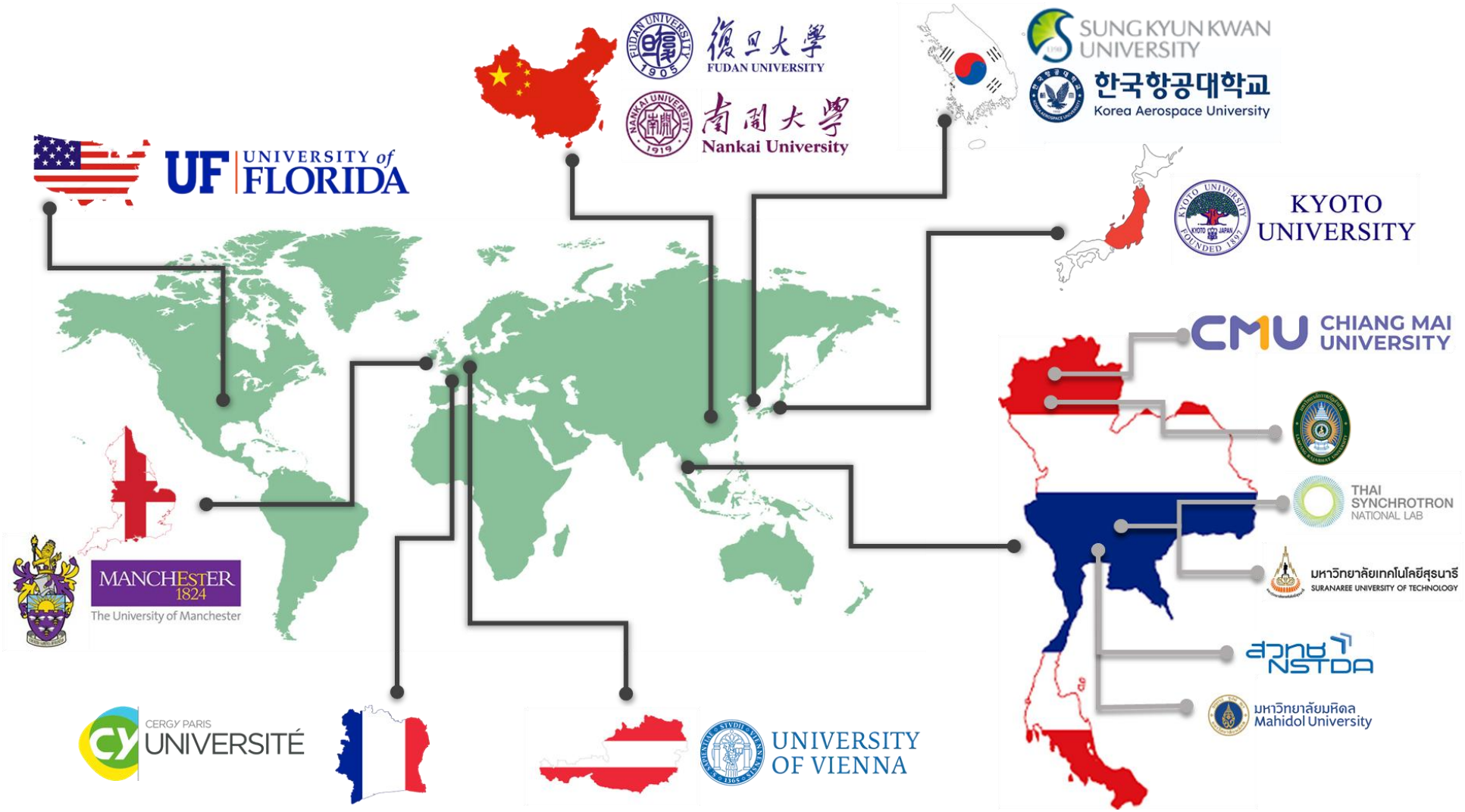
NEC TECHNOLOGY

**MsRC PILOT PLANT**

# OUR COLLABORATIONS



## Research collaborations




## Industry collaborations

**KNP Marketing Co., Ltd**
Scientific Instrument &Manufacturers.,
Thailand

**Puditec Co., Ltd**
Scientific Instrument &Manufacturers
Thailand

**N.E.C Technology Part., Ltd**
Engineering Manufacturers,
Thailand

**Strom (Thailand) Co., Ltd**
Electric bike,
Thailand

**Oska Holding Co., Ltd**
Batteries Storage Wholesale &
Manufacturers
Thailand




the 44th international conference
of the microscopy society of Thailand

# MST44

## IMAGING SCIENCE FOR GLOBAL IMPACT

## SCIENTIFIC TRACKS & SYMPOSIA

### BIOLOGICAL SCIENCE

**VIRAL STRUCTURES & NANOCARRIERS**
Viral structures & nanocarriers to rantrivus and nanoparticies

**CANCER MICROENVIRONMENT & CELL BIOLOGY**
Cancer, tumor microoenvironment & cells biology

**REGENERATIVE BIOLOGY & CLINICAL ANATOMY**
Regenerative biology cell, regenerative and clinical anatomy

**ADVANCED IMAGING IN PLANT & ANIMAL BIOLOGY**
Advanced imaging in annorra in plant & animal biology

### PHYSICAL SCIENCE & INDUSTRY

**INNOVATIVE MATERIALS & NANOTECHNOLOGY**
Nanotoch materials innovative materials and nanotechnology

**MICROSCOPY FOR INDUSTRIAL QA/QC**
Microscopy for industrial deterarins and industrial QA/QC

**NEXT-GEN INSTRUMENTATION & AI IN IMAGING**
Next-gen instrumentation & AI imaging, next-gen instrumentation

**CHARACTERIZATION OF ENERGY & GREEN TECH MATERIALS**
Characterization of energy energy & green tech materials

HOSTED BY: DEPARTMENT OF ANATOMY, FACULTY OF SCIENCE, MAHIDOL UNIVERSITY




**PACCON 2028 will be in Chiang Mai**




# *THANK YOU FOR YOUR KIND ATTENTION*

*Acknowledgements*

FACULTY OF SCIENCE
CHIANG MAI UNIVERSITY

MR CENTER

CHEMISTRY
CHIANG MAI UNIVERSITY

RENEWABLE
ENERGY
LABORATORY

สกสว

Energy Policy
and Planning Office
MINISTRY OF ENERGY

PMUC
Program Management Unit for Competitiveness

STEP
CMU
SCIENCE AND TECHNOLOGY PARK
CHIANG MAI UNIVERSITY

สร้างคน
ข้ามพรมแดน