Biomass-derived Porous Carbon Anode Materials for Lithium-ion Batteries

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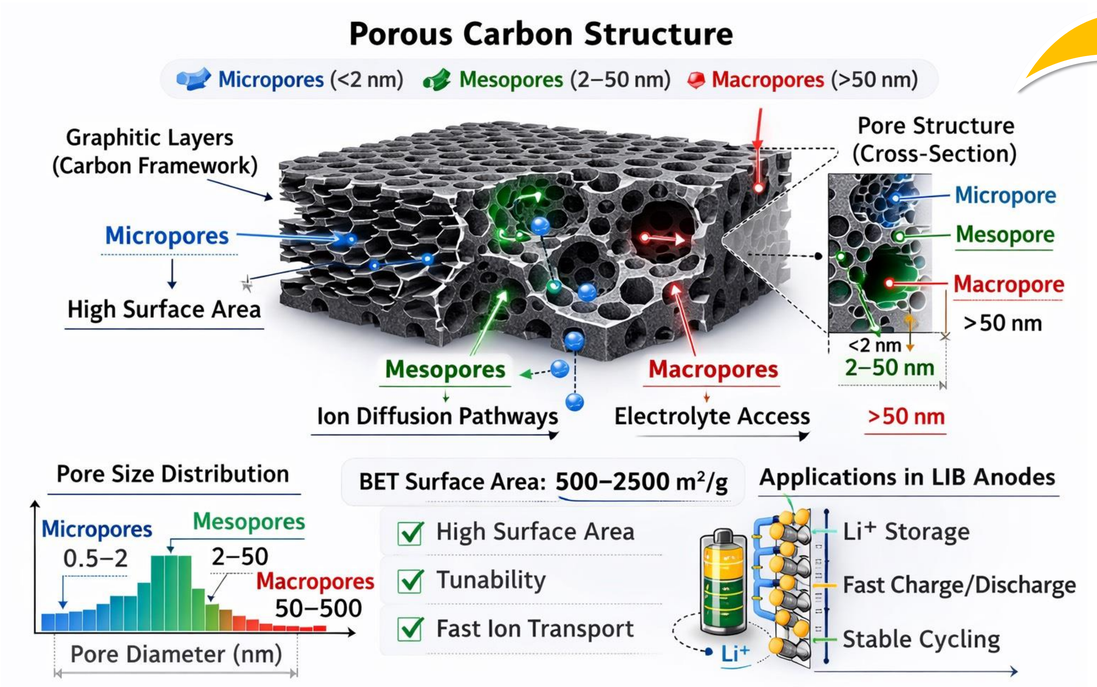
ABSTRACT

Lithium-ion batteries (LIBs) are widely used in portable electronics, electric vehicles, and grid storage due to their high energy density and long cycle life. However, commercial graphite anodes have a limited theoretical capacity of 372 mAh g^{-1}, restricting further improvements in battery performance. To address this issue, renewable biomass-derived carbon materials have gained attention because of their low cost, abundance, and tunable properties. In this study, porous carbon materials were synthesized from biomass wastes including elephant ear stem, lotus leaves, lotus stems, water lettuce leaf, and water poppy stems using carbonization, microwave treatment, and KOH activation. XRD confirmed amorphous carbon structures, while scanning electron microscopy (SEM) shows porous morphologies. Electrochemical testing reveals that lotus stem-derived carbon delivered the best performance, achieving a specific capacity of 302 mAh g^{-1} after 200 cycles with good rate capability. Cyclic voltammetry confirmed reversible lithium-ion intercalation behavior. These results demonstrate that biomass-derived porous carbon is a promising sustainable and cost-effective anode material for LIBs while also supporting biomass waste utilization.



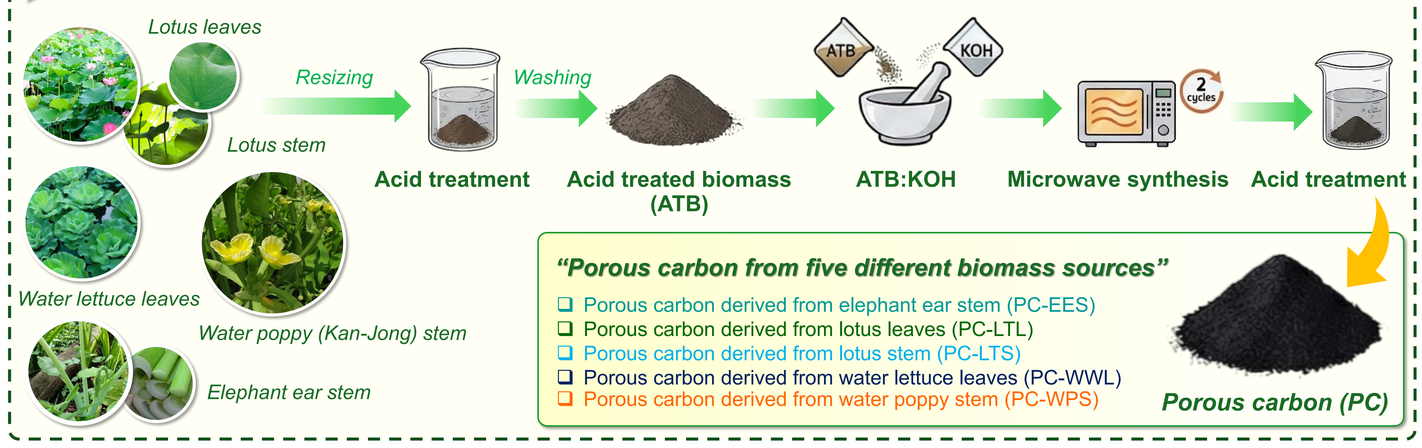
Ref: *https://www.iberdrola.com/about-us/our-innovation-model/lithium-ion-batteries*

HIGHLIGHT OF WORK

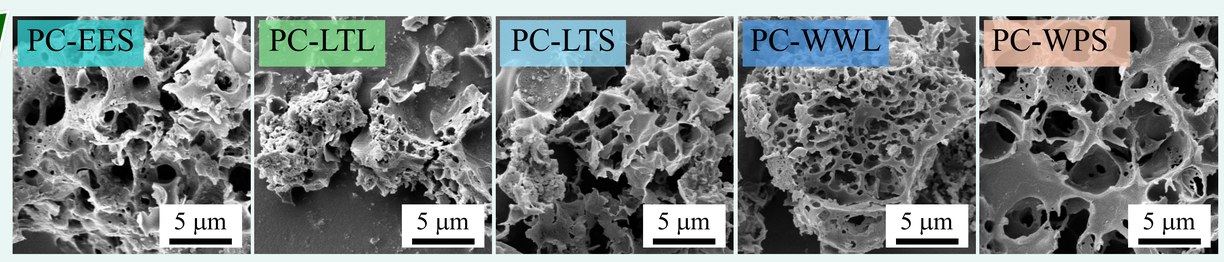


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EXPERIMENTAL PROCEDURE



MICROSTRUCTURE



SEM images of porous carbon surfaces derived from different biomass sources.

- SEM images show that all biomass-derived samples possess well-developed porous carbon structures with rough and irregular surfaces.
- The pores are mainly formed during the KOH activation and carbonization processes. The resulting pore structure is predominantly macroporous.
- This macroporous structure acts as an electrolyte reservoir and facilitates lithium diffusion, which is beneficial for improving the electrochemical performance of LIB anodes.

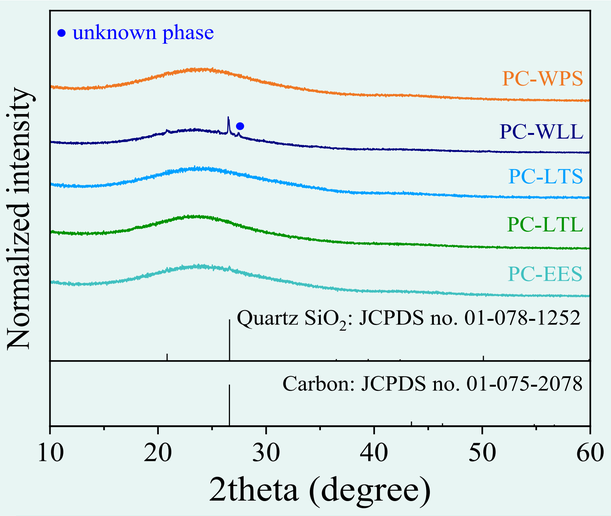
Pore size of porous carbon derived from different biomass sources.

Materials	Average of pore size (nm)	
	Large pore	*Small pore*
PC-EES	1758.52±537.02	299.72±77.87
PC-LTL	627.58±141.42	264.23±33.22
PC-LTS	1275.90±650.63	222.58±54.82
PC-WWL	1695.48±591.98	188.47±61.86
PC-WPS	2748.23±745.44	600.47±217.42



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PHASE CHARACTERIZATION

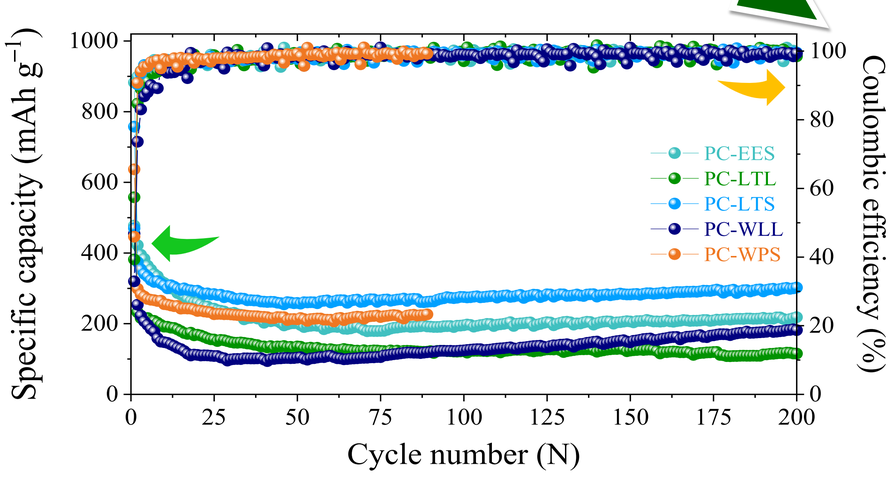


XRD patterns of biomass-derived porous carbons.

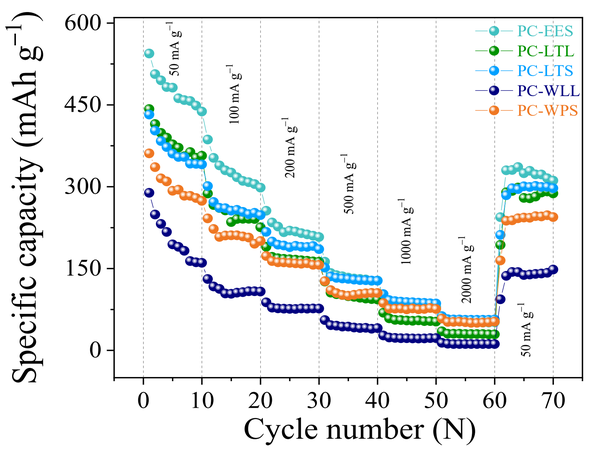
- XRD patterns of all biomass-derived porous carbons show broad peaks at approximately $2\theta \approx 26°$ and 43°, corresponding to the (002) and (100) planes of carbon, indicating a carbon structure with low crystallinity.
- However, PC-WLL exhibits additional sharp peaks at around 21° and 26°, attributed to quartz silica (SiO_2), suggesting the presence of SiO_2 impurities from the natural inorganic components of the biomass precursor.
- During the activation process, SiO_2 remains stable and may partially crystallize, resulting in detectable diffraction peaks.

ELECTROCHEMICAL PERFORMANCES

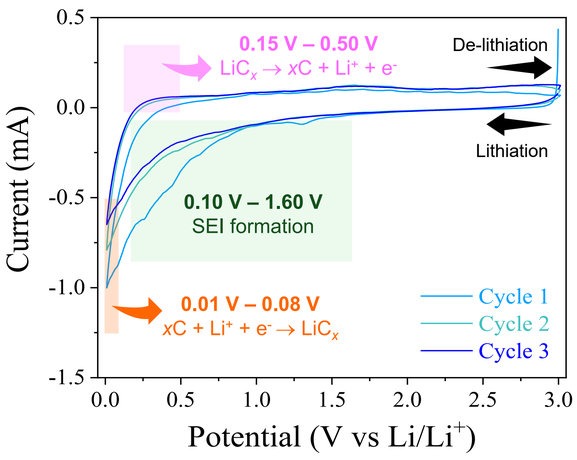
- The electrochemical performance of the prepared porous carbons is evaluated to assess their suitability as potential anode materials for LIBs, providing insight into their capacity, stability, and the lithiation-delithiation behavior.
- All porous carbons have good cycle stability and rate performance.
- ***"PC-LTS"*** delivers the highest capacity of 302 mAh g^{-1} after 200 cycles.
- The CV curves of ***"PC-LTS"*** show good reversable reaction between Li^+ and carbon anodes.
- Because of the porous structure, the electrochemical performance is improved.



Cycle stability measured at a current density of 100 mA g^{-1} for 200 cycles.



Rate performance at different current densities.



CV curves of PC-LTS for the first three cycles.

CONCLUSION

Biomass-derived porous carbon materials are successfully synthesized via microwave-assisted KOH activation for use as anodes in LIBs. The materials exhibit low crystallinity of carbon with well-developed porosity, predominantly macropores. This structure could act as electrolyte reservoir and facilitate efficient lithium storage. Electrochemical results demonstrate good cycling stability and rate capability, with PC-LTS delivering the highest capacity of 302 mAh g^{-1} after 200 cycles. These findings suggest that biomass-derived porous carbon materials could be utilized as sustainable and promising anodes for LIBs.

ACKNOWLEDGEMENT

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REFERENCES

Feng *et al.*, Biomass-derived porous carbon as anode materials for lithium-ion batteries, *International Journal of Electrochemical Science*, 2024, 19, 100694.

Issatayev *et al.*, Biomass-derived porous carbon from agar as an anode material for lithium-ion batteries, *Nanomaterials*, 2022, 12, 22.

Guan *et al.*, Characterization and preparation of nano-porous carbon derived from hemp stems as anode for lithium-ion batteries, *Nanoscale Research Letters*, 2019, 14, 338.