

Charged up: Revolutionizing rechargeable sodium-ion batteries with 'doped' carbon anodes

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Simple Technique for the Development of New-Generation Sodium Batteries

Lithium-ion batteries are widely used

Laptop Phone Electric car

But lithium is rare and its extraction is environmentally-destructive

Sodium-ion batteries (SIBs) are a better alternative, but they are too big to pass through the graphite anode in modern cells

Na⁺ Li⁺

How can we engineer better carbon-based materials to increase the performance of SIBs?

Novel nanoscale nitrogen-doped carbon material

Macro-pores Meso-pores Micro-pores

Aggregate Agglomerate Primary particle

Shorter Na⁺ diffusion

Wide pathway Turbostratic structure

Extrinsic defect by N doping increases the number of active sites (~2 nm)

Crystalline domain (10-20 Å)

Nitrogen atoms are inserted into the carbon structure to create more space

Higher density macro- and meso-pores (more active sites) Increased Na⁺ transport and adsorption

In practice: Higher performance than lithium-ion batteries

80% High (80%) initial coulombic efficiency (energy density in the cell)

Anodes made from nitrogen-doped carbonaceous material allow SIBs to outperform lithium-ion batteries

Maximizing the rate capability of carbon-based anode materials for sodium-ion batteries

Kim et al. (2020) | DOI: 10.1016/j.jpowsour.2020.228973

NATIONAL KOREA MARITIME & OCEAN UNIVERSITY

Researchers in Korea have developed a 'heteroatom-doped' (modified) carbon-based anode that helps sodium-ion batteries to surpass the performance of lithium-ion batteries. Credit: Korea Maritime and Ocean University

As the world becomes aware of the imminent environmental crisis, scientists have begun a search for sustainable energy sources.

Rechargeable batteries like lithium-ion batteries are seeing a popularity surge, concurrent with production of 'greener' technologies such as electric propulsion ships (which are being developed to meet the environmental regulations by the International Maritime Organization) and other electric vehicles. But, lithium is rare and difficult to distribute, putting its sustainability in doubt while also risking sharp increases in cost.

Researchers have thus turned to [sodium-ion batteries](#) (SIBs), which are electrochemically similar to lithium-ion batteries and offer advantages like higher abundance of sodium and cheaper production. However, currently, the standard anode material in SIBs is graphite, which is thermodynamically unstable with [sodium ions](#) and leads to lower reversible capacity (a measure of its storage) and [poor performance](#).

To this end, researchers at Korea Maritime and Ocean University, Korea, set out to find a suitable non-graphite anode material for SIBs. Dr. Jun Kang, the lead scientist, says, "Because SIBs have low performance—only 1/10th the capacity of a lithium-ion battery—it is crucial to find an efficient anode that retains graphite's low cost and stability."

Now, in their latest study published in the *Journal of Power Sources*, the scientists reported the following strategies to overcome the limitations of carbon-based anode materials for SIBs: (1) Employing a hierarchical porous structure capable of promoting rapid Na⁺ transport from the bulk zone of the electrolyte to the interface of the active material; (2) retaining large specific surface areas where Na⁺ migrates to the interface, which can be easily accessed in the active material; (3) retaining surface defects and pore structures that enable co-intercalation from the surface to the interior; (4) retaining nanostructures in Na⁺ inserted into the active material from defects and pores that can have short diffusion paths; and (5) increasing the number of active sites due to

extrinsic defects that result from these elements through hetero-element doping. These strategies led to the electrochemical performance of the battery being significantly improved, even surpassing that of current [lithium-ion batteries!](#)

In two of their previous studies, they successfully tested this method using phosphorus and sulfur, which were featured on the cover pages of *Carbon* and *ACS Applied Materials & Interfaces*, respectively.

Dr. Kang is optimistic about the various potential applications of their technology, such as in electric propulsion ships and other vehicles, drones, and even high-performance CPUs. "These five factors afford good capacity retention, reversible capacity, ultrahigh cycling stability, high initial coulombic efficiency (80%), and remarkable rate capability. This means they can be used for a long time even with intense battery use," he explains.

Considering the advantages of sodium over lithium, these findings certainly have important implications for the engineering of sustainable, inexpensive, high-performance batteries and can take us a step closer to the realization of an energy-efficient future.

More information: Dae-Yeong Kim et al, Maximizing the rate capability of carbon-based anode materials for sodium-ion batteries, *Journal of Power Sources* (2020). [DOI: 10.1016/j.jpowsour.2020.228973](https://doi.org/10.1016/j.jpowsour.2020.228973)

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