Can sodium-ion batteries replace trusty lithium-ion ones?

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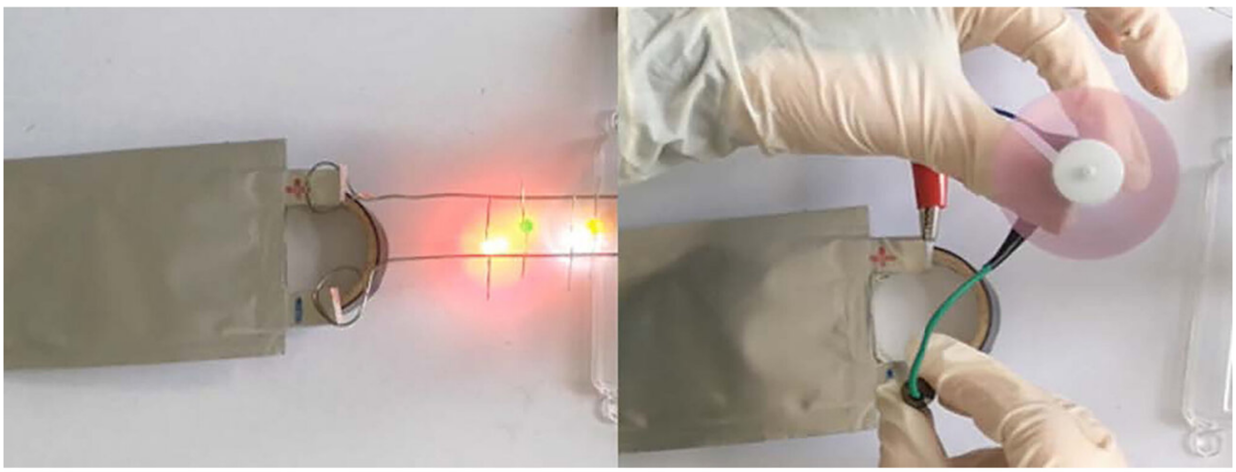

In Applied Physics Reviews, researchers in China describe how they applied basic physical concepts of atomic scale to build high-performance anodes for sodium-ion batteries.This image shows a homemade softpack sodium-ion battery they made. Credit: Jiangping Tu, Yuqian Li, Liyuan Zhang, Xiuli Wang, Xinhui Xia, Dong Xie, and Changdong Gu

Sodium-ion batteries are a potential replacement for lithium batteries, but the anodes—positively charged electrodes—that work well for lithium-ion batteries don't provide the same level of performance for sodium-ion batteries.

Amorphous carbon, which lacks a crystalline structure, is known to be a useful anode, because it has defects and voids that can be used to store sodium ions. Nitrogen/phosphorus-doped carbon also offers appealing electrical properties.

In *Applied Physics Reviews*, researchers in China from Zhejiang University, Ningbo University, and Dongguan University of Technology describe how they applied basic physical concepts of atomic scale to build high-performance anodes for sodium-ion batteries.

"Recent studies have shown that doped amorphous carbon, especially electron-rich element-doped amorphous carbon, is a good anode for sodium storage," said Tu. "But there was no common explanation for how sodium storage works or the doping effect of doped carbon."

On a quest for answers, the researchers used the concept of energy level orbitals to explain the affinity of pyrrolic nitrogen and a phosphorus-oxygen bond, their atomic interaction, electron distribution, and electron cloud configuration.

To get a closer look at distinct storage behavior, they applied first principles calculations, which is a method that uses basic physical quantities to calculate physical properties. It is based on electron density function, a concept of quantum mechanics that can reveal a crystal's molecular structure.

When they analyzed the electron distribution, system chemical parameters, and adsorption energies of sodium ions embedded within modified carbon materials, they found that pyrrolic nitrogen and phosphorus-oxygen bonds show real potential for sodium storage.

"Sodium ions tend to be stored within these two structures," Tu said.

The researchers designed a hydrothermal treatment to build the precursor of a phosphorus-oxygen structure, then doped a carbon anode with the dual electron-rich elements. It shows "enhanced electrochemical performance in cycle life and capacity for batteries," said Tu.

Their anode achieved a life cycle of 5,000 cycles, with an enhanced capacity of 220 milliampere hours/gram, and reduced capacity loss (0.003%/cycle).

"Our work fills the theoretical gap about the sodium storage behavior of electron-rich element-doped amorphous carbon and provides the experimental basis for using carbon," said Tu. "We provide directions to modify carbon materials for large-scale sodium-ion batteries."

More information: "Sodium storage behavior of electron-rich element-doped amorphous carbon" *Applied Physics Reviews*, aip.scitation.org/doi/10.1063/5.0029686

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