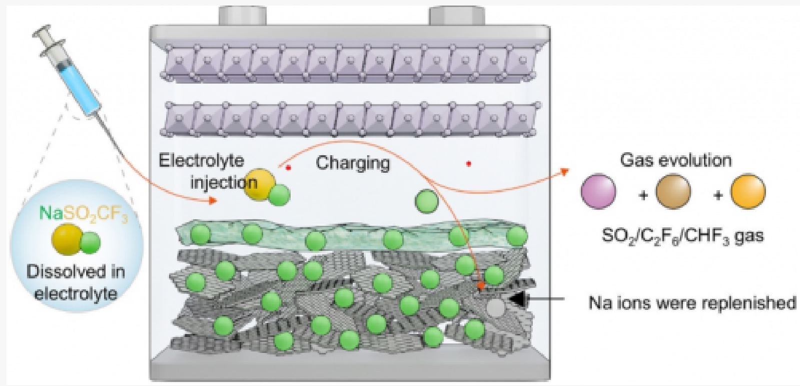
A cleaner sodium boost for better batteries

FAYETTEVILLE, GA, UNITED STATES, June 24, 2026 /EINPresswire.com/ -- Sodium-ion batteries are gaining attention as a lower-cost and more resource-abundant alternative to lithium-ion systems, but their practical performance is often weakened before they truly begin working. A major obstacle is the loss of active sodium ions during the first charge-discharge cycle, especially when hard carbon anodes are used. A new study reports a residue-free electrolyte additive, sodium trifluoromethanesulfinate ($NaSO_2CF_3$), designed to release sodium ions at the right stage of battery formation while avoiding harmful solid leftovers. By combining molecular design, electrochemical testing, and pouch-cell validation, the work offers a practical route to improving initial efficiency, cycle life, and manufacturability in sodium-ion batteries.



Residue-free sodium-ion supply via electrolyte additive.

Sodium-ion batteries are widely viewed as promising energy-storage devices because sodium is naturally abundant and cost-effective. However, hard carbon anodes, one of the most practical anode choices, typically suffer from low initial Coulombic efficiency (ICE), causing 10–20% initial capacity loss as active sodium ions are consumed in side reactions and solid electrolyte interphase (SEI) formation. Existing sodium-ion supply strategies, including cathode additives and electrolyte-based approaches, often face incomplete decomposition, poor solubility, electrode damage, or unwanted residues. Because of these challenges, further research is needed to develop sodium-ion supply additives that combine suitable oxidation potential, high solubility, clean decomposition, electrode compatibility, and manufacturing stability.

The State Key Laboratory of Molecular Engineering of Polymers, Department of Macromolecular Science, Institute of Fiber Materials and Devices, Research Center of Artificial Intelligence (AI) for Polymer Science, and Collaborative Innovation Center of Chemistry for Energy Materials at Fudan University reported (DOI: 10.1016/j.esci.2025.100498) this study on May 2026, in eScience. The research developed sodium trifluoromethanesulfinate ($NaSO_2CF_3$) as a residue-free electrolyte additive to supply sodium ions, aiming to improve the ICE, cycling stability, and manufacturing compatibility of sodium-ion batteries.

The study began with substituent-driven molecular engineering of organic sodium sulfinates. The team compared different R-group substituents, including trifluoromethyl (–CF□), ethyl (–C□H□), phenyl (–C□H□), fluorophenyl (–C□H□F), and pentafluoroethyl (–C□F□), to determine how electronic effects control solubility, oxidation potential, and decomposition behavior. Density functional theory (DFT) calculations and electrochemical tests showed that the strong electron-withdrawing –CF□ group reduced the binding energy between sodium ions and anions, giving NaSO□CF□ high solubility and an oxidation plateau at 3.65 V. During the first charge, NaSO□CF□ released sodium ions and formed gaseous products, including sulfur dioxide (SO□), hexafluoroethane (C□F□), and fluoroform (CHF□), rather than harmful solid residues. Nuclear magnetic resonance (NMR), in situ Raman spectroscopy, X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM), differential electrochemical mass spectrometry (DEMS), and gas chromatography-mass spectrometry (GC-MS) confirmed complete conversion and minimal disturbance to electrode interfaces. In hard carbon|Na□V□(PO□)□ pouch cells, the additive improved ICE from 82.6% to 96.0% and maintained 81.2% capacity retention after 600 cycles.

The authors said the key advance is not simply adding more sodium, but delivering it in a way that fits real battery manufacturing. By dissolving NaSO□CF□ directly into the electrolyte, the approach avoids extra electrode-processing steps and reduces the risk of residue-related performance loss. They said the –CF□ group acts as a molecular “switch,” giving the additive the right balance of solubility, oxidation potential, and clean gas-forming decomposition. This makes the strategy different from conventional sodium compensation methods that may leave solid byproducts or disturb electrode structure.

The findings point to a scalable strategy for sodium-ion batteries, especially for systems using hard carbon anodes where first-cycle sodium loss remains a major barrier. Because NaSO□CF□ can be added through the electrolyte and removed as gas during formation, it may be more compatible with existing pouch-cell production lines than many solid presodiation additives. The study also showed compatibility with multiple cathode materials, including P2–Na□/□Ni□/□Mn□/□Ti□/□O□, O3–NaNi□/□Fe□/□Mn□/□O□, and Prussian white–Na□Mn[Fe(CN)□], suggesting broader applicability. Beyond this specific molecule, the work provides a molecular design framework for clean ion-supply chemistry in next-generation batteries.

References
DOI
10.1016/j.esci.2025.100498

Original Source URL
https://doi.org/10.1016/j.esci.2025.100498

Funding Information
This work was supported by the National Key Research and Development Program of China (2022YFB2402300), the National Natural Science Foundation of China (2247090114), the

Fundamental Research Funds for the Central Universities (20720220010), and Shanghai Municipal Commission of Economy and Infomatization, AI for Science Program (2025-GZL-RGZN-BTBX-01005).

Lucy Wang
BioDesign Research
email us here
