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From Charge Storage Mechanism to Performance: A Roadmap toward High Specific Energy Sodium-Ion Batteries through Carbon Anode Optimization

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While sodium-ion batteries (SIBs) represent a low-cost substitute for Li-ion batteries (LIBs), there are still several key issues that need to be addressed before SIBs become market-ready. Among these, one of the most challenging is the negligible sodium uptake into graphite, which is the keystone of the present LIB technology. Although hard carbon has long been established as one of the best substitutes, its performance remains below that of graphite in LIBs and its sodium storage mechanism is still under debate. Many other carbons have been recently studied, some of which have presented capacities far beyond that of graphite. However, these also tend to exhibit larger voltage and high first cycle loss, leading to limited benefits in terms of full cell specific energy. Overcoming this concerning tradeoff necessitates a deep understanding of the charge storage mechanisms and the correlation between structure, microstructure, and performance. This review aims to address this by drawing a roadmap of the emerging routes to optimization of carbon materials for SIB anodes on the basis of a critical survey of the reported electrochemical performances and charge storage mechanisms.