Biowaste-derived electrode and electrolyte materials for flexible supercapacitors

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1. Introduction

- The increasing energy consumption of modern societies have led to serious environmental pollution, which resulted in an urgent need for sustainable and renewable energy storage systems (fuel cells, batteries, and supercapacitors).
- Due to the growing demand for flexible/wearable electronics, flexible supercapacitors (SCs) have attracted extensive research interest due to their superior properties including fast charge-discharge capability, high power density, and long cycling life.
- Herein, we developed porous carbon (PC) and nanocellulose-based (CNC) hydrogel from animal bones and beer residues, respectively. The PC and CNC hydrogel were employed as electrode material and electrolyte for flexible supercapacitors, respectively.

2. Synthesis protocol

Fig. 1. Schematic illustration for the synthesis of Al-CNC and PC to assemble the flexible supercapacitor (PC//Al-CNC//PC).

3. Results & Discussion

3.1 Gelation of cellulose nanocrystals

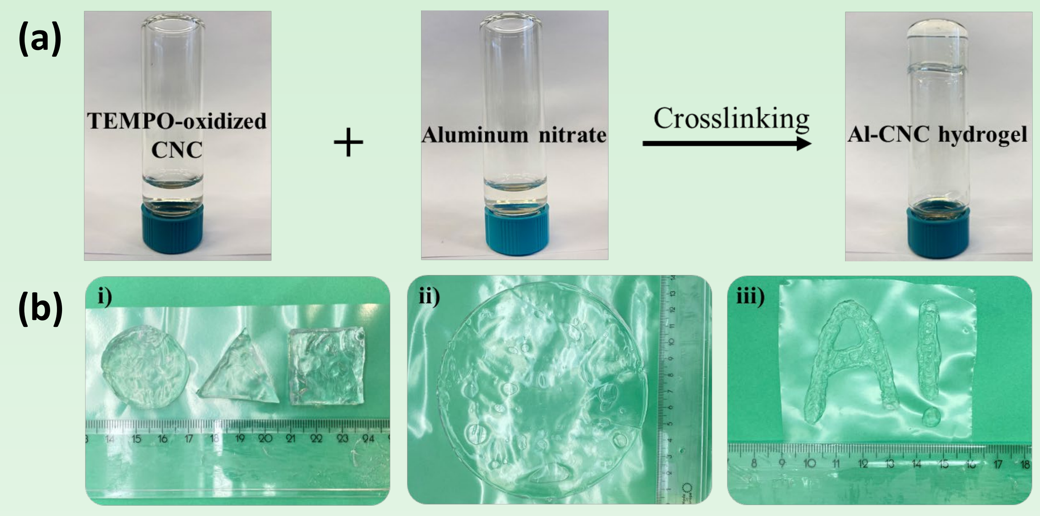


Fig. 2. (a) Gel formation of Al-CNC by physical crosslinking; (b) Al-CNC hydrogels i) different geometries, ii) larger dimensions, and iii) manual printing.

3.4. Electrochemical measurements

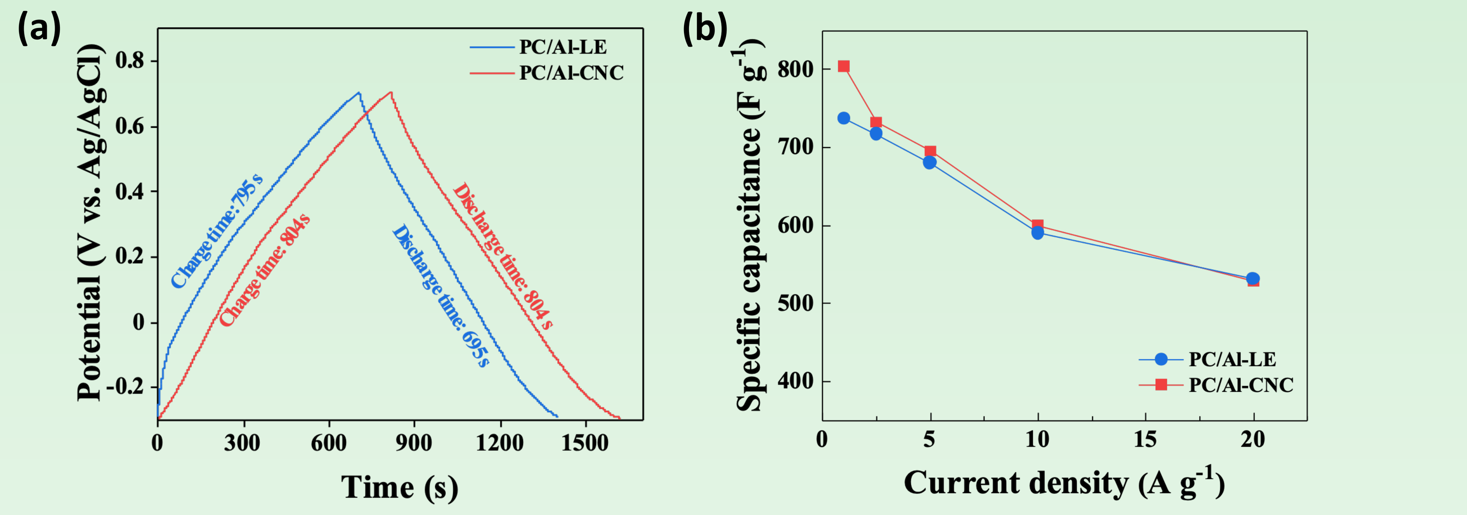


Fig. 6. Electrochemical evaluation of PC/Al-CNC compared to PC/Al-LE electrolyte by (a) GCD of PC/Al-LE and PC/Al-CNC at a current density of 1 A g^{-1}. (c) Specific capacitance vs current density.

3.2 Optical & morphological characterization

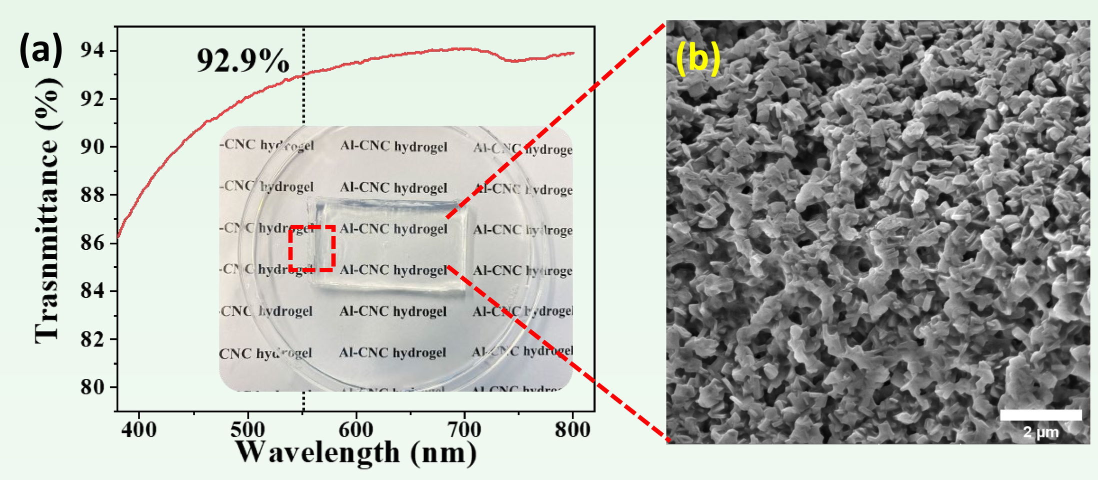
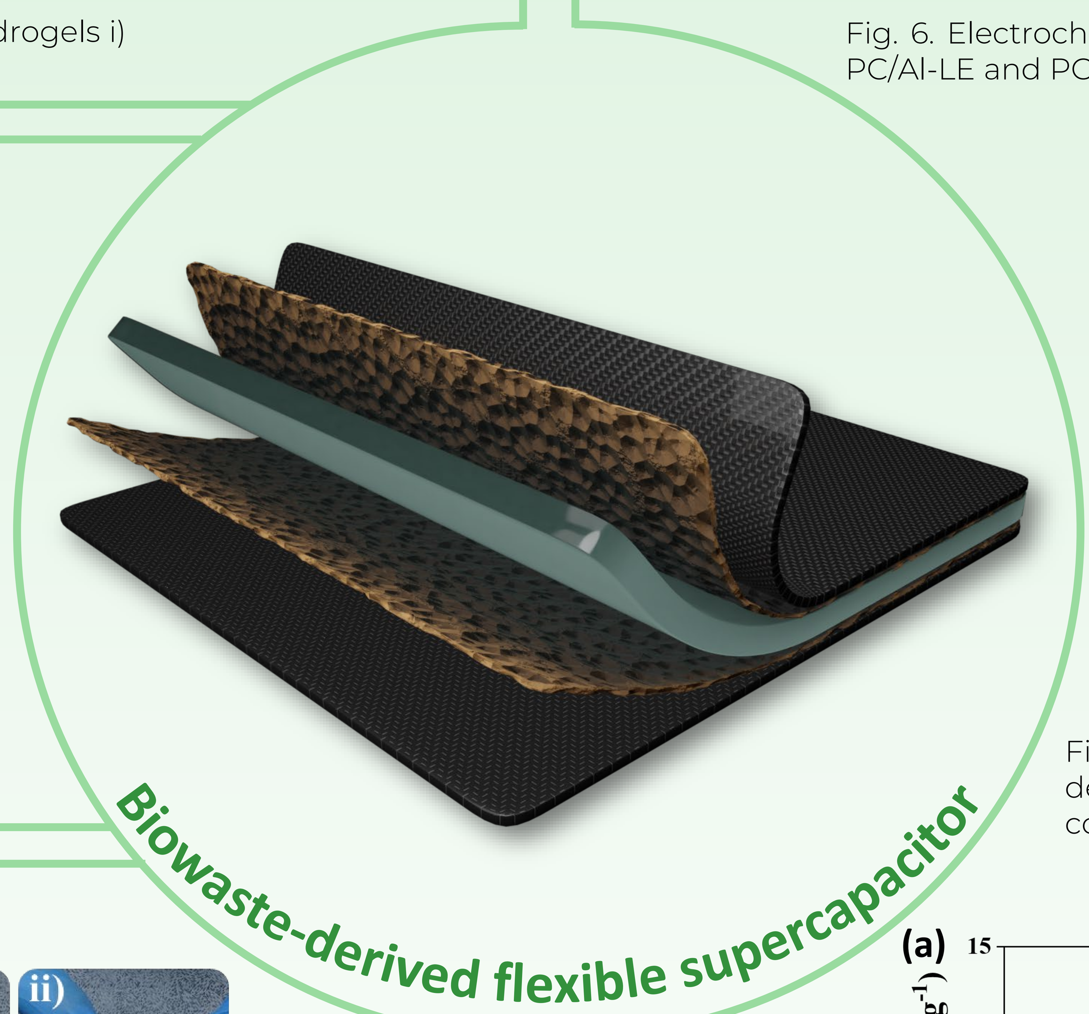


Fig. 3. (a) Total transmittance of Al-CNC (380–800 nm); (b) SEM image of freeze-dried Al-CNC.



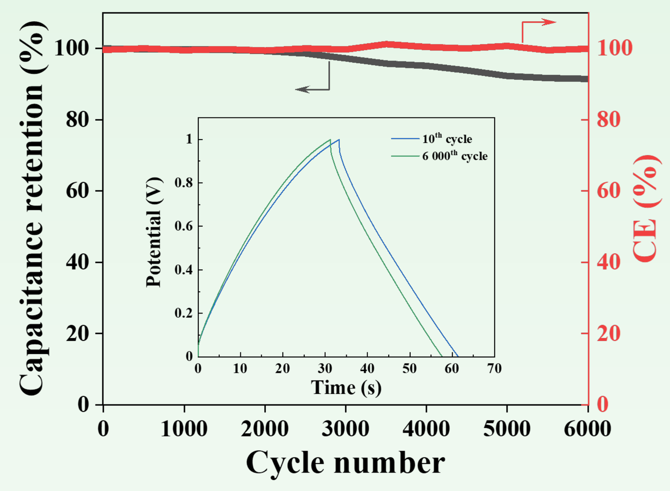


Fig. 7. Cycling performance and Coulombic efficiency of supercapacitor at a current density of 5 A g^{-1} after 6 000 consecutive charge–discharge cycles (inset shows the corresponding GCD curves of 10th and 6 000th cycles).

3.3 Mechanical properties

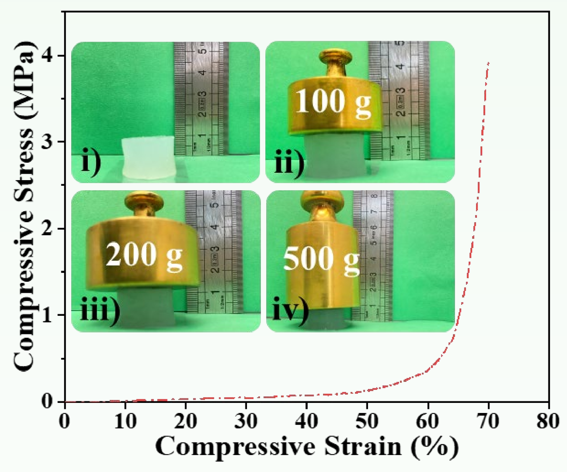


Fig. 4. Compressive stress–strain for Al-CNC hydrogel; inset photographs of Al-CNC hydrogel with different loads i) no load; ii) 100 g; iii) 200 g; and iv) 500 g.

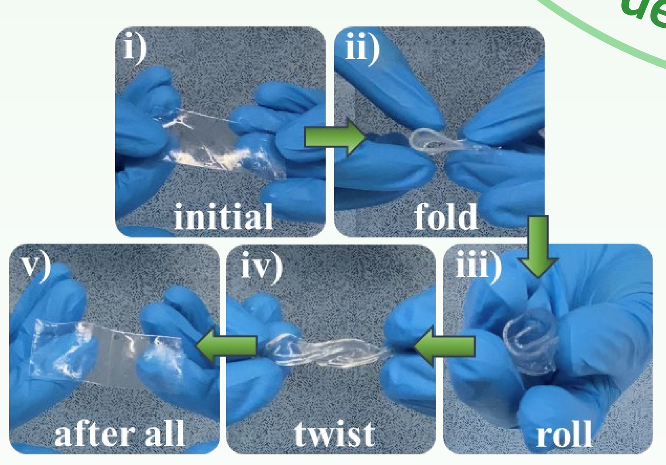


Fig. 5. Photographs of Al-CNC hydrogel under various deformations i) initial; ii) folding; iii) rolling; iv) twisting; and v) recovering.

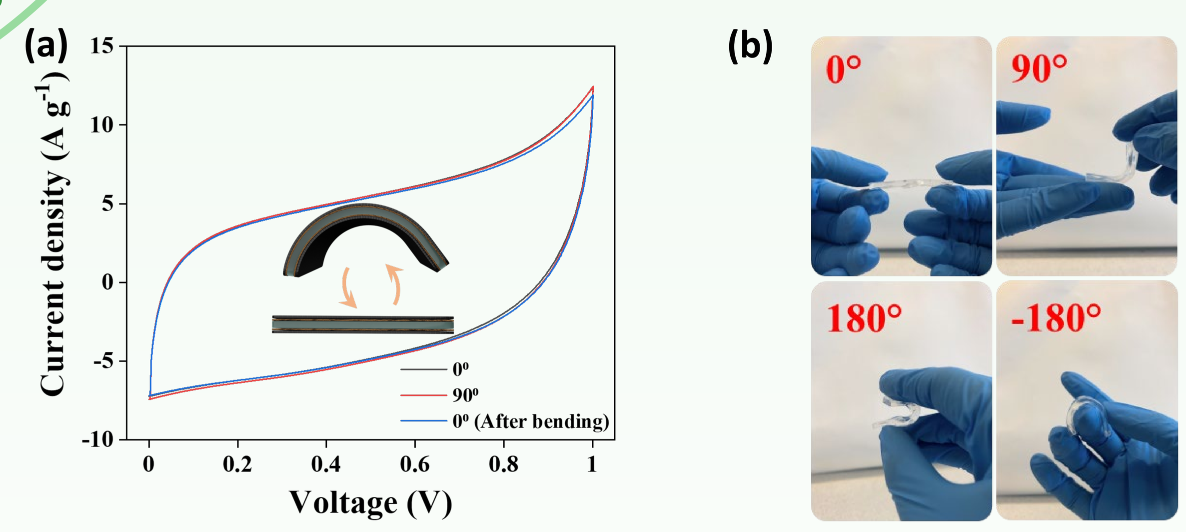


Fig. 8. The effect of bending on the electrochemical performance of the cell: (a) CV at a scan rate of 50 mV s^{-1}; (b) Photographs of Al-CNC hydrogel at various bending angles (0°, 90°, 180°, and −180°).

4. Conclusion

- All-biowaste-derived flexible supercapacitor was successfully developed from our daily lives' biowaste, animal bones and beer residues.
- Hydrogel electrolyte, synthesized from beer residues, exhibited excellent mechanical properties, transparency, and ionic conductivity.
- The developed flexible supercapacitor delivered high energy/power densities as well as showed outstanding electrochemical stability at different bending angles.

5. References

- Al Haj, Y. et al. Biowaste-derived electrode and electrolyte materials for flexible supercapacitors. Chem. Eng. J. 435, (2022).

6. Acknowledgements

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