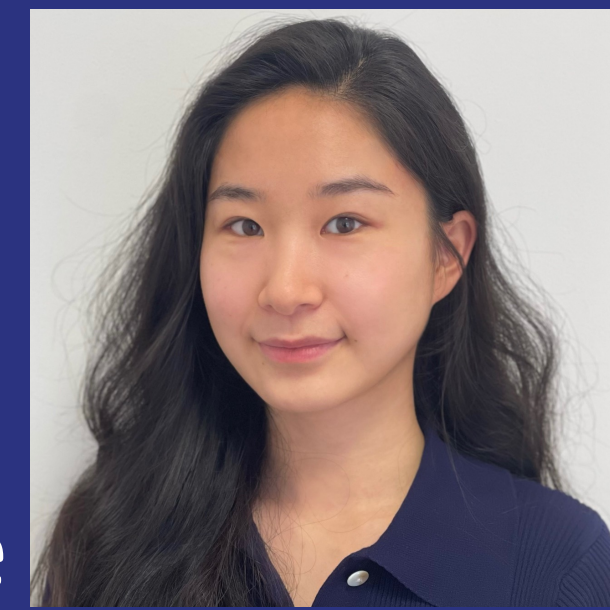


# Waste Biomass-Derived Hard Carbon for Enhanced Sodium-ion Battery Performance

## Investigating the Effects of Particle Size of Hard Carbon on Battery Performance



Yunchu Sun, Jack Fitzpatrick, Oliwia Wojtal, Nuria Tapia-Ruiz

### Abstract

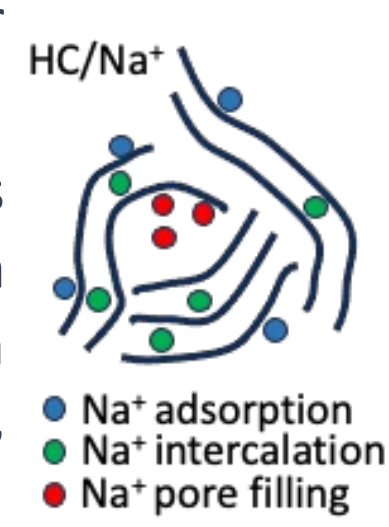
Sodium-ion batteries (SIBs) hold promise for large-scale energy storage due to sodium's abundance<sup>[1,2]</sup>.

**Hard carbons (HCs)** are compelling anode materials for SIBs due to abundant **biomass sources** and energetically favorable **Na<sup>+</sup> intercalation** driven by their larger interlayer spacing than graphite<sup>[3]</sup>.

This project demonstrates improved electrochemical performance by **reducing the particle size** of HC through **sieving**.

### Motivation

- HCs exhibit excellent **cycling stability**, yet there is still potential for enhancing specific capacity<sup>[4]</sup>.
- Bläubaum et al. showed that smaller graphite particle sizes in LIBs enhance capacity and rate performance by shortening **ion diffusion pathways**<sup>[5]</sup>. However, the applicability of this phenomenon to HCs in SIBs remains uncertain, as HCs have a different **ion storage mechanism**, encompassing adsorption, intercalation and pore filling processes<sup>[3]</sup>.



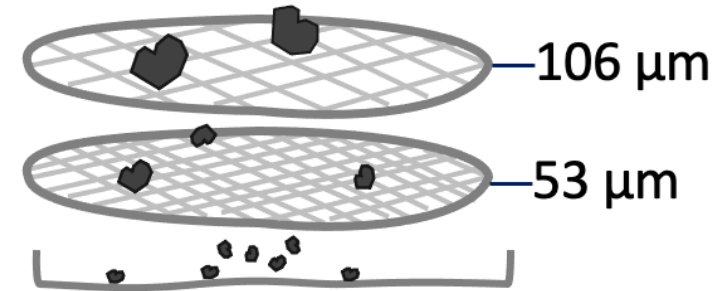
### Methods

#### Hard Carbon Synthesis:

Pyrolysis of a waste biomass-derived precursor under a flowing N<sub>2</sub> atmosphere. Precursors were heated at a rate of 5 °C/min to 700, 900 or 1100 °C for 2 hours and then cooled to room temperature.

#### Reducing Particle Size:

**Sieving:** Synthesised HC powders were hand ground in a pestle and mortar until they passed through 106 and 53 µm sieves.



#### Structural characterisation:

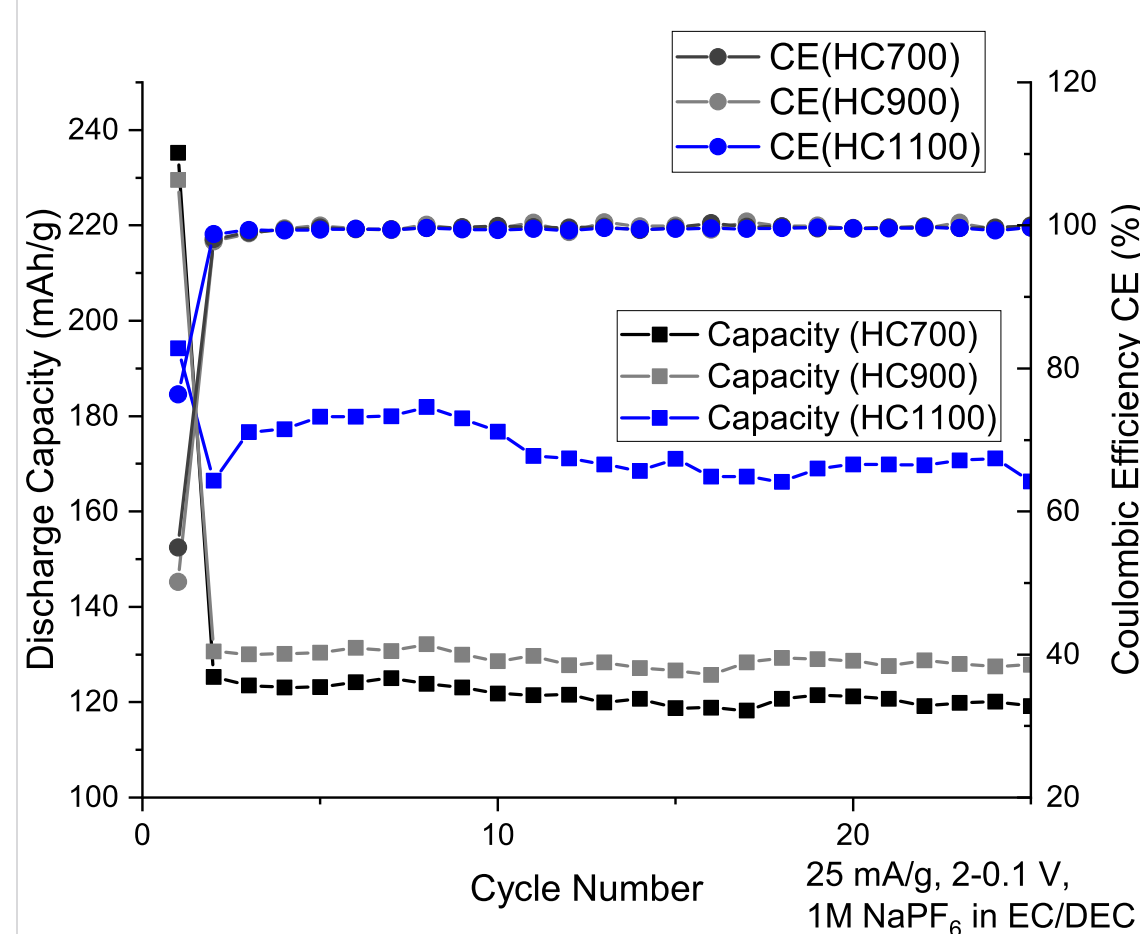
**SEM and XRD** to obtain particle sizes and structural information

#### Assessing Electrochemical Performance:

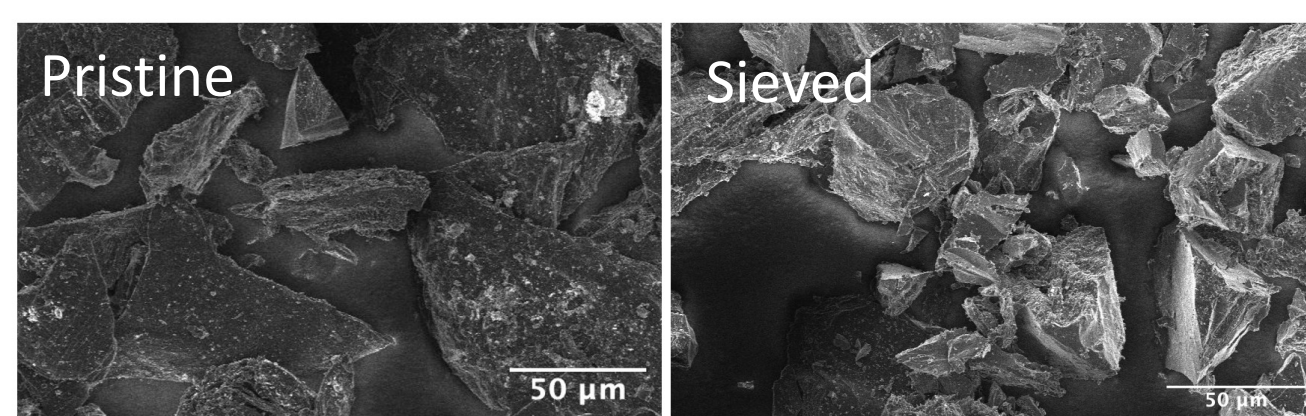
Assembled coin cells for **CV, GCD, C-rate** test, and assembled symmetric HC EI-cells for **EIS**

### Material Selection

- HC synthesised at 1100 °C (HC1100) was selected for the study of particle sizes, due to its higher capacity than HC synthesised at 700 °C (HC700) and 900 °C (HC900).

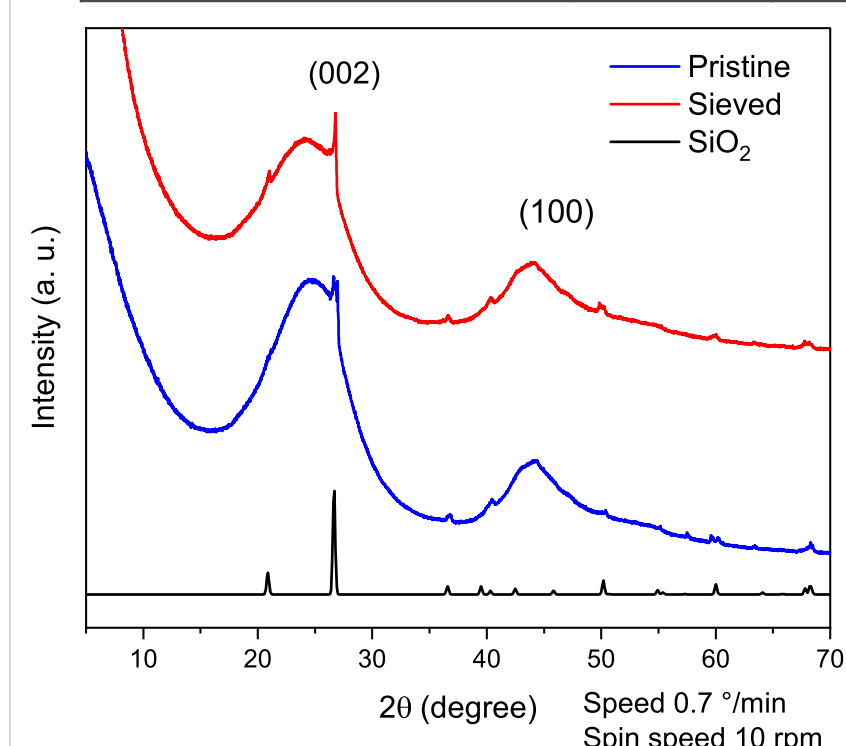


### Structural Characterisation



	Pristine	Sieved
Mean Particle Size (µm)	62	39
Standard deviation	35	20

Sieving reduced particle size, yet a wide size distribution remains.



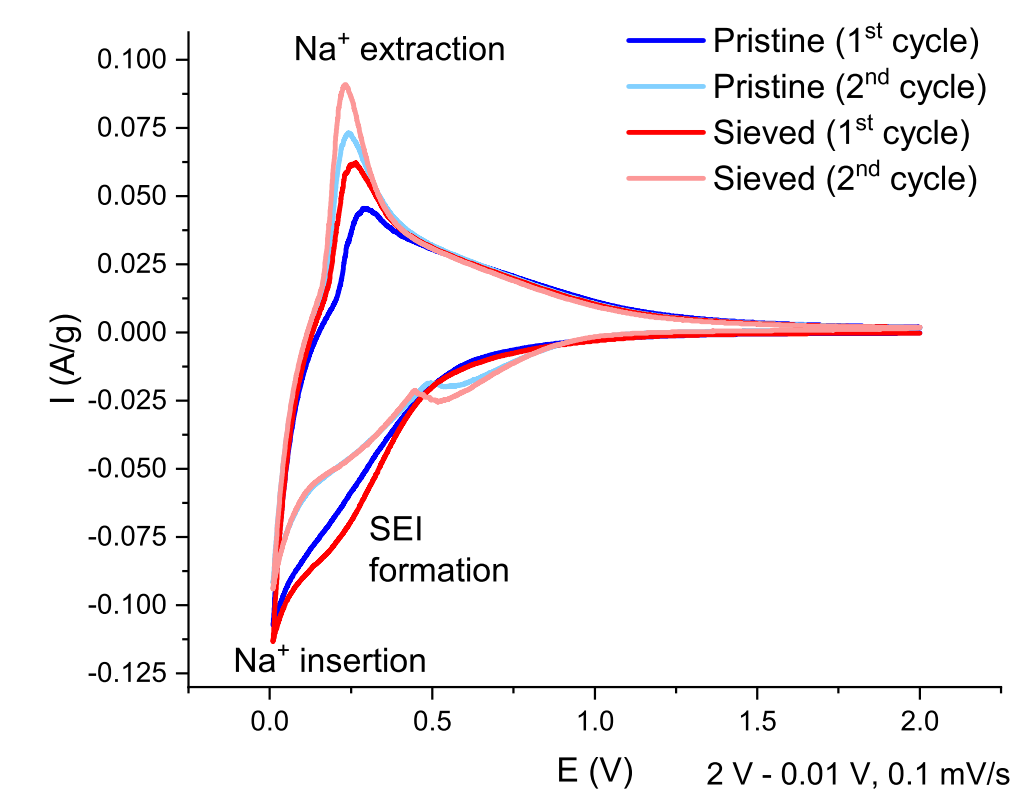
Broad peaks in (002) and (100) are indicative of a **disordered structure** in hard carbons.

XRD shows the presence of **SiO<sub>2</sub> impurities** in both pristine and sieved HC.

### Electrochemical study

Reduced particle size led to:

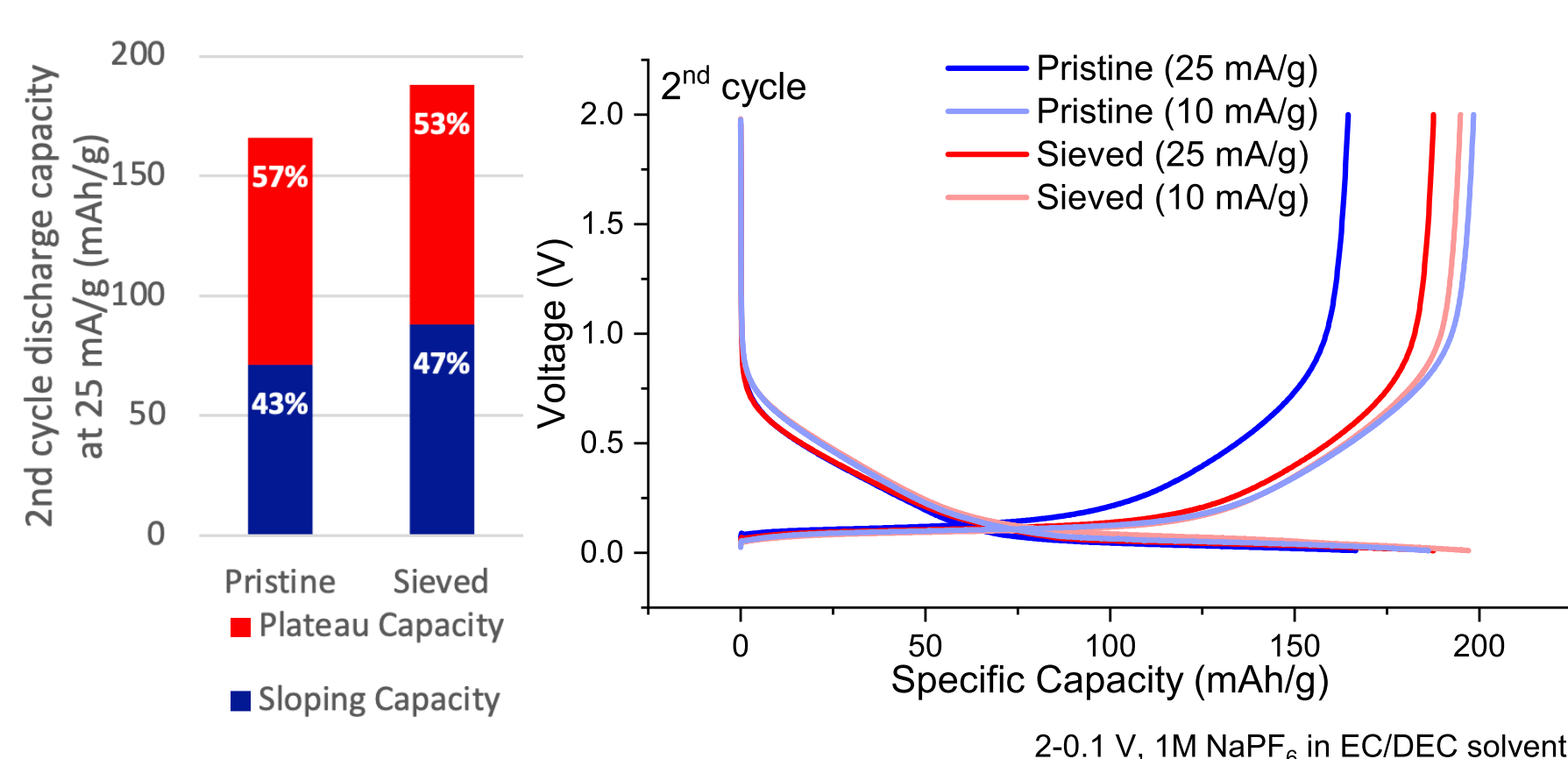
- More **irreversible SEI formation** during the first CV cycle as overall surface area increased.
- An amplified Na<sup>+</sup> extraction peak that shifted to a lower potential, indicating improved **reversible Na<sup>+</sup> storage**, in line with cycling results.



The peak at 0.5 V may result from SiO<sub>2</sub> impurities.

### Cycling Performance

Sieving HC boosted specific discharge capacities by 22 mAh/g at 25 mA/g, primarily via an increase in **sloping capacity**, suggesting enhanced Na<sup>+</sup> storage through adsorption and intercalation<sup>[4]</sup>.

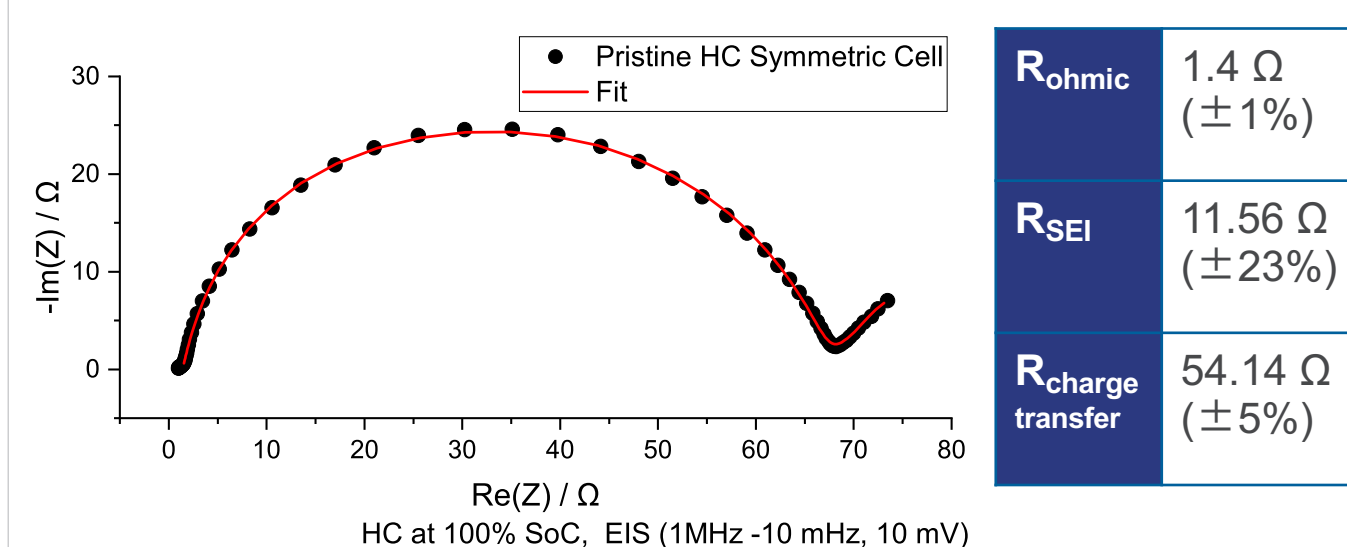


	Overpotential (V) in 2 <sup>nd</sup> cycle upon charge at 25 mA/g
Pristine	0.073
Sieved	0.057

Improved **capacity retention** with increasing current and reduced **overpotential** in sieved HC pointed to reduced **kinetic losses** and shorter **Na<sup>+</sup> diffusion pathways** compared to pristine HC<sup>[5]</sup>.

### Next steps

- Conduct EIS characterisation on sieved HC and compare **dynamic behaviour** (diffusion coefficient) and **kinetic contributions** with the pristine result obtained.



- Develop method of **controlled sieving** to obtain smaller and less distributed particle sizes

### Conclusion

- Sieving** reduced hard carbon **particles sizes**, boosting capacity performance in SIBs by **increasing sloping capacity**.
- Smaller particles improved **reversible Na<sup>+</sup> storage**, as evidenced by GCD and CV results. This effect is likely attributed to **shorter Na<sup>+</sup> diffusion pathways** in smaller particles, as indicated by lower overpotential values. Further research on diffusion behaviour is needed to confirm this.

### References

- [1] D. Larcher and J.-M. Tarascon, *Nature Chemistry*, 2014, 7, 19–29.
- [2] C. P. Grey and J. M. Tarascon, *Nature Materials*, 2016, 16, 45–56.
- [3] J. R. Fitzpatrick, S. I. R. Costa and N. Tapia-Ruiz, *Johnson Matthey Technology Review*, 2022, 66, 44–60.
- [4] H. Alptekin, H. Au, A. C. Jensen, E. Olsson, M. Goktas, T. F. Headen, P. Adelhelm, Q. Cai, A. J. Drew and M.-M. Titirici, *ACS Applied Energy Materials*, 2020, 3, 9918–9927.
- [5] L. Bläubaum, F. Röder, C. Nowak, H. S. Chan, A. Kwade and U. Krewer, *ChemElectroChem*, 2020, 7, 4755–4766.

### Intern bio

Yunchu is a final-year MSci undergraduate studying Chemistry at Imperial College London. During her study, she is particularly interested in electrochemistry and material chemistry. She is passionate in research of energy storage and energy conversion. Aspiring to complete a PhD for fulfilling her research passion, contributing her efforts on solving environmental issues.

