

Preparation Conditions of Precursor Solution for Carbon-Coated $\text{Na}_3\text{V}_2(\text{PO}_4)_2\text{F}_3$

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ABSTRACT

$\text{Na}_3\text{V}_2(\text{PO}_4)_2\text{F}_3$ (NVPF) is emerging as a promising positive electrode for sodium-ion batteries due to its high operating voltage. However, its inherent low electronic conductivity is the main obstacle to practical application. Although carbon incorporation could address this issue, it also accelerates fluorine loss during synthesis, forming impurities such as $\text{Na}_3\text{V}_2(\text{PO}_4)_3$ that compromise the high operating voltage of NVPF. Herein, the synthesis conditions are systematically investigated to obtain pure phase NVPF via a direct heating of the prepared precursor. According to the analytical results, the amounts of fluorine and carbon sources play an important role in the successful synthesis of pure phase NVPF, whereas the pH of the precursor solution has an unexpectedly limited impact on impurity suppression. The sample prepared in the optimal condition achieves excellent electrochemical performance, delivering 119.5 mAh g^{-1} at 0.1C and remarkable long-term cycling stability. These findings provide insights into scalable synthesis of high-purity NVPF for sodium-ion batteries.

Keywords: Sodium-ion batteries, positive electrode, $\text{Na}_3\text{V}_2(\text{PO}_4)_2\text{F}_3$, fluorine loss, carbon-coating

1. INTRODUCTION

As a dominant technology for energy storage systems, lithium-ion batteries (LIBs) have been widely used in portable electronics, electric vehicles, and grid-level energy storage due to their high energy density, durability, and low environmental impact. However, the scarcity, high costs of lithium resources, and safety concerns associated with LIBs have compelled efforts to explore alternative technologies to meet the growing energy demands.¹ Recently, sodium-ion batteries (SIBs) have received intensive attention as a promising candidate for energy storage owing to their abundant and low-cost sodium resources.² Despite these advantages, practical applications for SIBs still face challenges including relatively low energy density and poor cycle life, primarily due to the large radius and mass of Na^+ .^{3, 4}

In this regard, positive electrode materials are crucial components that play an important role in the electrochemical performance of SIBs, affecting specific energy and power and cycle life.^{5, 6} Given that the output voltage of a battery depends on the potential difference between positive and negative electrodes, it is imperative to develop positive electrode materials with high output voltage and capacity to break through the energy density bottleneck.^{7, 8} Common positive electrode materials for SIBs include layered transition metal oxides (LTMOs), polyanionic compounds, and Prussian blue analogs (PBAs). However, both LTMOs and PBAs encounter challenges in cycling stability, which currently falls short of industry standards.^{9, 10} In contrast, polyanionic compounds with good structural integrity and open crystal framework are promising electrode materials because of their long-term cycling and thermal stability.^{11, 12}

Among polyanionic compounds, $\text{Na}_3\text{V}_2(\text{PO}_4)_2\text{F}_3$ (NVPF) stands out due to its high average working voltage (~ 3.95 V) and large theoretical capacity (~ 128 mAh g^{-1}), delivering a superior gravimetric energy comparable to commercial positive electrodes for LIBs.^{13, 14} Moreover, NVPF

has an open three-dimensional framework consisting of interconnected $[\text{V}_2\text{O}_8\text{F}_3]$ bi-octahedron and $[\text{PO}_4]$ tetrahedra, providing large channels that facilitate rapid Na^+ diffusion and minimize volume changes during Na^+ insertion/extraction.^{15, 16} Nevertheless, its further application is constrained by the low intrinsic electronic conductivity ($2.4 \times 10^{-12} \text{ S cm}^{-1}$), which leads to limited performance.^{17, 18} Carbon coating is an effective strategy to overcome this issue. Besides enabling electrode reaction, the carbon layer also buffers volume changes of NVPF and suppresses side reactions with the electrolyte.^{19, 20} However, introducing carbon materials results in more F loss during high-temperature synthesis, leading to the formation of $\text{Na}_3\text{V}_2(\text{PO}_4)_3$ (NVP) impurity.^{21, 22} This issue is evidenced by a plateau around 3.4 V in reports on carbon-coated NVPF, which reduces gravimetric energy.²³⁻²⁵ The formation of NVP can be attributed to two reactions: the formation of VF_3 during high-temperature sintering and the hydrolysis of NaF to HF under acidic conditions.^{26, 27} Thus, it is imperative to optimize the synthesis process to obtain pure phase NVPF. For instance, Deng et al.²⁸ demonstrated that adjusting the pH of precursor solution through ammonia water addition could successfully synthesize pure phase NVPF, while Li et al.²⁴ synthesized pure phase NVPF by controlling calcination temperatures below 600 °C. Excessive NaF has been added to replenish fluorine loss, but this approach introduces inert sodium salt that compromises the electrochemical performance.^{27, 29-31} Some fluorine supplements have also been explored to compensate for fluorine loss during the synthesis, such as polytetrafluoroethylene (PTFE),^{32, 33} polyvinylidene fluoride (PVDF),^{34, 35} fluorinated ionic liquid,²⁵ and NH_4F .^{36, 37} Therefore, it is of paramount importance to understand how preparation conditions and fluorine supplements affect the chemical composition and electrochemical performance of NVPF.

In this work, the synthetic conditions of NVPF are systematically investigated using a facile method with additional NH_4F as a fluorine source, focusing on the effects of pH, carbon content,

and temperature on its crystal structure, morphology, and electrochemical performance. Through a comprehensive analysis in terms of preparation conditions, the critical factors controlling the formation of an almost pure NVPF phase are prepared. The synthesized NVPF-C is characterized by X-ray diffraction (XRD) and field emission scanning electron microscopy (FE-SEM) to examine its crystal structure and morphology, respectively. Several representative samples are selected to evaluate their electrochemical performance.

2. EXPERIMENTAL SECTION

2.1 Materials and Handling.

Commercially available 1 mol dm⁻³ Na[PF₆]-EC/DMC (1:1 v/v) (Kishida Chemical, battery grade) and FEC (Fujifilm Wako Pure Chemicals) were used as received, whereas 1 mol dm⁻³ Na[PF₆]-EC/DMC with 3 wt% FEC was prepared, labeled as OE. The salts, Na[FSA] ([FSA]⁻ = bis(fluorosulfonyl)amide) and [C₃C₁pyrr][FSA] ([C₃C₁pyrr]⁺ = *N*-methyl-*N*-propylpyrrolidinium), were dried under vacuum before use. The Na[FSA]-[C₃C₁pyrr][FSA] ionic liquid electrolyte was prepared by dissolving Na[FSA] in [C₃C₁pyrr][FSA] in the molar ratio of 3:7, labeled as IL. All the air-sensitive materials and cell assembly were handled in an Ar-filled glove box (H₂O and O₂ < 1 ppm).

The NVPF-C composites were synthesized by following procedures. Firstly, stoichiometric V₂O₅ and H₂C₂O₄·2H₂O were dissolved in deionized water and stirred at 75 °C for 1 h to form a blue homogeneous solution. Then, stoichiometric NH₄H₂PO₄ and NaF were added to it, followed by the addition of NH₄F (NH₄F/V₂O₅: 1/1 in molar ratio) and sucrose in varying amounts, depending on the target sample. To investigate the pH effect, 25 wt% ammonia solution was additionally mixed with the solution. The resulting solution was continuously stirred at 80 °C for

approximately 10 h and then transferred to an oven and maintained at 120 °C overnight to obtain the precursor. The precursor was subsequently transferred to a tube furnace and preheated at 350 °C for 4 h under an 80 cm³ min⁻¹ argon flow. After grinding, the preheated sample was further heated at 600 °C (or 550 °C and 650 °C to investigate the effect of heating temperature on NVPF synthesis) for 8 h under an 80 cm³ min⁻¹ argon flow to obtain the final NVPF-C composites. No palletization was applied through this process because pressure and packing density were not controlled parameters.

2.2 Materials Characterization.

The crystallinity and purity of the synthesized materials were characterized through XRD using a Rigaku Smart Lab diffractometer with Cu-*K*α radiation (40 kV and 30 mA). Morphological and compositional analyses of these materials were performed by FE-SEM (Hitachi SU-8020) equipped with an EDX analyzer (Horiba EMAXEvolution X-max). The surface area of the samples was evaluated through nitrogen adsorption analysis based on the Brunauer–Emmett–Teller (BET) theory, conducted with a Tristar II 3020 system (Shimadzu Corp.). The particle size distribution of powder samples was determined using a particle size distribution analyzer (Microtrac MT3000 II, Nikkiso, Japan).

2.3 Electrochemical Measurements.

The positive electrodes were prepared by mixing the NVPF-C composite, Super C65 (Timcal Ltd.), and PVDF binder (poly(vinylidene fluoride), Kureha Corp.) in a weight ratio of 80:15:5 with NMP (*N*-methyl-2-pyrrolidone, FUJIFILM Wako Pure Chemical Corp.) solvent. The resulting slurry was mixed by a planetary mixer (AR-100, Thinky, Tokyo, Japan) and cast onto an Al foil (20 μm).

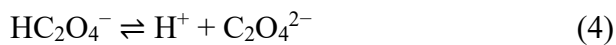
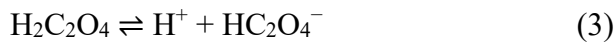
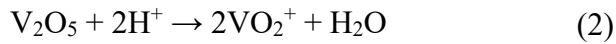
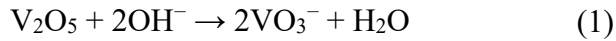
After drying at 60 °C for 4 h, the electrodes were punched (10 mm in diameter) and vacuum-dried overnight at 60 °C. The mass loading of the active materials in the electrodes was approximately 2 mg cm⁻². Sodium metal (Aldrich, 99.95 purity) was cut into a disk and fixed on an Al plate current collector as the counter electrode. Glass fiber or polypropylene (PP) separators were used in 2032-coin cells for electrochemical tests. The charge-discharge, rate, and cycling performance were measured at 25 °C with HJ-SD8 charge-discharge system (Hokuto Denko) using the thermostatic chamber (SU-242, ESPEC) in the voltage range of 2.0-4.3 V.

3. RESULT AND DISCUSSION

Figure 1 shows the schematic illustration of the synthesis route for NVPF-C. The prepared samples are listed in **Table 1** with their synthetic conditions and abbreviations. The sample name, Cx-pHy-T, indicates the theoretical carbon content calculated from sucrose *x* (wt%), pH *y* (U is unadjusted (≈ 4.3), and temperature *T* (°C). The amount of NH₄F was fixed as NH₄F/V₂O₅ = 1/1 in mol. First of all, the precursor samples prepared in the condition of carbon source = 5 wt% and pH = 7 were heated at 550, 600, and 650 °C to investigate the impact of heating temperature on the products. **Figure 2** presents XRD patterns of these samples at different heating temperatures. The main diffraction peaks of samples align well with the tetragonal NVPF structure indexed to a primitive tetragonal cell, in agreement with the previous report (the *P4₂/mnm* space group).^{38, 39} A small amount of Na₃VF₆ appears at low heating temperature and disappears as the temperature increases.⁴⁰ However, heating at 650 °C results in the appearance of the peaks at ~ 14.22 , 20.05, 20.31, 23.75, 31.57, 31.97, 35.63, and 48.63°, indicating the presence of the NVP impurity phase.⁴¹ The formation of NVP impurity is attributed to F loss, which can be explained by two side reactions:^{24, 27, 34} (1) the hydrolysis of NaF to produce HF ($H^+ + F^- \rightarrow HF$) in an acidic condition,

where volatile HF is eliminated under constant stirring and heating conditions and (2) the decomposition of NVPF to form VF₃ at high temperature ($\text{Na}_3\text{V}_2(\text{PO}_4)_3\text{F}_3 + \text{VPO}_4 \rightarrow \text{Na}_3\text{V}_2(\text{PO}_4)_3 + \text{VF}_3 \uparrow$). Reaction (2) can be prevented by lowering heating temperatures. However, reaction (1) is endothermic, and high temperature promotes the generation of HF, driving the reaction forward. In addition, the HF volatilization causes the formation of F vacancies, inducing structural defects in NVPF, which then decomposes above 600 °C. In consideration of the heating temperature effect, the heating temperature was fixed at 600 °C for further study to optimize other parameters in the preparation of NVPF.

As previously discussed, NH₄F serves as a critical source of fluorine to compensate for fluorine loss during synthesis. In addition to the sufficient supply of fluorine source, the previous study indicated that the pH of the precursor solution is a critical factor in obtaining a pure-phase NVPF.^{28, 42} For the preparation of the precursor solution, the reactions involving V₂O₅ and H₂C₂O₄ are distinct across varying pH conditions. Detailed reactions include:²⁸



The complexation reaction between H₂C₂O₄ and vanadium species may alter under different pH conditions, consequently influencing the structural evolution of NVPF and the quality of the final product. To evaluate the influence of pH, NVPF-C composites were synthesized at varying pH values (unadjusted, 5.5, 7, and 9) in the condition of carbon source = 2.5 wt% and heating temperature = 600 °C. The additional NH₄F and reduced amount of carbon sources were added to the precursor (this study also revealed that the sample with a lower carbon content is more sensitive

to impurity formation compared to C2.5-pH7-600 and C5-pH7-600). The XRD patterns for NVPF-C composites synthesized with varying pH are displayed in **Figure 3**. For the pH-unadjusted sample of C2.5-pHU-600, the predominant diffraction peaks are well-indexed to the primitive tetragonal cell of NVPF, suggesting the product is primarily composed of NVPF. However, several minor peaks corresponding to NVP are observed at ~ 19.97 , 20.29 , 23.72 , 31.57 , and 31.94° , indicating a little NVP impurity in the as-prepared sample. After pH adjustment, the number and intensity of characteristic peaks associated with the NVP phase increase, suggesting a higher level of NVP impurity in the samples. In addition, other minor peaks can be attributed to Na_3PO_4 and V_2O_3 impurities, as well as unidentified phases in trace amounts. The formation of these impurities can be attributed to the decomposition of unstable phosphate species or NVPF itself during the heating process.^{43, 44} Among the pH-adjusted samples, the composite synthesized at pH = 7 exhibits comparatively less impurity peaks, suggesting that it contains fewer impurities than those prepared at pH = 5.5 and 9.

To evaluate the electrochemical performance of the prepared C2.5 series samples, the Na/NVPF-C half cells using OE were tested in the cutoff voltage of 2.0-4.3 V. **Figure S1** compares the initial charge and discharge profiles of the cells for the C2.5 samples synthesized at different pH values at a rate of 0.1C ($1\text{C} = 128\text{ mA g}^{-1}$). For C2.5-pHU, two pairs of main voltage plateaus at $\sim 3.7/3.6\text{ V}$ and $\sim 4.2/4.1\text{ V}$ (vs. Na^+/Na) are observed during charge and discharge, corresponding to two Na^+ extraction/insertion reactions characteristic of the NVPF phase. After adjusting the pH, an additional pair of plateaus clearly appears at $\sim 3.4/3.3\text{ V}$ (vs. Na^+/Na) in all the samples, being ascribed to the presence of NVP impurity.^{24, 45} The capacity of this low-voltage plateau reflects the relative content of the NVP phase.²⁸ Notably, the longer low-voltage plateau observed for C2.5-pH5.5-600 and C2.5-pH9-600 compared to C2.5-pH7-600 indicates a lower

NVP impurity content in the sample prepared at pH = 7, which aligns with the XRD results. Furthermore, the large potential gaps between the charge and discharge curves for C2.5-pH5.5-600 and C2.5-pH9-600 may stem from the worse structural stability caused by their higher impurity levels. For C2.5-pHU-600, a slight plateau is observed at ~3.4 V in the charge/discharge profiles, consistent with the trace amount of NVP impurity detected in its XRD pattern. Although the primary goal of this study is to investigate the synthesis of pure NVPF phase, an interesting observation is that a controlled amount of NVP impurity might be beneficial for improving sodium storage performance. For example, C2.5-pH7-600 achieves the highest discharge capacity of 114.1 mAh g⁻¹, compared to 97.4 mAh g⁻¹ for C2.5-pHU-600.

Considering that C2.5-pH7 exhibits a relatively lower impurity content with the highest discharge capacity, pH = 7 was selected as the optimal pH condition for further investigation on the production of the NVPF-C composite. Moreover, it is worth noting that the amount of carbon source plays a pivotal role in the preparation process, affecting not only the crystallinity and electrical conductivity of NVPF but also the formation of the pure NVPF phase.^{23, 46} **Figure 4** compares the XRD patterns of C5-pH7-600 and C5-pHU-600 samples. Notably, all the diffraction peaks can be indexed to the tetragonal NVPF phase, confirming the successful synthesis of NVPF with less impurities in both cases. This finding suggests that the combination of increased carbon source and NH₄F addition could effectively suppress impurity formation and promote the production of pure phase NVPF. Furthermore, these results substantiate that pH adjustment is not critical for achieving phase-pure NVPF under the optimized synthetic conditions. The morphology and microstructure of the as-prepared NVPF-C composites were investigated by SEM, as shown in **Figures 5a, b** (see **Figure S2** for samples at different magnifications). Both the samples mainly exhibit micro-sized clusters of approximately 5-10 μm. The negligible morphological differences

between the two samples reveal that pH adjustment does not significantly influence the morphologies of the synthesized materials. The elemental composition and distribution of the samples were examined by EDX analyses. The resulting EDX elemental mapping demonstrates that Na, V, P, O, and F elements are uniformly distributed (see **Figure S3** for C5-pH7-600 and **Figure S4** for C5-pHU-600). The quantitative elemental analysis further indicates that the weight percent of the F element closely aligns with its theoretical value, suggesting that fluorine loss during synthesis is effectively mitigated. These observations are consistent with the XRD results.

To provide further insights into the material characteristics, the specific surface area and particle size distribution of the C5-pH7-600 sample were evaluated. **Figure 5c** depicts the BET surface area measured by nitrogen absorption-desorption isotherms. The specific surface area of C5-pH7-600 is $19 \text{ m}^2 \text{ g}^{-1}$. **Figure 5d** presents the particle size distribution measured by laser diffraction analysis in water, revealing a median diameter of $18.2 \text{ }\mu\text{m}$ for C5-pH7-600 without sonication. In addition, the actual C content of C5-pH7-600 was 3.4 wt%, obtained by combustion analysis.

Based on the systematic exploration of the synthesis conditions, the optimal parameters for obtaining NVPF-C were identified as follows: precursor preparation with a carbon content of C5, NH_4F addition at a molar ratio of $\text{NH}_4\text{F}/\text{V}_2\text{O}_5 = 1/1$, pH 7, and heating at $600 \text{ }^\circ\text{C}$. The C5-pH7-600 sample was then selected as the representative to evaluate its electrochemical performance. **Figure 6a** illustrates the galvanostatic charge and discharge curves of C5-pH7-600 in the OE electrolyte at various C-rates from 0.1C to 5C, with the first cycle at each rate shown. Two pairs of distinct and stable voltage plateaus, located at $\sim 3.7/3.6 \text{ V}$ and $\sim 4.2/4.1 \text{ V}$ (vs. Na^+/Na), correspond to the $\text{V}^{3+}/\text{V}^{4+}$ redox pair associated with the extraction and insertion of Na^+ in NVPF. As the current density increases, a gradual decrease in the voltage plateau is observed due to the internal ohmic

drop and the increasing electrode overpotential. Compared to the samples under different conditions, such as C2.5-pH7 (**Figure S1**), the charge-discharge curves of C5-pH7-600 exhibit a significantly weaker plateau around 3.4 V, suggesting that the formation of NVP impurity has been effectively suppressed, although trace amounts may still remain. Similarly, the appearance of a small plateau at ~3.25 V in the discharge curve may be attributed to trace amounts of NVP impurity that are not readily detectable by lab-scale XRD but remain electrochemically active. **Figure 6b** depicts the favorable rate capability of the C5-pH7-600 electrode, with average discharge capacities of 119.5, 118.0, 113.2, 107.5, 99.8, and 84.9 mAh g⁻¹ at 0.1, 0.2, 0.5, 1, 2, and 5C. Remarkably, when the current density is reduced back to 0.5C after 30 cycles, the discharge capacity recovers to 116.3 mAh g⁻¹, which is comparable to its initial value, suggesting outstanding rate performance and cycle stability at high rates. **Figures 6c** and **S5** demonstrate the cycle performance of C5-pH7-600 in the OE electrolyte at rates of 5C and 1C, respectively. At 5C, the electrode retains 92.2% of its initial capacity after 200 cycles. The lower capacity retention (84.5%) observed at 1C may be attributed to prolonged interfacial reactions between the electrolyte and the positive electrode material, which deteriorate the electrode structure stability. In addition, the coulombic efficiency (CE) remains close to 100% throughout the entire cycling process, further demonstrating the remarkable electrochemical reversibility of C5-pH7-600. The material based on the optimized synthesis parameters exhibits enhanced specific capacities (compared to C2.5-pHU-600 in **Figure S1**), high rate capability, and satisfactory cycling stability.

The cycle stability of C5-pH7-600 was further evaluated in the IL electrolyte (**Figure S6**) because the Na metal counter electrode exhibits low polarization and long-term stability, and a stable cathode-electrolyte interphase is formed in the IL electrolyte.⁴⁷ The high anodic stability, including Al current collector, of the IL electrode is also preferable for cycle tests.⁴⁸ Specifically,

C5-pH7-600 shows a high capacity retention of 82.4% after 1500 cycles at 2C, with an average CE of 99.9%. Moreover, the long-term cycling performance of C5-pH7-600 at 5C is presented in **Figure S7**. While the discharge capacity is lower in the IL compared to OE electrolyte, C5-pH7-600 shows higher long-term cycling stability with a capacity retention of 96.2% after 5000 cycles and an average CE of 98.9%. The lower capacity observed in the IL electrolyte may be attributed to its relatively high viscosity and low ionic conductivity compared to OE, which can limit ion transport.⁴⁹ High viscosity increases the overpotential on both electrodes, which results in steeper slopes in the charge-discharge curves and the disappearance of the second voltage plateau (not active), thus reducing the overall capacity. The exceptional cycling stability in the IL could be ascribed to the high durability of ionic liquid against redox reactions, including stabilities toward Na metal, oxidative decomposition, and Al corrosion, as well as the formation of a robust cathode-electrolyte interface layer from the oxidation of FSA⁻.^{47, 50, 51} These factors effectively minimize side reactions and preserve electrode integrity during prolonged cycling.

4. CONCLUSION

In summary, the synthesis conditions for NVPF-C were systematically investigated, considering the effects of pH, the addition of NH₄F, the amount of carbon content, and heating temperature on the preparation of the precursor solution. The results show that the formation of phase-pure NVPF is mainly controlled by the combination of NH₄F supplementation and carbon content, while the influence of pH becomes less significant when sufficient NH₄F and carbon are provided. The optimized NVPF-C sample, prepared at 600 °C with 5 wt% carbon and NH₄F addition, exhibited suppressed impurity phases and uniform particle morphology. Electrochemical measurements revealed excellent rate capability, satisfactory cycling stability, and a high discharge capacity of

119.5 mAh g⁻¹ at 0.1C in the OE electrolyte. Moreover, superior long-term cycling stability was achieved, with 96.2% capacity retention after 5000 cycles at 5C in an IL electrolyte. While achieving a pure NVPF phase is ideal for structural consistency, the presence of minor NVP impurity under controlled conditions could offer unexpected advantages for performance enhancement. This comprehensive study reveals the relationship between key synthesis parameters and phase-pure NVPF preparation, and provides a simple, low-cost, and scalable synthesis strategy for NVPF-C.

Table 1. Synthetic conditions and abbreviations for the NVPF-C samples in this work.

Abbreviation	Carbon content theoretically (wt%) ^a	pH ^b	Temperature (°C)
C5-pH7-550	5	7	550
C5-pH7-600	5	7	600
C5-pHU-600	5	Unadjusted	600
C5-pH7-650	5	7	650
C2.5-pHU-600	2.5	Unadjusted	600
C2.5-pH5.5-600	2.5	5.5	600
C2.5-pH7-600	2.5	7	600
C2.5-pH9-600	2.5	9	600

^aCarbon content denotes the amount of carbon from sucrose not the amount of carbon-coated in the final product. ^bThe pH value of pH-unadjusted precursor solutions is ~4 for C5-pHU-600 and C2.5-pHU-600.

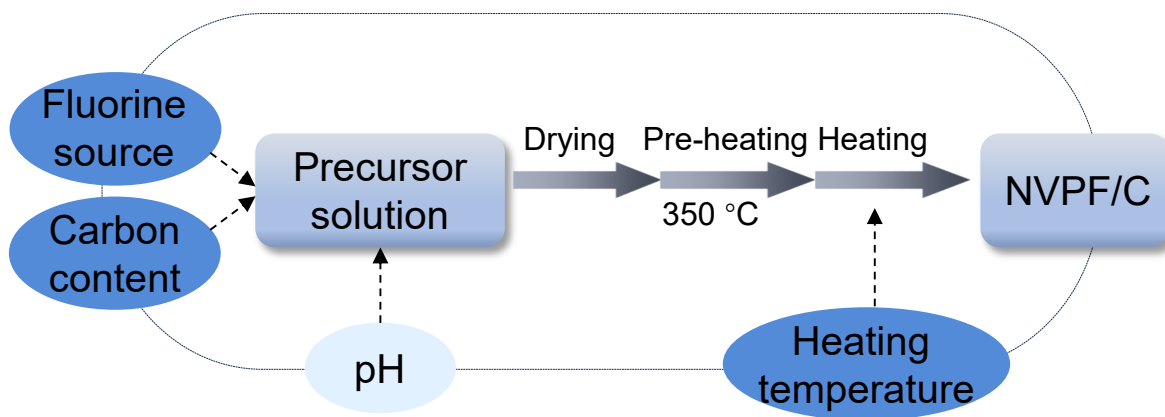


Figure 1. A schematic illustration of the NVPF-C synthesis process proposed in this study.

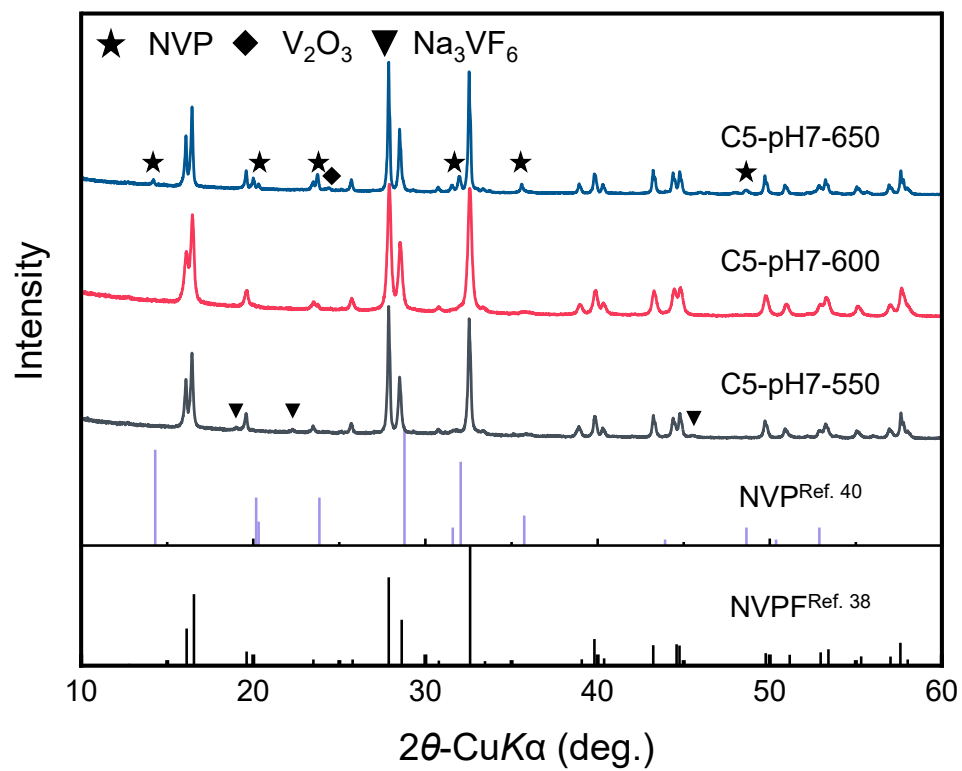


Figure 2. The XRD patterns of the NVPF-C composites synthesized at varying heating temperatures.

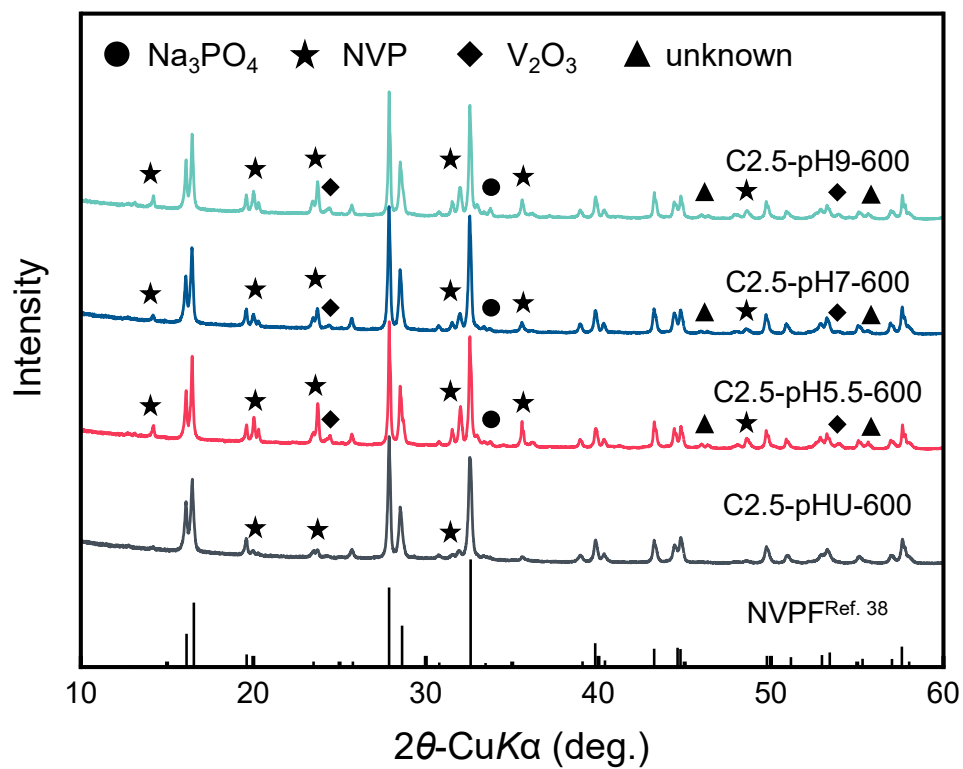


Figure 3. The XRD patterns of the NVPF-C composites synthesized at varying pH values.

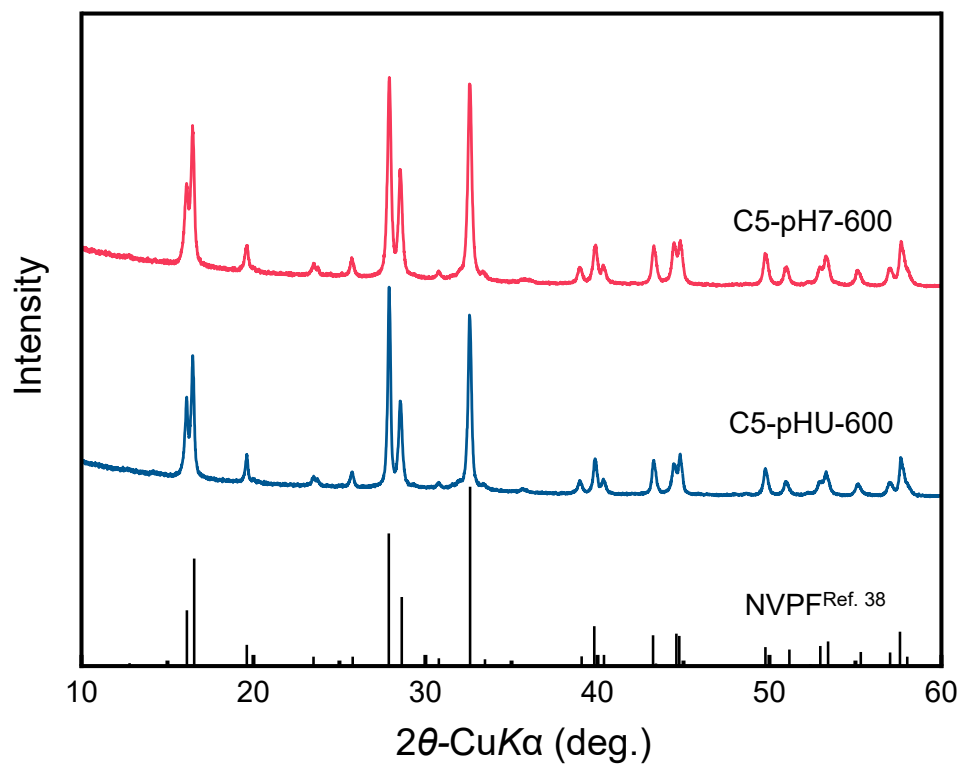


Figure 4. The XRD patterns of the NVPF-C samples at different pH values (C5-pH7-600 and C5-pHU-600).

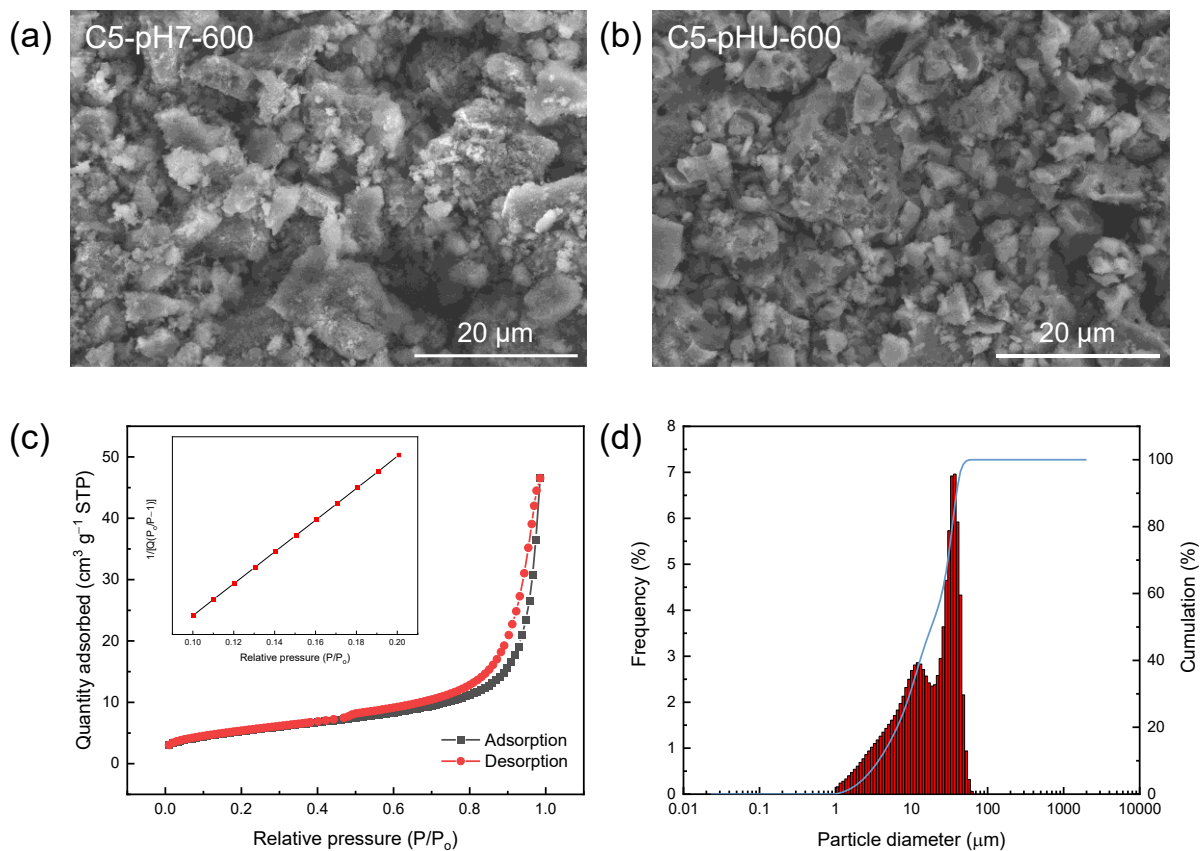


Figure 5. FE-SEM images of (a) C5-pH7-600 and (b) C5-pHU-600 samples. (c) Nitrogen adsorption-desorption isotherms and BET surface area plot (inset) for C5-pH7-600. (d) Particle size distribution of C5-pH7-600.

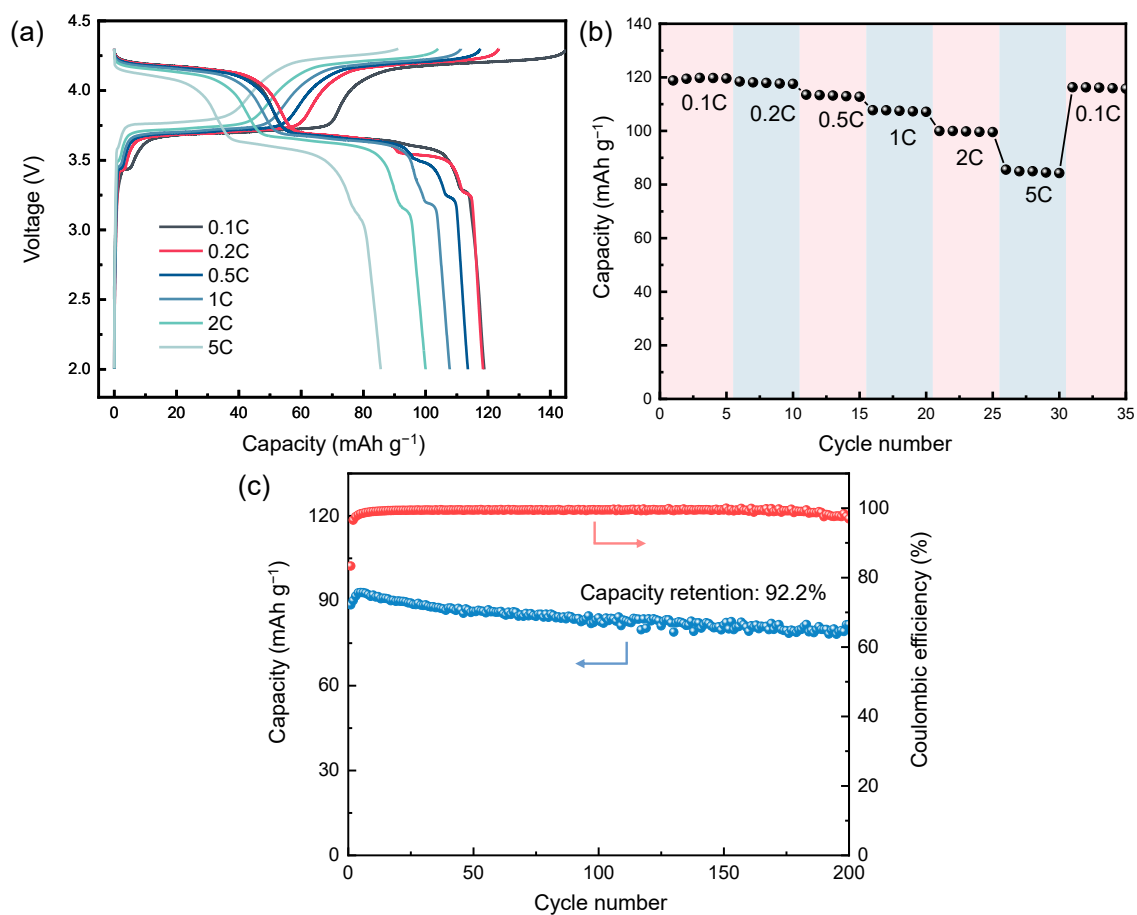


Figure 6. (a) Charge and discharge curves of the Na/C5-pH7-600 cell from 0.1C to 5C. (b) Rate capability and (c) Cycle stability of C5-pH7-600 at a rate of 5C using the OE electrolyte.

ASSOCIATED CONTENT

Supporting Information.

The Supporting Information is available free of charge at DOI: xx.

Additional experimental results of SEM, EDX, charge-discharge curves, cycling performance (PDF)

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Notes

The authors declare no competing financial interest.

ACKNOWLEDGMENT

This study was supported by collaborative research on the development of polyanion-based materials for next-generation batteries, conducted between LG Japan and Kyoto University.

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TOC GRAPHICS

