Doped amorphous carbon anodes enhance sodium-ion battery performance

Sodium-ion batteries (SIBs) offer many potential advantages over their lithium counterparts due to the limited supply of lithium. Since sodium and lithium belong to the same group in the periodic table and have similar properties, they are expected to be comparable in terms of their efficiency in batteries. Despite this, the anodes used in lithium-ion batteries (LIBs) have presented low performance when used in SIBs due to their poor sodium storage capacity. Recent studies have shown that amorphous carbon can be a suitable anode for SIBs, where the defects on the anode surface can store sodium ions.

Now Yuqian Li of Zhejiang University, Liyuan Zhang of Ningbo University, Dong Xie of Dongguan University

of Technology, and their colleagues report their study of the sodium storage behavior in electron-rich, element-modified amorphous carbon doped using nitrogen (N) and phosphorus (P). N- and P-doping have demonstrated an improvement in the electrochemical properties of carbon materials because of larger and higher capacity retention. The researchers published their findings in a recent issue of *Applied Physics Reviews* (<https://doi.org/10.1063/5.0029686>).

Although it has been understood that using doped carbon in SIBs has a positive effect, it has not yet been possible to explain how sodium storage works and what the effect is of doping carbon materials. Looking for answers, the researchers used the energy of the highest occupied molecular orbital and that of the lowest unoccupied molecular orbital to explain the affinity of pyrrolic N (N-doped specie) and a P-oxygen bond. They also studied the electron

cloud distribution, the relative electron density, and the atomic interaction of these N- and P-doped materials.

The researchers concluded that as N and P are electron-rich elements, their use as dopants creates many defects that provide storage sites for Na ions. Also, the high electron density attracts cations, which increases the mobility of sodium ions from the cathode.

The researchers found that pyrrolic N and P–O bonds are required in N and P codoped amorphous carbon to show sodium storage potential.

Based on this, the researchers designed a hydrothermal treatment to build the precursor of the necessary P–O structure. Then they synthesized a carbon anode doped with dual electron-rich elements that shows enhanced electrochemical performance in terms of cycle life and capacity in batteries.

The researchers were able to design an N and P codoped carbon electrode (anode) that shows a long cycle life (over 5000 cycles), enhanced capacity (over 220 mAh/g⁻¹), and with reduced capacity loss (0.003% per cycle). The **Figure** demonstrates the application potential of this battery power to make multiple bulbs and motors work.

“These research results fill the theoretical gap of sodium storage behavior of electron-rich, element-doped, amorphous carbon and provide the experimental basis for its application,” the research team writes.

Joan Stephanie Torres-Rodríguez

Homemade soft pack sodium-ion battery. Credit: *Applied Physics Reviews*.

CONGRATULATIONS!

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