Synthesis of Hierarchical V$_2$O$_5$ Hydrate Composite Micronanostructures as Cathode Materials for Aqueous Zinc-ion Batteries with Good Performance

Hailong Fei

State Key Laboratory of Photocatalysis on Energy and Environment, College of Chemistry, Fuzhou University, Fuzhou, Fujian 350002, China
E-mail: hailongfei@fzu.edu.cn

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It is important to discover novel electrode materials and optimize the performance of existing cathode materials for aqueous zinc-ion batteries. Here, two V$_2$O$_5$·3H$_2$O composites are achieved via a facile hydrothermal route. One is flake-like V$_2$O$_5$·3H$_2$O built up with multiple platelets with surface defects in parallel or normal positions, and the other is V$_2$O$_5$·3H$_2$O composite microflowers built up with multilayered microplatelets in a radial position without surface defects. Both can be used as cathode materials for aqueous zinc-ion batteries. The former showed higher discharge capacity and better rate performance. The electrode of V$_2$O$_5$·3H$_2$O flakes exhibits stable discharge capacity at current densities of 50, 100, 250, 500, 750, 1000, 1500 and 50 mAg$^{-1}$. The capacity retention is 90.3% after 80 cycles from 237.2 mAhg$^{-1}$ to 214.1 mAhg$^{-1}$. While V$_2$O$_5$·3H$_2$O microflowers do not exhibit stable discharge capacity at current densities of 50, 100, 250, 500, 750, 1000, 1500 and 50 mAg$^{-1}$. The capacity retention is 47.96% after 80 cycles from 223.9 mAhg$^{-1}$ to 107.4 mAhg$^{-1}$. The difference in cycling performance can be ascribed to surface defects and different compositions.

Keywords: Paramontroseite VO$_2$; Hollow microspheres; Anode; Lithium-ion battery; Cathode

1. INTRODUCTION

Currently, great interest is being shown in zinc-ion batteries for their large-scale energy storage and portable electronic applications due to their low cost, material abundance, high safety, acceptable energy density and environmental friendliness [1]. The concern mainly focuses on the design and synthesis of various electrode materials for aqueous zinc-ion batteries with improved properties in capacities, cycling stability, voltage and electrolyte properties [2], such as manganese oxide [3], and polypyrrole [4].

It is important to determine a suitable cathode with high energy density and voltage for batteries. Vanadium-based materials are the most fascinating materials for energy storage in aqueous
zinc-ion batteries due to their high capacity and excellent cycling stability at high discharge rates, which are even better than lithium-ion batteries. A series of promising cathode materials have been developed in recent years. \( \text{Zn}_{0.25} \text{V}_2 \text{O}_5 \cdot \text{nH}_2 \text{O} \) showed a reversible \( \text{Zn}^{2+} \) ion (de) intercalation storage process at fast rates, resulting in a capacity up to 300 mAhg\(^{-1}\) and a capacity retention of more than 80% over 1,000 cycles [5]. VS\(_6@\text{rGO}\) electrodes deliver a capacity of 180 mAhg\(^{-1}\) with a capacity retention of 93.3% after 165 cycles at a current density of 1 Ag\(^{-1}\)[6]. (NH\(_4\))\(_2\)\(\text{V}_{10} \text{O}_{25}\)·8H\(_2\)O nanobelts have a discharge capacity of 123.6 mAhg\(^{-1}\) with a capacity retention of 94.2% after 5000 cycles at a current density of 5 A g\(^{-1}\), ascribed to large layer distance [7]. The discharge capacity of Li\(_x\)\(\text{V}_2 \text{O}_5\)·nH\(_2\)O is 232 mAhg\(^{-1}\) at a current density of 5 A g\(^{-1}\) after 500 cycles due to the expansion of the \(\text{V}_2 \text{O}_5\)·nH\(_2\)O layer distance [8]. Ca\(\text{V}_6\)\(\text{O}_{16}\)·3H\(_2\)O microwires have a discharge capacity between 160 and 170 mAhg\(^{-1}\) at a current density of 5 A g\(^{-1}\) after 300 cycles [9]. K\(_2\)\(\text{V}_8\)\(\text{O}_{21}\) has a discharge capacity of 185 mAhg\(^{-1}\) at a current density of 5 A g\(^{-1}\) after 100 cycles [10]. However, V\(_{10}\)\(\text{O}_{24}\)·12H\(_2\)O had a capacity of 164.5 mAhg\(^{-1}\) at a high current density of 10 Ag\(^{-1}\) [11]. Sodium vanadate hydrate (Na\(\text{V}_3\)\(\text{O}_8\)·1.5H\(_2\)O) nanobelts serve as positive electrodes and zinc sulfate aqueous solution with sodium sulfate additive is used as the electrolyte and shows a high reversible capacity of 380 mAhg\(^{-1}\) and capacity retention of 82% over 1000 cycles. The excellent performance is ascribed to simultaneous proton, and zinc-ion insertion/extraction processes [12]. The discharge capacity of NH\(_4\)\(\text{V}_4\)\(\text{O}_{10}\) reaches 255.5 mAhg\(^{-1}\) at a current density of 10 Ag\(^{-1}\) after 1000 cycles [13]. The H\(_2\)\(\text{V}_3\)\(\text{O}_8\) NW/graphene composite exhibits superior zinc ion storage performance including a high capacity of 394 mAhg\(^{-1}\) at 1/3 C, a high rate capability of 270 mAhg\(^{-1}\) at 20 C and excellent cycling stability of up to 2000 cycles with a capacity retention of 87% [14]. H\(_2\)\(\text{V}_3\)\(\text{O}_8\) nanowires exhibit a capacity of 423.8 mAhg\(^{-1}\) at 0.1 Ag\(^{-1}\), and good cycling stability with a capacity retention of 94.3% over 1000 cycles, which is attributed to the larger spacing of H\(_2\)\(\text{V}_3\)\(\text{O}_8\) [15]. We also first tested H\(_6\)\(\text{V}_4\)\(\text{O}_{10}\) microspheres as cathode materials for aqueous zinc-ion batteries, which had a capacity retention of 238.8 mAhg\(^{-1}\) and 87.8% after 26 cycles [16]. It can be found that vanadium oxides and vanadates with hydrate, valence between V\(^{4+}\) and V\(^{5+}\) and a large interlayer distance above 0.9 nm are ideal high-energy cathode materials for aqueous zinc-ion batteries except their lower operation voltage. A suitable vanadium-based cathode with high energy density and voltage for aqueous zinc-ion batteries is being pursued.

Organic pillar preintercalated \(\text{V}_2 \text{O}_5\)·3H\(_2\)O nanocomposites maintain a considerable a capacity of 133 after 1000 cycles at a high current density of 10 Ag\(^{-1}\) owing to the interlayer expansion of organic molecules and the enlarged interlayer and mixed valence [17]. However, in the reference, there is no comparison of \(\text{V}_2 \text{O}_5\)·3H\(_2\)O with the original interlayer distance cathode performance for aqueous zinc-ion batteries. Na- and K-ion intercalated \(\text{V}_2 \text{O}_5\)·3H\(_2\)O nanostructures could be high-performance symmetric electrochemical capacitors [18]. There are few reports on the rare material of \(\text{V}_2 \text{O}_5\)·3H\(_2\)O [19]. Herein, we have developed a straightforward way to prepare two \(\text{V}_2 \text{O}_5\)·3H\(_2\)O microstructure composites. One is Navajoite \(\text{V}_2 \text{O}_5\)·3H\(_2\)O with impurities of \(\text{V}_2 \text{O}_2(\text{OH})_3\) microflowers and the other is Navajoite \(\text{V}_2 \text{O}_5\)·3H\(_2\)O-\(\text{V}_4\)\(\text{O}_{17}\)-\(\text{H}_0.37\)\(\text{VO}_2\) composite microplates. The electrochemical properties of \(\text{V}_2 \text{O}_5\)·3H\(_2\)O for aqueous zinc-ion batteries were improved via the control of surface defects and composition. \(\text{V}_2 \text{O}_5\)·3H\(_2\)O-\(\text{V}_4\)\(\text{O}_{17}\)-\(\text{H}_0.37\)\(\text{VO}_2\) composite microplates showed better cycling stability and excellent rate performance as the cathode material for aqueous zinc-ion batteries.
2. EXPERIMENTAL PROCEDURE

In a typical procedure for the preparation of flake-like \( \text{V}_2\text{O}_5\cdot3\text{H}_2\text{O} \) composites, 30 ml 0.5 mol/L ammonium vanadate, 0.4 mol/L g oxalic acid solution and 0.1 mol/L LiNO\(_3\) were mixed and stirred for 2 h in a beaker at room temperature. After that, the pH of the solution was adjusted to 9, transferred to a 50 ml autoclave, sealed, and heated at 180 °C for 24 h. Then the autoclave was cooled to room temperature. The black-green precipitation was centrifuged and dried at 110 °C for 3 h. For comparison, the pH of the solution was adjusted to 8 under the identical conditions, and a flower-like \( \text{V}_2\text{O}_5\cdot3\text{H}_2\text{O} \) composite was achieved.

Scanning electron microscopy (SEM) was performed with a Hitachi S-4800 field emission scanning electron microscope. Transmission electron microscopy (TEM) was performed with USA FEI-Tecnai G2. X-ray diffraction (XRD) were collected with a PANalytical, and X’Pert diffractometer. A Land CT2001A battery tester controlled the cycling performance of the battery. Cyclic voltammetry (CV) was performed with a Chi660E electrochemical workstation. Electrochemical measurements were performed with a DH7001 electrochemical test system (Jiangsu Donghua Analytical Instruments Co., Ltd.).

Both flake-like and flower-like \( \text{V}_2\text{O}_5\cdot3\text{H}_2\text{O} \) were tested as cathode materials for aqueous zinc-ion batteries. The active material, a conductive material (superpure carbon) and binder polyvinylidene difluoride (PVDF) were pasted onto the graphite paper in a weight ratio of 7/2/1. The Zn foil was the counter electrode. The electrolyte was 1 M ZnSO\(_4\) aqueous solution.

3. RESULTS AND DISCUSSION

![Figure 1](image-url).

**Figure 1.** Wide-angle powder XRD patterns of samples (a) \( \text{V}_2\text{O}_5\cdot3\text{H}_2\text{O} \) flakes, (b) \( \text{V}_2\text{O}_5\cdot3\text{H}_2\text{O} \) microflowers

X-ray diffraction (XRD) patterns confirm that the crystalline structure of samples prepared at a pH value of 9 was Navajoite \( \text{V}_2\text{O}_5\cdot3\text{H}_2\text{O} \) with impurities of \( \text{V}_4\text{O}_7 \) and \( \text{H}_{0.37}\text{V}_2\text{O}_2 \) (JCPDS 07-0332), as
shown in Fig. 1a. The sample prepared at a lower pH of 8 is also ascribed to Navajoite V$_2$O$_5$·3H$_2$O with impurities of V$_2$O$_2$(OH)$_3$ (JCPDS 07-0332) in Fig. 1b. Obviously, the latter has a weaker crystalline structure for fewer diffraction peaks than the former.

SEM images show that the sample prepared at a pH of 9 has a morphology of flakes (Fig. 2), which are between 8 and 14 μm long (Fig. 2a), several hundred nm thick. The surfaces of some flakes are not smooth and covered with thin parallel plates in the vertical position. This unique morphology is rare for vanadium-based materials. Other flakes are completely built up with platelets in the parallel position. Fig. 2b clearly shows the border of these flakes. TEM was further performed to observe the surface characteristics of the flakes, as shown in Fig. 2c. Certain platelets are composed of three layers of thin platelets. The surfaces of platelets have macropores, a long gap and many crystalline finger-like intervals, as shown in Fig. 2c. The magnified TEM image shows that the long gaps are also composed of crystalline finger-like intervals, as shown in Fig. 2d. Therefore, V$_4$O$_7$ microflakes were built up with multiple platelets with surface defects in the parallel parallel or normal position.

**Figure 2.** SEM images of samples prepared at a pH value of 9 (a, b) and the corresponding TEM images (c, d).

Fig. 3 shows SEM and TEM images of Navajoite V$_2$O$_5$·3H$_2$O with impurities of V$_2$O$_2$(OH)$_3$. It has a morphology of microflowers composed of microplatelets as shown in Fig. 3a. The large microflower can be up to 16.5 μm long and 8 μm wide. The magnified SEM image shows that these
microplatelets are so thin that some microplatelets become curved, as shown in Fig. 3b. The thickness of these microplatelets is approximately 30 - 40 nm thick. Fig. 3c is the TEM image of certain small microflowers. It can be clearly found that this microflower is built up with multilayered microplatelets in a radial position. The magnified SEM image confirms that the surface of microplatelets is smooth without any defects in Fig. 3d.

![SEM images of samples prepared at a pH value of 8 (a, b) and the corresponding TEM images (c, d).](image)

**Figure 3.** SEM images of samples prepared at a pH value of 8 (a, b) and the corresponding TEM images (c, d).

Both V$_2$O$_5$·3H$_2$O flakes and V$_2$O$_5$·3H$_2$O microflowers are found to be potential electrode materials for aqueous zinc-ion batteries. V$_2$O$_5$·3H$_2$O microflowers show higher discharge capacity and better cycling stability. Cyclic voltammetry (CV) was further performed to study the zinc-ion intercalation for V$_2$O$_5$·3H$_2$O flakes and microflowers. The first CV curve of the V$_2$O$_5$·3H$_2$O flake presents one cathodic peak at 0.396 V in Fig. 4a, which shifts to 0.435, 0.449 and 0.482 V after three sequent cycles. Zinc ions can be reversibly intercalated at approximately 0.5 V for V$_2$O$_5$·3H$_2$O flakes. In V$_2$O$_5$·3H$_2$O microflowers, no extra cathodic peaks appear which implies that zinc-ions cannot be reversibly intercalated to impurities of V$_4$O$_7$ and H$_{0.37}$VO$_2$. More peaks appear in the V$_2$O$_5$·3H$_2$O
composite microflower CV curves in Fig. 4b. Similar catholic peaks to $V_2O_5\cdot3H_2O$ flakes are at 0.373, 0.429, 0.439 and 0.445 for the first, second, third and fourth cycles, respectively. However, two pairs of new peaks, (0.599, 0.800) and (0.792, 0.991), appear in the second cycle.

Figure 4. Cyclic voltammograms of samples (a) $V_2O_5\cdot3H_2O$ flakes, (b) $V_2O_5\cdot3H_2O$ microflowers.

Figure 5. The 1st, 2nd and 20th charge-discharge profiles of $V_2O_5\cdot3H_2O$ flakes /Zn cell at a current density of 50 mAg$^{-1}$ (a), the cyclic performance at current densities of 750, 1000 and 2000 mAg$^{-1}$ (b) and its corresponding evolution of the reversible capacity at current densities of 50, 100, 250, 500, 750 1000, 2000 and 50 mAg$^{-1}$ using 0.05-1.3 V potential window (c).
The (0.792, 0.991) pair of peaks disappeared, while (0.599, 0.800) was intact in the third and fourth cycles. Zinc-ion can be reversibly intercalated to impurity phase $\text{V}_2\text{O}_5(\text{OH})_3$ in $\text{V}_2\text{O}_5\cdot3\text{H}_2\text{O}$ microflowers. It is clear that the number and sites of zinc-ion intercalation can be controlled by selecting suitable impurity phases.

Fig 5a shows the charge-discharge curves of $\text{V}_2\text{O}_5\cdot3\text{H}_2\text{O}$ flakes at a current density of 50 mAg$^{-1}$. The charge curves are nearly the same. The 1$^{\text{st}}$, 2$^{\text{nd}}$ and 20$^{\text{th}}$ discharge capacities are 209.0, 219.7 and 217.1 mAhg$^{-1}$, respectively. The electrode of the $\text{V}_2\text{O}_5\cdot3\text{H}_2\text{O}$ flakes can cycle 500 cycles at current densities of 750, 1000 and 2000 mAg$^{-1}$ with second discharge capacities of 130.3, 87.9 and 40 mAhg$^{-1}$, respectively. After 500 cycles, the discharge capacities are up to 120.0, 101.8 and 50.1 mAhg$^{-1}$. The capacity retentions are 92.1%, 115.8% and 125.2% for current densities of 750, 1000 and 2000 mAhg$^{-1}$, respectively. The corresponding discharge rate capability of $\text{V}_2\text{O}_5\cdot3\text{H}_2\text{O}$ flakes is also tested at current densities of 50, 100, 250, 500, 750, 1000, 1500 and 50 mAg$^{-1}$, which exhibits stable discharge capacity in Fig. 5c. The capacity retention is 90.3% after 80 cycles from 237.2 mAhg$^{-1}$ to 214.1 mAhg$^{-1}$.

Figure 6. (a) The 1$^{\text{st}}$, 2$^{\text{nd}}$ and 20$^{\text{th}}$ charge-discharge profiles of $\text{V}_2\text{O}_5\cdot3\text{H}_2\text{O}$ microflowers / Zn cell at a current density of 50 mAg$^{-1}$ (a), the cyclic performance at current densities of 750, 1000 and 2000 mAg$^{-1}$ (b) and its corresponding evolution of the reversible capacity at current densities of 50, 100, 250, 500, 750, 1000, 2000 and 50 mAg$^{-1}$ using 0.05-1.3 V potential window(c)

The same electrochemical performance was also obtained for the electrode of $\text{V}_2\text{O}_5\cdot3\text{H}_2\text{O}$ composite microflowers. Fig. 6a shows the charge-discharge curves at a current density of 50 mAg$^{-1}$. There is a large big bias between the charge curves because of polarization. The 20$^{\text{th}}$ discharge curves are different from the 1$^{\text{st}}$ and 2$^{\text{nd}}$ discharge curves. The first, second and twentieth discharge capacities
are 196.4, 197.9 and 112.3 mAhg\(^{-1}\), respectively. The electrode of the \(\text{V}_2\text{O}_5\cdot3\text{H}_2\text{O}\) microflowers cannot stably cycle between 500 cycles at current densities of 750, 1000 and 2000 mAg\(^{-1}\), in addition, the discharge capacity is lower in Fig. 6b. The second discharge capacities at current densities of 750, 1000, and 2000 mAg\(^{-1}\) are 130.3, 87.9 and 40 mAhg\(^{-1}\), respectively. The corresponding discharge rate capability of \(\text{V}_2\text{O}_5\cdot3\text{H}_2\text{O}\) microflowers was also tested at current densities of 50, 100, 250, 500, 750, 1000, 1500 and 50 mAg\(^{-1}\), which does not exhibit stable discharge capacity in Fig. 6c. The capacity retention is 47.96\% after 80 cycles from 223.9 mAhg-1 to 107.4 mAhg\(^{-1}\). The acceptable electrochemical performance of the two \(\text{V}_2\text{O}_5\cdot3\text{H}_2\text{O}\) composites is ascribed to their novel micronanostructures [20-24] and the presence of 3H\(_2\)O. Ultrathin \(\text{V}_2\text{O}_5\cdot4\text{VO}_2\cdot2.72\text{H}_2\text{O}\) nanobelts can effectively shorten the Zn\(^{2+}\) diffusion path, which contributes to a good contribution to good cycling performance for aqueous rechargeable zinc-ion batteries [25]. 3D Ti\(_3\)C\(_2\)T\(_x\)@MnO\(_2\) microflowers delivered a high capacity of 301.2 mA h g\(^{-1}\) at 100 mA g\(^{-1}\) as the cathode for an aqueous zinc-ion batteries with a high tapping density (1.52 g cm\(^{-3}\)), fast charge-transfer kinetics and superior structural integrity [26]. Under our experimental conditions, we found that the \(\text{V}_2\text{O}_5\) electrode showed a very low discharge capacity and poor cycling stability. Both electrolyte and material structures play an important role in the cycling stability and rate performance of aqueous zinc-ion batteries. Most \(\text{V}_2\text{O}_5\) based cathode materials showed a higher discharge capacity at a high discharge rate in the presence of a high concentration and expensive \(\text{Zn(CH}_3\text{F}_3\text{SO}_3\text{)}_2\) electrolyte[27-40], as listed in Table 1. In this paper, we achieved good cycling and rate performance with a low concentration of ZnSO\(_4\) electrolyte.

**Figure 7.** The fitted and original Nyquist-diagram of (a) \(\text{V}_2\text{O}_5\cdot3\text{H}_2\text{O}\) flakes, (b) \(\text{V}_2\text{O}_5\cdot3\text{H}_2\text{O}\) microflowers (The top is the fitting impedance circuit model).
Table 1. The reported V$_2$O$_5$ based cathode materials for zinc-ion batteries

<table>
<thead>
<tr>
<th>Ref.</th>
<th>Materials</th>
<th>Voltage (vs. Zn$^{2+}$/Zn) (V)</th>
<th>Electrolyte</th>
<th>Discharge capacity (mAh g$^{-1}$)</th>
<th>Current density (Ag$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>V$_2$O$_5$ hollow spheres</td>
<td>0.2-1.6</td>
<td>3.65 mol L$^{-1}$</td>
<td>132</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ZnSO$_4$ aqueous solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>skin-core</td>
<td>0.2-1.8</td>
<td>2M Zn(CH$_3$F$_3$SO$_3$)$_2$</td>
<td>191.7</td>
<td>0.3</td>
</tr>
<tr>
<td></td>
<td>NaV$<em>6$O$</em>{15}$/V$_2$O$_5$</td>
<td></td>
<td>aqueous solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>3D porous architectures</td>
<td>0.4-1.6</td>
<td>1 M Zn(ClO$_4$)$_2$ in propylene carbonate</td>
<td>336</td>
<td>0.05</td>
</tr>
<tr>
<td></td>
<td>V$_2$O$_5$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>V$_2$O$_5$ nanopaper</td>
<td>0.2-1.6</td>
<td>2 M ZnSO$_4$</td>
<td>335.1(100)</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>aqueous solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Cu$^{2+}$- intercalated V$_2$O$_5$</td>
<td>0.3-1.4</td>
<td>2 M ZnSO$_4$</td>
<td>180</td>
<td>10</td>
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<td></td>
<td></td>
<td></td>
<td>aqueous solution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Vanadium pentoxide</td>
<td>0.01-1.4</td>
<td>3 M Zn (CF$_3$SO$_3$)$_2$</td>
<td>503.1</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>nanosheets grown on</td>
<td></td>
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</table>
The electrochemical impedance measurements elucidate the electrochemical difference in \( V_2O_5 \cdot 3H_2O \) composite flakes and \( V_2O_5 \cdot 3H_2O \) composite microflower electrode as shown in Fig. 7. The fitted equivalent electrical circuit model is on the top of Fig. 7a. R is an active electrolyte resistance and CPE is the double-layer capacitance. The impedance of a faradaic reaction is made up of an active
charge transfer resistance $R_{ct}$ and a specific electrochemical element of diffusion $ZW$ called the Warburg element.

The fitted values of $R$, $R_{ct}$ and $Z_W$ are 4.701, 108.9, and $8.364 \times 10^{-3}$ $\Omega$ for $V_2O_5 \cdot 3H_2O$ composite flakes, while 4.694, 90.27 and $7.114 \times 10^{-3}$ $\Omega$ for $V_2O_5 \cdot 3H_2O$ composite microflowers, respectively. The $V_2O_5 \cdot 3H_2O$ composite microflowers have smaller charge transfer and Warburg resistance than $V_2O_5 \cdot 3H_2O$ composite flakes. However, $V_2O_5 \cdot 3H_2O$ composite flakes are more stable than the $V_2O_5 \cdot 3H_2O$ composite microflowers during the process of inserting/deinserting zinc ions. The low $R_{ct}$ shows a fast zinc-ion intercalation kinetics and the small Warburg impedance favors the fast diffusion of zinc ions on the interface between the active material and electrode [41-44]. The fast zinc ion intercalation and diffusion will destroy the crystalline structure of the $V_2O_5 \cdot 3H_2O$ composite, resulting in fast discharge capacity decay. This is the reason that $V_2O_5 \cdot 3H_2O$ composite flakes have better electrochemical properties than $V_2O_5 \cdot 3H_2O$ composite microflowers.

4. CONCLUSIONS

Navajoite $V_2O_5 \cdot 3H_2O$ with impurities of $V_2O_5(OH)_3$ microflowers and Navajoite $V_2O_5 \cdot 3H_2O-V_4O_7 \cdot 3H_2O$ composite microplates were selectively prepared via a facile hydrothermal route. The latter showed higher discharge capacity and better rate performance ascribed to surface defects and different compositions. This research sheds some light on the design and application of electrode materials with surface defects.

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References


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