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Enhancing the performance of waste hemp hurd-based carbons in SIBs through H_2SO_4-assisted hydrothermal pretreatment

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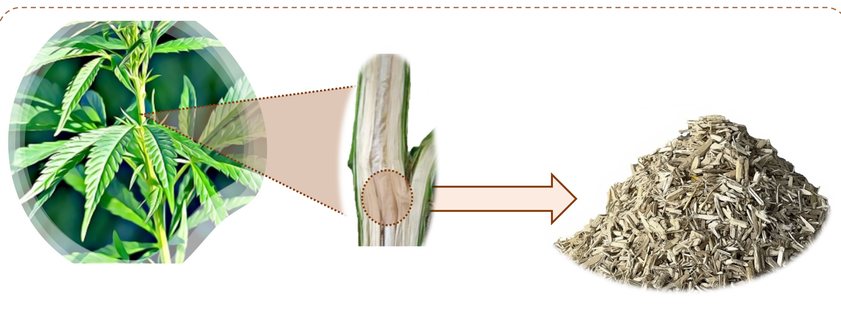
Introduction

Sodium-ion batteries (SIBs) are a promising option due to the wide availability and low cost of sodium. Hard carbons (HCs) are considered as potential anodes in SIBs due to their ability to store Na^+ ions, via intercalation into graphitic layers, adsorption on defects and functional groups on surface, as well as pore filling.

In this study, waste hemp hurd (WHH) was as a renewable and sustainable carbon precursor.

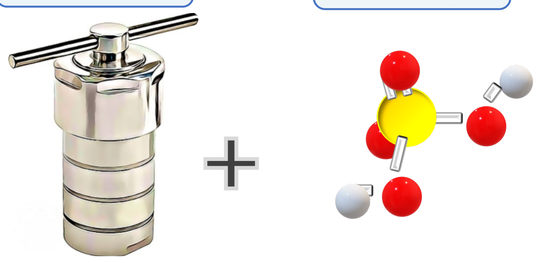
Hydrothermal carbonization (HTC) of biomass wastes can promote the enlargement of HC pores and the formation of surface nanospheres, thereby improving the reversible capacity of the electrode. Additionally, the HTC process allows the addition of other chemicals to the aqueous solution to facilitate specific decomposition or doping reactions. This study aims to investigate the effect of HTC pretreatment —in water and in H_2SO_4 aqueous solutions— on the electrochemical performance of the resulting HCs as working electrodes in SIB half-cells.

Materials and methods



HEMP PLANT — Waste Hemp Hurd

HTC + **H_2SO_4** + **CARBONIZATION**



Temperature: 180 °C (12 h)

Solution:
(1) 60 mL distilled water
(2) 60 ml H_2SO_4 1 mol dm^{-3}
(3) 60 ml H_2SO_4 2 mol dm^{-3}
(4) 60 ml H_2SO_4 4 mol dm^{-3}

HYDROCHAR

Temperature: 800 – 1000 °C
Conditions: 5 °C min^{-1} (Ar as carrier gas)

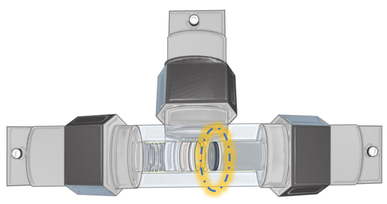
HC

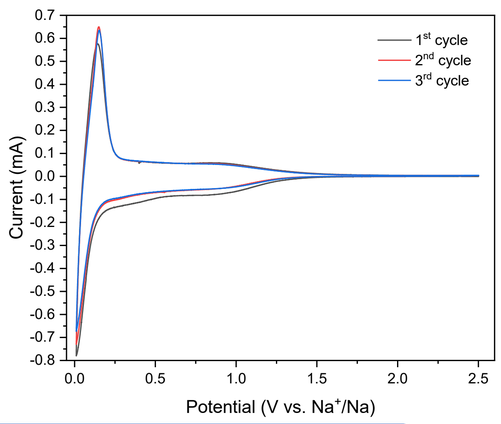
POST-TREATMENTS

HCl washing: 2 mol dm^{-3} (2 h)
Vacuum Drying: 120 °C (12 h) Ground and sieved: < 90 µm

Hard Carbon (80 %)
Conductive Carbon (10 %)
Binder (10 %) — CMC-Na (5 %), SBR (5 %)

ELECTRODE SLURRY AND MANUFACTURING

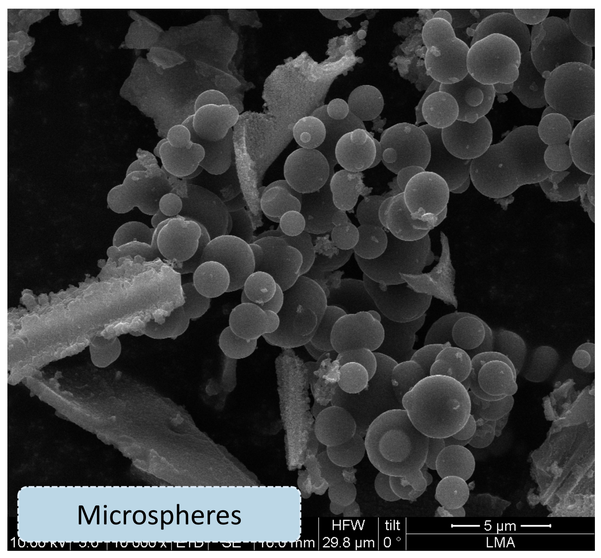


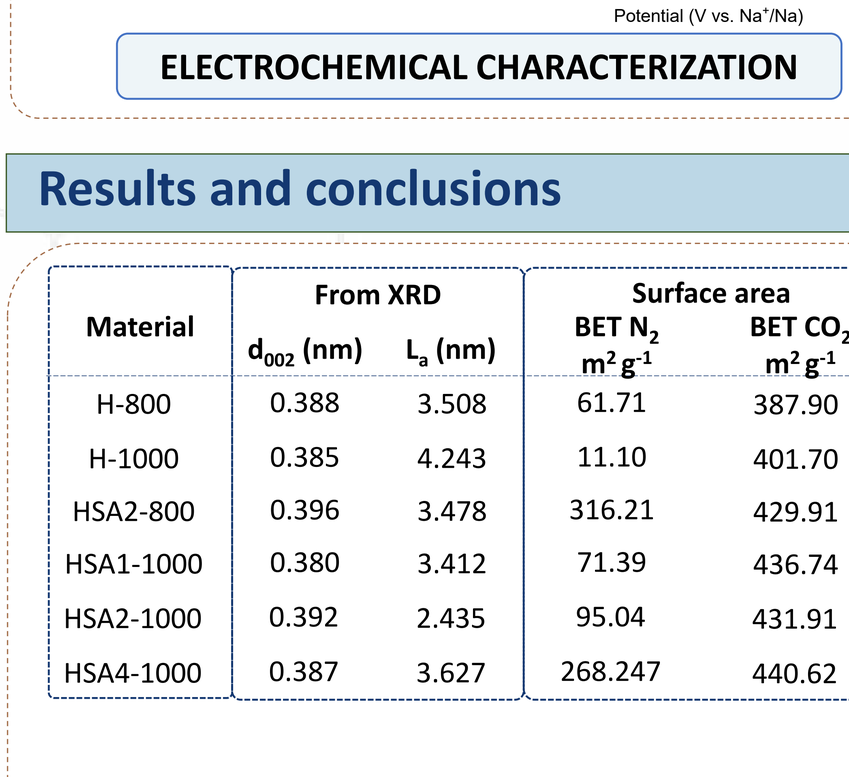


ELECTROCHEMICAL CHARACTERIZATION

Results and conclusions

Material	From XRD		Surface area		ICE (%)
	d_{002} (nm)	L_a (nm)	BET N_2 $m^2 g^{-1}$	BET CO_2 $m^2 g^{-1}$	(0.1 A g^{-1})
H-800	0.388	3.508	61.71	387.90	43.13
H-1000	0.385	4.243	11.10	401.70	74.75
HSA2-800	0.396	3.478	316.21	429.91	50.80
HSA1-1000	0.380	3.412	71.39	436.74	67.35
HSA2-1000	0.392	2.435	95.04	431.91	68.38
HSA4-1000	0.387	3.627	268.247	440.62	45.86





CONCLUSIONS

- The electrochemical performance of synthesized HCs was significantly affected by both carbonization temperature and hydrothermal medium.

H_2SO_4 – assisted HTC

- During the HTC process H_2SO_4 promotes the hydrolysis, dehydration and decomposition of the organic compounds.
- Microspheres can shorten the difusión pathway of both electrolyte and Na^+ ions. The resulting interparticle voids between the microspheres could provide additional active sites for Na-ion storage.

Electrochemical results

- Best performance: HSA2-1000
  Reversible capacity: 459 mA h g^{-1} at 0.1 A g^{-1}
  185 mA h g^{-1} at 1 A g^{-1}
  125 mA h g^{-1} at 2 A g^{-1}
- HSA1-1000 & HSA4-1000 showed excelent stability over 300 cycles
  Capacity retention ≈ 100 %
  (when cycled again at 0.1 A g^{-1})

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