

# Microwave-Assisted Synthesis Optimization of $\text{Na}_3\text{V}_2(\text{PO}_4)_2\text{O}_2\text{F}$ Cathode Materials for Sodium-Ion Batteries

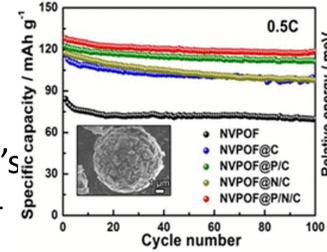
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## Background

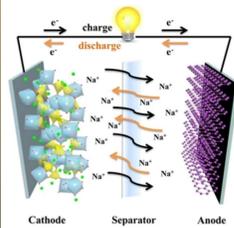
### Why Sodium-Ion Batteries and NVPOF?

- Sodium-ion batteries offer a low-cost and sustainable alternative to lithium-ion systems due to sodium's abundance and potential for large-scale, renewable energy storage applications



Electrochemical Performance of NVPOF and Doped Composites  
Source: ACS Applied Materials & Interfaces

### Synthesis Challenges and Advantages



Na-ion Battery  
Qingbo Zhou 2021, Volume 4, pages 793-823

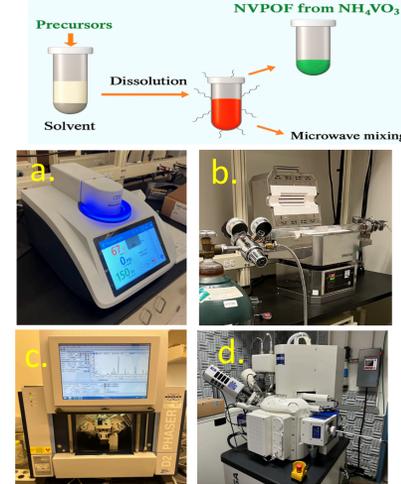
- Conventional solid-state and hydrothermal methods need high temperatures and long times, causing high energy use and uneven particles
- Microwave-assisted synthesis provides rapid, uniform heating, reducing reaction time and energy use while improving particle uniformity and crystallinity

## Research Purpose

- Optimize microwave-assisted synthesis of Fe-doped NVPOF by adjusting Fe content and calcination temperature to improve conductivity, phase purity, and electrochemical performance
- Establish a fast, energy-efficient, and scalable synthesis route for high-performance sodium-ion battery cathodes

## Method

### Schematic of Synthesis Process



### Synthesis Methods

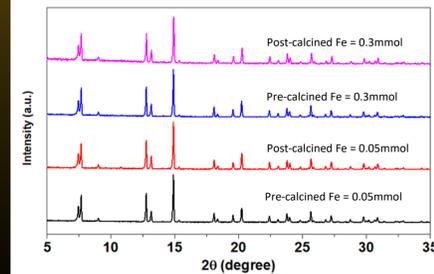
- (a) Precursors were dissolved in solvent and then heated using a CEM Discover microwave reactor
- (b) The obtained precursor powder was calcined in a tube furnace under air to improve crystallinity and phase stability

### Analysis Methods

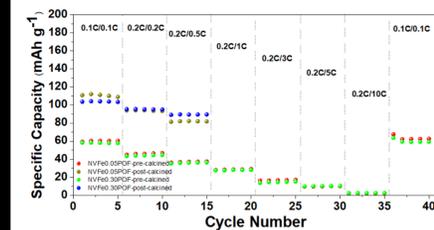
- (c) XRD can identify crystal structure and phase purity of Fe-doped NVPOF
- (d) SEM observes particle morphology and size distribution after synthesis and calcination

## Result

### XRD Result

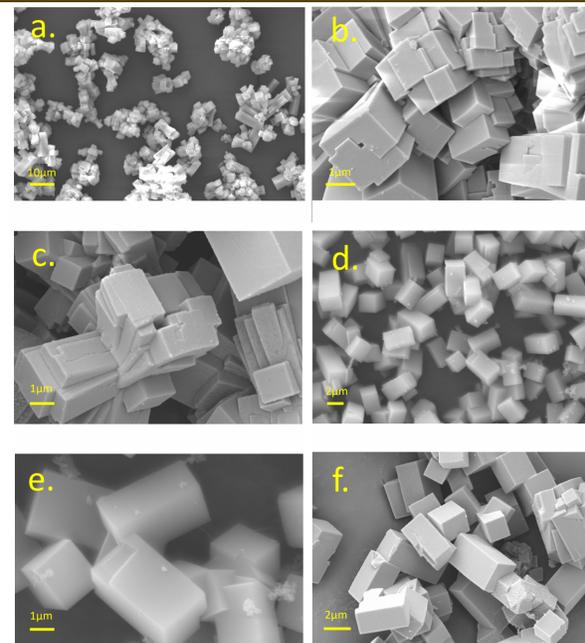


### Electrochemical Performance



### SEM Result

From (a)-(b): Pre-calcinated NVPOF with 0.05mmol Fe (c): Post-calcinated NVPOF with 0.05mmol Fe  
From (d)-(e): Pre-calcinated NVPOF with 0.30mmol Fe (f): Post-calcinated NVPOF with 0.30mmol Fe



## Discussion

- Fe doping enhances electronic conductivity and  $\text{Na}^+$  diffusion pathways, improving capacity retention
- Calcination led to better crystallinity and stable framework integrity, minimizing capacity fading
- Microwave-assisted synthesis dramatically reduced total reaction time (<30min) and energy consumption compared to conventional hydrothermal methods

## Conclusion

- Successfully synthesized Fe-doped NVPOF using a microwave-assisted method
- Identified clear relationships between dopant addition, calcination temperature, and electrochemical behavior
- Demonstrated that MW synthesis is an effective, low-energy approach for producing high-performance sodium-ion battery cathodes

## Future Work

- Explore other transition metal dopants to further improve conductivity and stability
- Systematically vary microwave temperature and calcination conditions to optimize crystallinity and morphology

## Reference

- "N/P-Dual-Doped Carbon-Coated  $\text{Na}_3\text{V}_2(\text{PO}_4)_2\text{O}_2\text{F}$  Microspheres as a High-Performance Cathode Material for Sodium-Ion Batteries" L.L. Zhang et al., ACS Appl. Mater. Interfaces, 2020, 12(3), 3670-3680
- "Sodium Superionic Conductors (NASICONs) as Cathode Materials for Sodium-Ion Batteries" Qingbo Zhou et al., Electrochemical Energy Reviews, 2021, 4, 793-823

## Acknowledgements

Linqin Mu, Kumlachew Zelalem WALLE, Yuwei Zhu, Yuan Lu, FURI Program financial support