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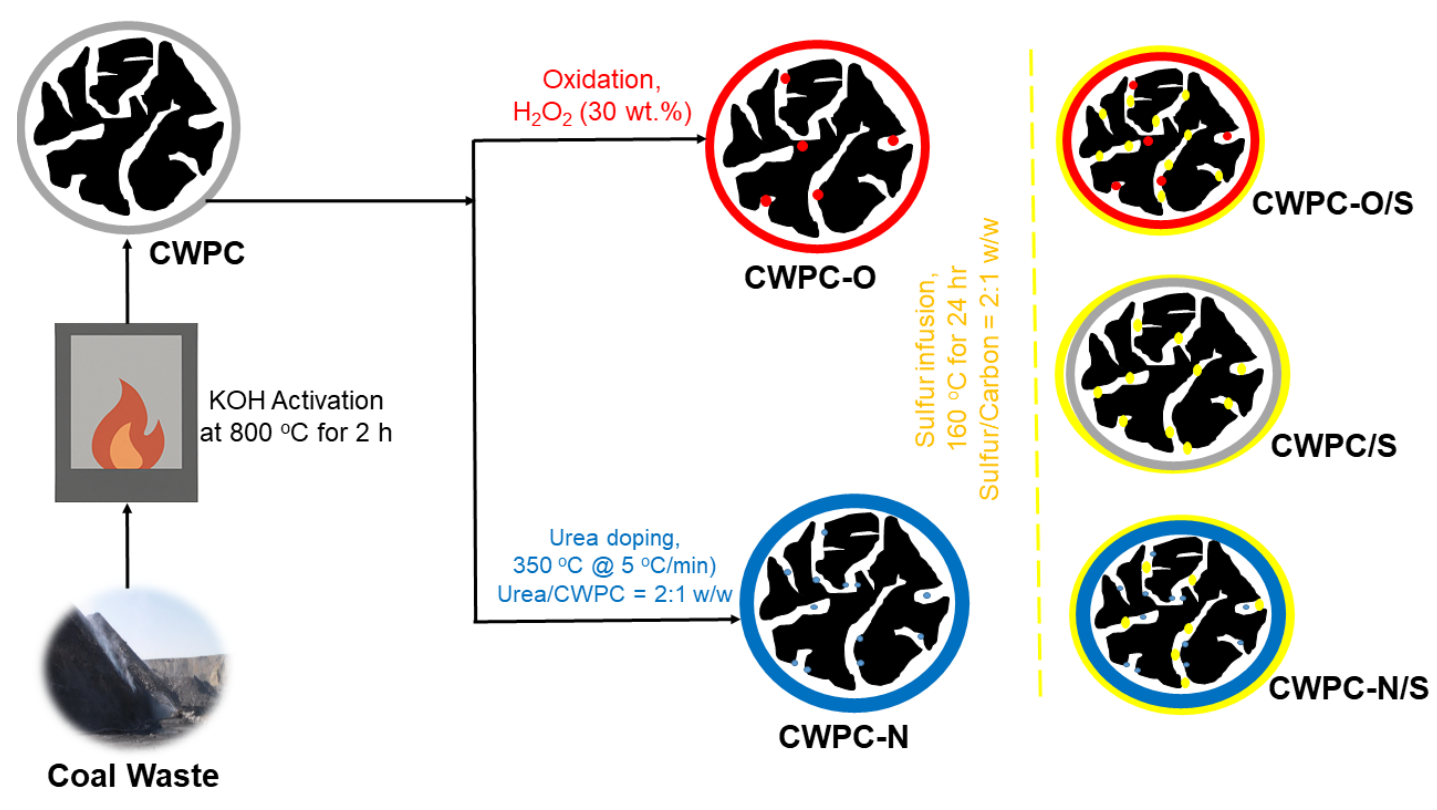
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Introduction

Lithium-sulfur (Li-S) batteries are compelling energy storage alternatives, offering exceptional theoretical capacity (1675 mAh g^{-1}) and energy density (2600 Wh kg^{-1}), with sulfur being abundant and inexpensive compared to scarce cathode metals. However, three critical barriers limit practical deployment: polysulfide shuttling causing rapid capacity fading, poor electronic conductivity of sulfur, and volumetric expansion ($\sim 80\%$) during cycling. Confining sulfur within porous carbon hosts with engineered surface chemistry, specifically heteroatom doping (oxygen, nitrogen), creates polar adsorption sites for polysulfides while maintaining hierarchical pore structures that balance ion diffusion and sulfur loading. Coal waste represents an attractive, low-cost, and sustainable precursor for such engineered carbons. This work synthesizes coal waste-derived carbons with tailored oxygen and nitrogen doping, comparing three variants: pristine CWPC, oxygen-doped CWPC-O, and nitrogen-doped CWPC-N.

Synthesis

- Coal waste ball-milled, mixed with KOH, and activated at 800°C to yield CWPC.
- H_2O_2 treatment for O-doping. Urea-assisted thermal treatment at for N-doping
- Sulfur composites prepared via ball milling and hydrothermal treatment (160°C , 24 hours) to yield CWPC/S, CWPC-O/S, and CWPC-N/S



Characterization

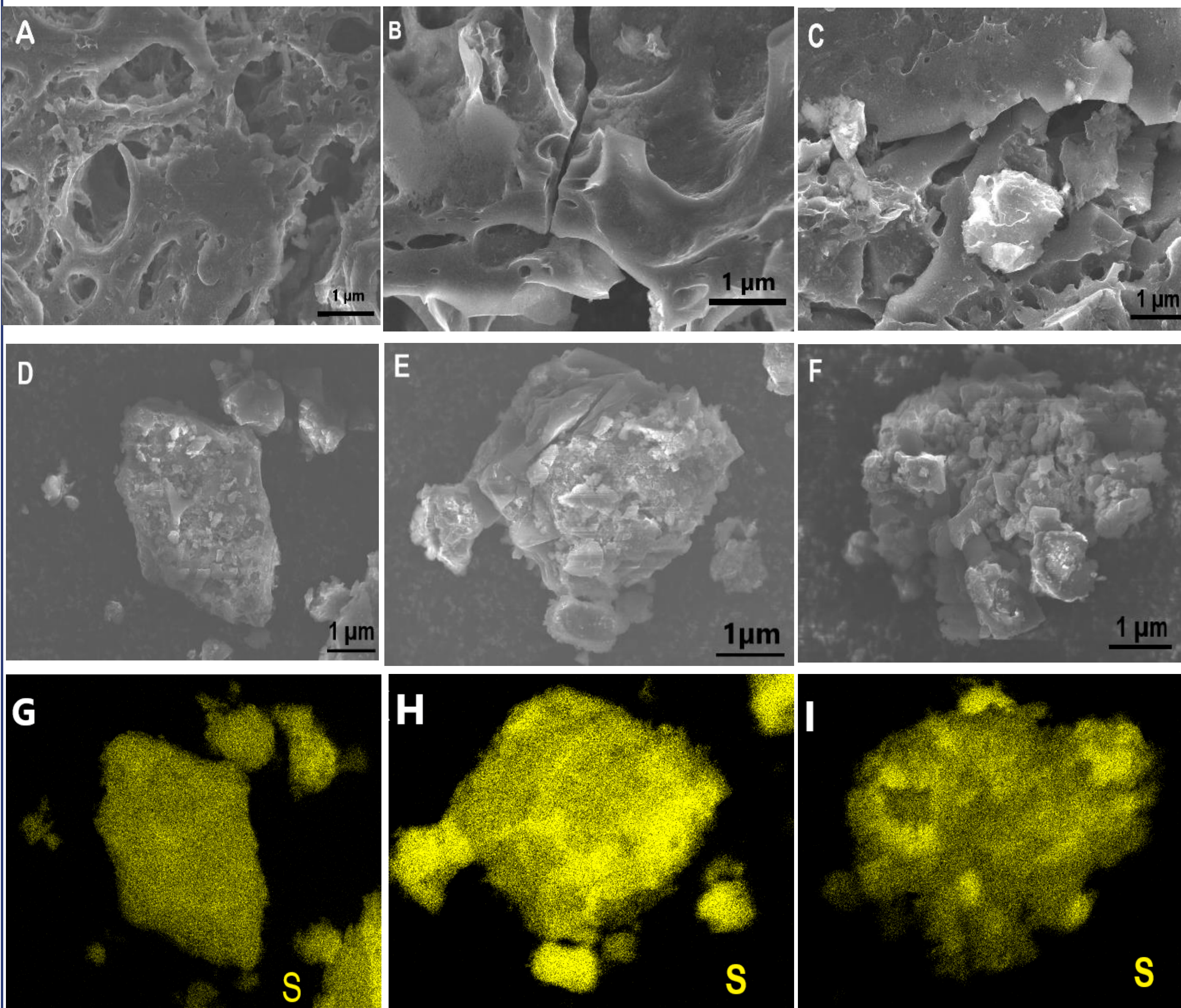


Figure. SEM images (A – F) and EDS mapping images (G – I) of CWPC/S, CWPC-O/S, and CWPC-N/S.

Electrochemical Properties

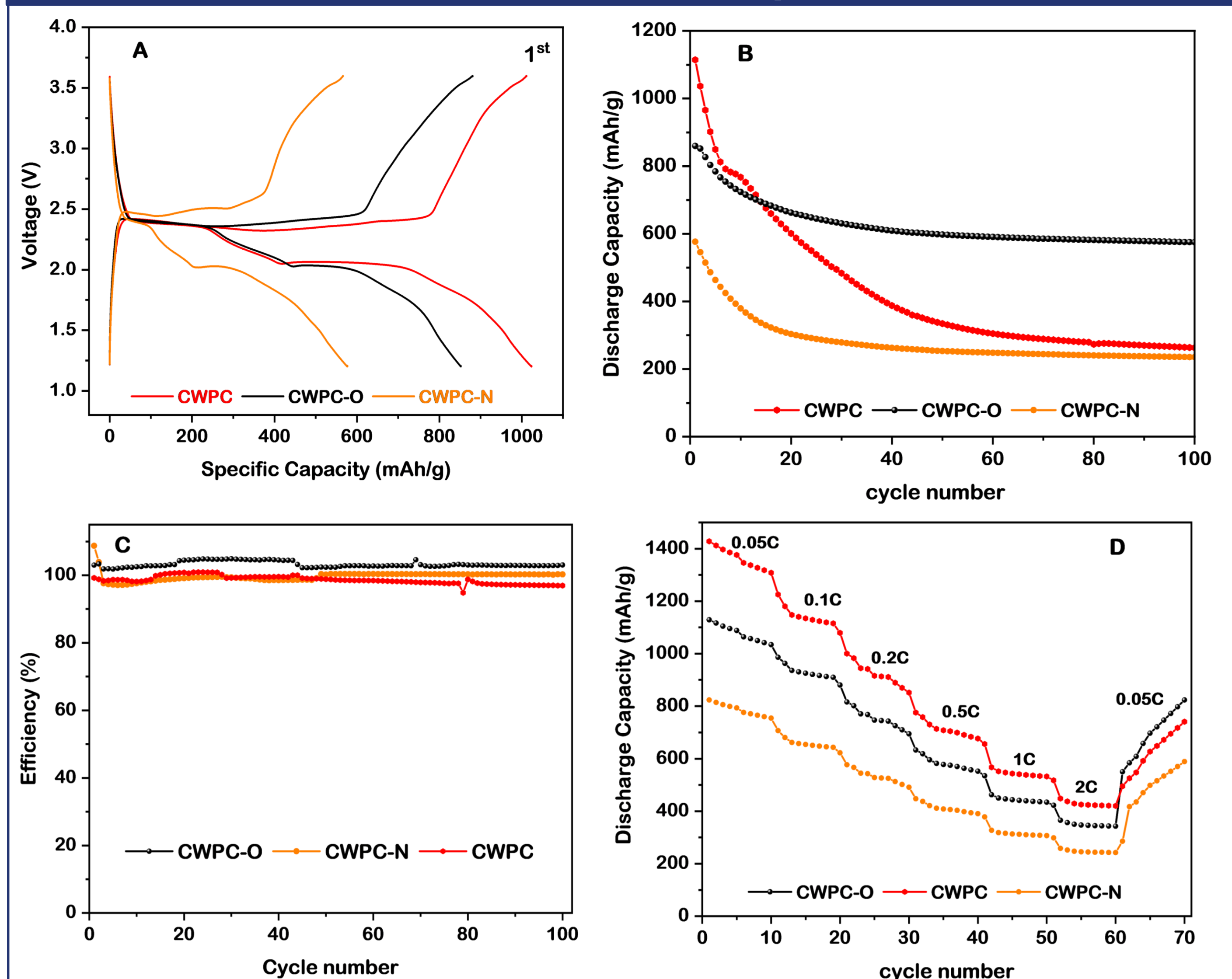


Table 1. Electrochemical performance indicators of CWPC, CWPC-O and CWPC-N

Sample	Initial discharge capacity (mAh g ⁻¹)	Capacity after 100 cycles (mAh g ⁻¹)	Capacity retention (%)	1 st cycle Coulombic Efficiency (%)
CWPC	1114	263	24	103.2
CWPC-O	860	575	67	97
CWPC-N	577	235	41	99.8

- CWPC-O achieves optimal balance: 860 mAh g^{-1} with 67% retention vs. CWPC's 24%
- Coulombic efficiency $>97\%$ indicates robust electrochemistry
- Rate capability enhanced by oxygen doping vs. nitrogen doping

Conclusions and outlook

- Textural properties govern initial sulfur capacity, while surface chemistry dictates long-term cycling stability—establishing dual design criteria for effective sulfur hosts.
- CWPC-O optimally balances polysulfide confinement and pore accessibility, achieving 860 mAh g^{-1} initial capacity with 67% retention after 100 cycles.
- Coal waste valorization provides a sustainable, cost-effective pathway to transform industrial waste into high-performance Li-S battery materials aligned with circular economy principles.

References

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