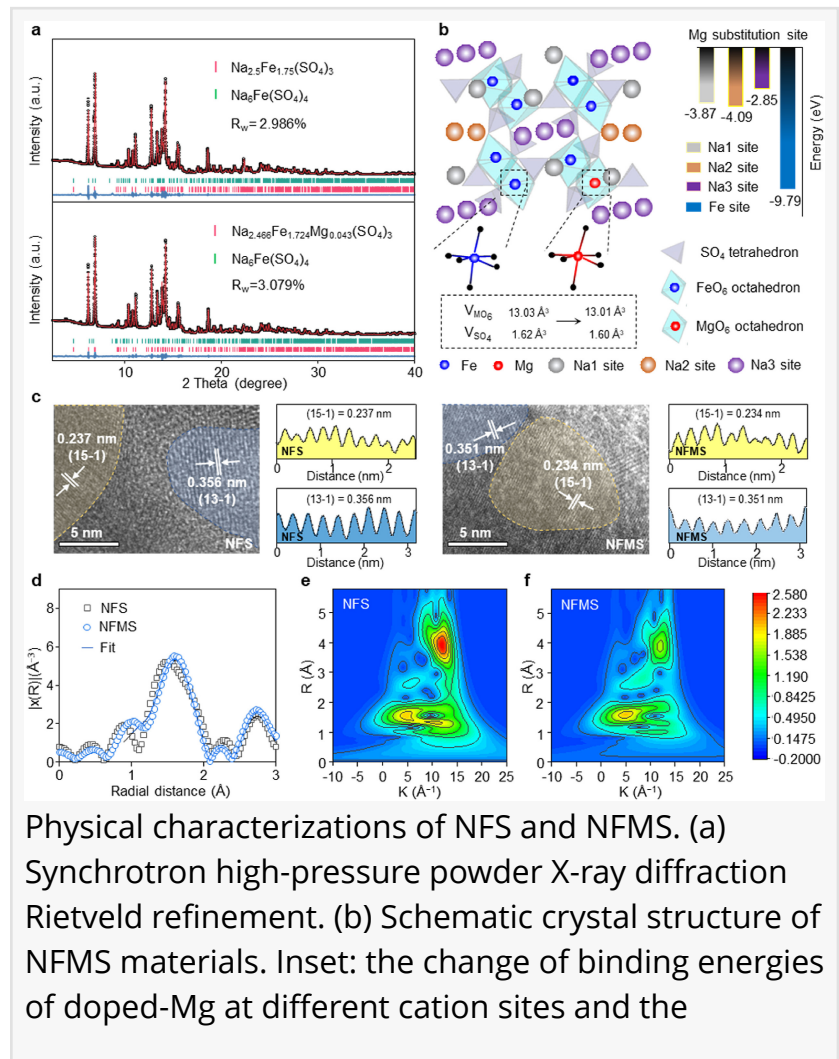


Cation tweaks unlock heat-resistant sodium battery performance

GA, UNITED STATES, August 15, 2025 /EINPresswire.com/ -- To meet the growing demand for high-performance, low-cost sodium-ion batteries, researchers have developed a novel iron sulfate cathode material enhanced with magnesium doping. This modified structure improves the material's stability under high temperatures and harsh electrochemical environments. The newly engineered cathode demonstrates enhanced reaction reversibility, reduced interfacial degradation, and excellent long-term cycling performance—even at elevated temperatures of 60°C. The innovation lies in using Mg cations to reduce the crystal's electron density, thereby mitigating harmful side reactions with water and electrolytes. This breakthrough presents a promising direction for developing durable sodium-ion batteries suitable for large-scale energy storage applications.



Sodium-ion batteries (SIBs) are gaining attention as cost-effective alternatives to lithium-ion systems, especially for grid-scale energy storage. Iron-based sulfates, particularly of the alluaudite type, are attractive cathode materials due to their high voltage and earth-abundant composition. However, their poor ionic conductivity and instability in humid air and high-voltage electrolytes severely limit their practical use. These challenges arise from the material's high surface nucleophilicity and sluggish Na⁺ ion transport within the crystal lattice. Based on these challenges, there is a pressing need to structurally redesign iron sulfate cathodes to improve their ionic pathways and environmental robustness, enabling their broader application in real-

world battery systems.

A research team from Zhengzhou University, in collaboration with the University of Wollongong, has reported a magnesium-doped iron sulfate cathode material for sodium-ion batteries, published in February 2025, in eScience. The study reveals that precise Mg substitution in the crystal lattice enhances both the structural integrity and electrochemical stability of the material, enabling long-lasting operation even at 60°C. The innovation improves reaction kinetics and suppresses unwanted reactions at the electrode interface, offering a practical solution for developing high-voltage, high-temperature sodium-ion storage systems.

The researchers synthesized a novel cathode material, $\text{Na}_x\text{Fe}_{1-x}\text{Mg}_x(\text{SO}_4)_2$ (NFMS), through Mg substitution at Fe sites in the iron sulfate lattice. This subtle doping reduces the volume of the polyhedral crystal units, opening wider pathways for Na^+ migration and lowering energy barriers for ion transport. Furthermore, the Mg ions decrease the surface electron density, reducing interactions with water and electrolyte molecules and improving the material's chemical stability. Electrochemical testing showed that NFMS delivered a specific capacity of 102.2 mAh/g¹, retained 70.8% capacity after 5000 cycles at 60°C, and achieved a high Coulombic efficiency of 99.3%. Unlike conventional materials, NFMS formed a uniform, inorganic-rich cathode–electrolyte interphase (CEI), effectively preventing gas formation and material degradation. Full-cell tests using a hard carbon anode confirmed the material's practical viability, with 70.3% capacity retention over 190 cycles. Additionally, in situ X-ray diffraction and impedance analyses revealed stable lattice structures and reduced charge transfer resistance throughout extended cycling, even under high thermal conditions. This study underscores the dual benefits of structural modulation and surface engineering in advancing next-generation sodium-ion battery technologies.

“This work provides a comprehensive strategy for stabilizing sodium-ion battery cathodes under extreme conditions,” said Prof. Weihua Chen, corresponding author of the study. “By intelligently modifying the crystal chemistry, we not only enhanced the material’s ionic kinetics but also greatly improved its resistance to environmental degradation. This dual-function design could pave the way for high-performance, cost-effective energy storage systems, especially in hot and humid climates where battery longevity has been a limiting factor.”

The magnesium-doped iron sulfate cathode offers significant promise for next-generation sodium-ion batteries aimed at grid-level energy storage, especially in tropical or thermally stressed environments. Its ability to maintain high capacity, structural integrity, and interfacial stability over thousands of cycles makes it a strong candidate for commercialization. The structural insights and interfacial engineering strategies outlined in this work can also inspire broader materials innovations across battery chemistries. Future applications could include renewable energy buffering, electric buses, and backup power systems in remote or hot regions—where conventional lithium-ion batteries may underperform or degrade rapidly.

References

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