The structure of hard carbons – unfolding the backstage of storing sodium ions

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Sodium-ion batteries (SIBs) with hard carbon (HC) anodes have proved promising for large-scale stationary energy storage due to their high storage capacity and abundant raw materials[1]. Nevertheless, the exact mechanism of sodium ion storage in HCs remains uncertain, motivating the ongoing research and discussions on the matter[2]. The structure of HCs does not have long-range order, which complicates the bulk characterization and, therefore the interpretation of the electrochemical correlations with the structural parameters. This presentation is inspired by the advantages of using the powerful combination of the complimentary wide-angle X-ray scattering (WAXS) and small-angle neutron scattering (SANS) techniques to quantify the structure of d-glucose derived HCs used as the basis of the SIB anode[3] (Figure 1). The exciting results from the sloping- and plateau capacity value correlations with the parameters from a broad length scale promote the understanding of the role of the HC structure in SIBs. The interplay between the lateral length parameters from WAXS and SANS shows the curvature of the graphene layer and its impact on the electrochemical behavior of SIBs. It is discussed, how the interactions of the structural parameters impact HCs ability to store sodium ions.

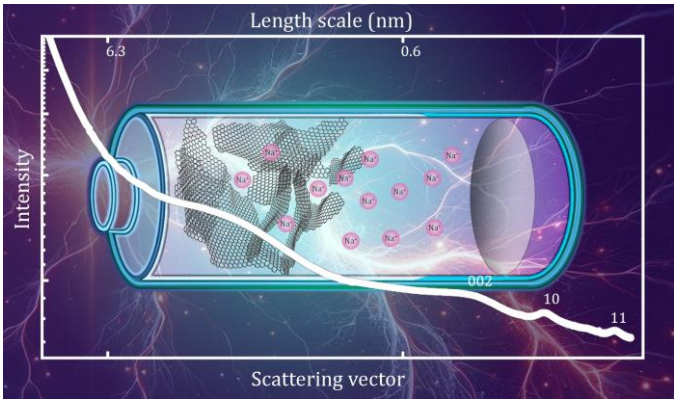

Figure 1: Combining complementary techniques to assess the structure of d-glucose derived hard carbons for the SIB.

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References
1 Critical Raw Materials for Strategic Technologies and Sectors in the EU A Foresight Study, 2020.
2 C. Huang, J. Yin, W. Shi, Y. Cheng and X. Xu, *Mater. Today Energy*, 2024, **40**, 101501.
3 L. Kalder, A. Olgo, J. Lührs, T. Romann, R. Härmas, J. Aruväli, P. Partovi-Azar, A. Petzold, E. Lust and E. Härk, *Energy Storage Mater.*, 2024, **67**, 103272.