Article

**Vanadium Carbide (V\textsubscript{4}C\textsubscript{3}) MXene as an Efficient Anode for Li-Ion and Na-Ion Batteries**

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**Abstract:** Li-ion batteries (LIBs) and Na-ion batteries (SIBs) are deemed green and efficient electrochemical energy storage and generation devices; meanwhile, acquiring a competent anode remains a serious challenge. Herein, the density-functional theory (DFT) was employed to investigate the performance of V\textsubscript{4}C\textsubscript{3} MXene as an anode for LIBs and SIBs. The results predict the outstanding electrical conductivity when Li/Na is loaded on V\textsubscript{4}C\textsubscript{3}. Both Li\textsubscript{1.5}V\textsubscript{4}C\textsubscript{3} and Na\textsubscript{2.5}V\textsubscript{4}C\textsubscript{3} (x = 0.125, 0.5, 1, 1.5, and 2) showed expected low-average open-circuit voltages of 0.38 V and 0.14 V, respectively, along with a good Li/Na storage capacity of (223 mAh/g\textsuperscript{−1}) and a good cycling performance. Furthermore, there was a low diffusion barrier of 0.048 eV for Li\textsuperscript{+}V\textsubscript{4}C\textsubscript{3} and 0.023 eV for Na\textsuperscript{+}V\textsubscript{4}C\textsubscript{3}, implying the prompt intercalation/extraction of Li/Na. Based on the findings of the current study, V\textsubscript{4}C\textsubscript{3}-based materials may be utilized as an anode for Li/Na-ion batteries in future applications.

**Keywords:** V\textsubscript{4}C\textsubscript{3}; MXene; Li-ion battery; Na-ion battery; electrochemical energy storage; DFT

1. **Introduction**

The everlasting consumption of fossil fuels leads to their depletion and greenhouse gas emissions, which are the primary cause of global warming [1–3]. A variety of endeavors are currently being dedicated to address these issues, including gas conversion reactions [4,5] and utilizing sustainable energy sources (i.e., solar power [6,7], hydrogen power [8], fuel cells [9,10], and energy storage devices [11–15]). Li-ion batteries (LIBs) and Na-ion batteries (SIBs), with their high energy, power density, and long cycle life, are among the most beneficial electrochemical energy conversion and storage technologies available for smart grids, mobile electronics, and electric vehicles [16–18]. The performance of LIBs and SIBs is primarily shaped by the electrochemical properties of the anode materials [16,17]. Graphitic carbon is the universally utilized commercial anode material, but its low Li/Na theoretical capacity (372/25 mAh/g) and low rate capability limit its widespread, practical use [19]. Despite the significant progress in LIBs and SIBs, the earth availability of Li/Na, charge time, durability, temperature tolerance, self-discharge, and recyclability of the decayed batteries are creating a significant challenge [16–22]. Therefore, developing novel anodes with high specific capacities, greater rate capabilities, and cycling longevity is imperative.

MXenes are a novel class of 2D transition metal carbide/carbonitride electrodes that have several advantages for LIBs, SIBs, and other applications, including hydrophilicity, high active surface areas, rich electron densities, and low costs [23–25]. Numerous MXenes such as Ti\textsubscript{3}C\textsubscript{2}, Ti\textsubscript{5}C\textsubscript{2}N\textsubscript{2}, V\textsubscript{2}C\textsubscript{2}, Nb\textsubscript{2}C\textsubscript{3}, and Mo\textsubscript{2}C were utilized as anodes for LIBs, and SIBs with...
the Ti$_3$C$_2$ MXene phase has been studied most extensively [23–28]. Distinct from other MXenes, V$_4$C$_3$ MXene offers many advantages, including greater interlayer spacing, better structural durability, and high specific capacity, which are essential for the fabrication of high-performance anodes for LIBs and SIBs [29–31]. Besides its excellent mechanical properties and thermal stability, V$_4$C$_3$ MXene possesses excellent metallic properties due to its narrow band gap at the Fermi level [32,33]. Meanwhile, the vanadium metal (V) in V$_4$C$_3$ MXene has a prosperous valence state from +2 to +5, which may enhance the electrochemical performance of LIBs and SIBs [29,34,35]. For instance, the V$_4$C$_3$ MXene/MoS$_2$/C electrode significantly boosted LIB activity compared to MoS$_2$/C and MoS$_2$ electrodes, showing an outstanding reversible capability of 0.622 Ah/g at 1 A/g after 450 cycles and maintaining a superior rate capability of 0.5 Ah/g at 10 A/g [36]. That is due to the outstanding electrical conductivity, structural durability, and fast reaction kinetics promoted by V$_4$C$_3$. Likewise, V$_4$C$_3$-$T_x$ (T = O, OH, and F), which is formed by the ball milling (B.M.) of V$_4$AlC$_3$ followed by HF etching (V$_4$C$_3$-$T_x$-BM-HF), enhanced the LIB performance over V$_4$C$_3$-HF and yielded a specific capacity of 0.225 Ah/g after 300 cycles at 0.1 A/g and 0.125 Ah/g at 1 A/g because of the superior interlayer spacing and specific surface area [37]. Despite the noted progress in V$_4$C$_3$ MXene, it is rarely reported on for applications in energy storage, and usually is exclusively with regard to LIBs; to the best of our knowledge, it has not been yet addressed theoretically for both LIBs and SIBs. 

In pursuit of this aim, we employed the first principle, DFT simulation, to predict the performance of V$_4$C$_3$ MXene as an anode for LIBs and SIBs as a function of Li and Na loading. V$_4$C$_3$ MXene loaded with Li/Na was investigated for lithiation, sodiation, electrical conductivity, and surface energy. The surface energy is calculated by considering Li/Na loading on V$_4$C$_3$ with a diffusion barrier of 0.023 eV for Li and 0.048 eV for Na migration.

2. Methodology

To conduct the current DFT investigations, we employed VASP software (Vienna, Austria) known as the Vienna *Ab Initio* Simulation Package [38], whereas correlation potential and the electronic exchange were examined by utilizing a generalized gradient (GGA) combined with a Perdew–Burke–Ernzerhof (PBE) functional (GGA-PBE). This is because the GGA-PBE is a nonempirical functional with judicious accuracy for qualitative and quantitative prediction of the molecules interacting and being stored with metal surfaces over a wide range of systems [39]. In the present calculations, we restricted the force value to 1/100 eV/Å, and the energy was $1 \times 10^{-6}$ eV. Based on the GGA-PBE level, we simulated the electronic structure of V$_4$C$_3$ and Li/Na loaded V$_4$C$_3$. For plane-wave expansion, cut-off energy of 500 eV was selected. The Monkhorst–Pack technique was employed to sample the k-points in the Brillouin zone, with a dense k-point grid of $17 \times 17 \times 1$ [40]. Additionally, the DFT-D2 model [41] was applied in our calculations to acquire reliable binding strength between Li/Na and V$_4$C$_3$. In the structure of V$_4$C$_3$, we generated a vacuum space of 20 Å to prevent coupling between V$_4$C$_3$ layers.

Our simulations found that the materials under research are spin-polarized with Li/Na content loading. The voltage and energy profiles were computed with increasing Li/Na content, such that $x = 0.125, 0.25, 0.5, 1.0, 1.5, \text{ and } 2$. The electronic structure calculations were carried out within the GGA-PBE to determine the electronic density of states (DOS). The AIMD simulations were used to investigate the change in the energy fluctuation of Li/Na-loaded V$_4$C$_3$ at 300 K within each time step of 1 fs for the total time duration of 5000 fs [42]. Several Li/Na concentrations were studied to procure the binding energies and voltage profile. The relationship of binding energy is shown in Equation (1) [43]:

$$E_b = (E_{Li-V_4C_3} + nE_{Li} - E_{V_4C_3}) / n,$$

where $E_{Li-V_4C_3}$ represents the Li-loaded V$_4$C$_3$ energy, $E_{V_4C_3}$ denotes the bare V$_4$C$_3$ energy, $E_{Li}$ is the metallic Li energy, and $n$ is the number of Li content loaded on the V$_4$C$_3$ sheet. Similarly, we adopt the above formula for Na adsorption by substituting Li with Na.
to estimate $E_b$. Next, we calculate the charge density difference based on the relation: 

$$\Delta \rho (r) = \rho_{Li-V_4C_3}(r) - \rho_{V_4C_3}(r) - \rho_{Li}(r).$$

Here, $\rho_{Li-V_4C_3}$ specifies the charge density of Li-loaded $V_4C_3$, $\rho_{V_4C_3}$ denotes the charge density of bare $V_4C_3$, and $\rho_{Li}$ is the charge density of Li (isolated). For Na-loaded $V_4C_3$, a similar formulation is employed by substituting only Li with Na.

For each concentration of the $Li_xV_4C_3$ compound, the open-circuit voltage (OCV) is evaluated by Equation (2) [44]:

$$V(x_1, x_2) = \left[ E_{Li_{x1}} - E_{Li_{x2}} + (x_2 - x_1) E_{Li} \right] / (x_2 - x_1)$$

where $E_{Li_{x1}}$, $E_{Li_{x2}}$, and $E_{Li}$ are the energies of $Li_{x1}V_4C_3$, $Li_{x2}V_4C_3$, and bulk Li, respectively. A detailed discussion of the voltage profile is given in the supporting information.

The theoretical capacity (C) can be determined through Equation (3):

$$C = nF/M_{V_4C_3}$$

where $n$ denotes the number of adsorbed Li/Na atoms, $F$ defines the Faraday constant (26,801 mAh/mol), and $M_{V_4C_3}$ is the molar weight of $V_4C_3$.

The Bader charge technique was employed to calculate the amount of charge transferred from Li/Na to $V_4C_3$ (Table 1). Finally, the charging and discharging processes were investigated by using the simulation of surface barriers and minimum energy paths (MEPs) of Li/Na migration in the $V_4C_3$ monolayer with the climbing nudged elastic band (CI-NEB) method. This technique approximately justifies metal-ion batteries’ lithiation/delithiation and sodiation/desodiation mechanisms [45].

Table 1. Structural parameters of pristine $V_4C_3$ MXene and Li/Na content-loaded $V_4C_3$ ($2 \times 2 \times 1$ supercell) at $x = 0.0625$, including binding energy and charge transfer.

| Parameters | Simulated Values |
|------------|------------------|
| Ead (eV) for Li | 1-site 0.90, 2-site 0.884, 3-site 0.828, 4-site 0.897 |
| Ead (eV) for Na | 1.21, 1.16, 1.15, 1.20 |
| Charge $q$ (e) for Li | 0.84, 0.83, 0.83, 0.883 |
| Charge $q$ (e) for Na | 0.67, 0.664, 0.66, 0.665 |
| Height ($h_{b-s}$) | 6.96 Å |
| Lattice constants ($a$, $b$) | 2.90 Å |

3. Results and Discussion

3.1. Structure of $V_4C_3$ Monolayer

As a first step, we shall examine the structure of the $V_4C_3$ monolayer, which can be viewed in Figure 1a where the top and side views are shown. The structure portrays four layers of vanadium (V) and three layers of carbon (C) atoms. Each carbon layer is sandwiched between two V layers. In the relaxed structure, a unit-cell of $V_4C_3$ is composed of four V atoms and three C atoms with lattice parameters $a = b = 2.90$ Å and thickness $d = 6.96$ Å. These structural parameters are in line with the preceding results [46]. Currently, experimental data are available for the structure of $V_4C_3$ MXene; thus, it is interesting to investigate its anodic properties for LIBs and SIBs using DFT calculations. To determine the binding energies, the Li and Na are first adsorbed on $V_4C_3$ MXene. We selected four stable sites on the surface of $V_4C_3$ for Li/Na adsorption. The calculated $E_b$ of the adsorbed four sites, site-1, site-2, site-3, and site-4 are 0.90 eV, 0.884 eV, 0.828 eV, and 0.897 eV, respectively, for Li ($x = 0.0625$). Similarly, for Na ($x = 0.0625$) adsorption, the binding energies are 1.21 (site-1) eV, 1.16 eV (site-2), 1.15 eV (site-3), and 1.20 eV (site-4) as depicted in Figure 1b. Comparatively, the adsorbed site-1 possesses greater binding energy for both Li/Na adsorptions. Thus, we picked site-1 for further adsorption of Li/Na loading. To avoid the repulsive interactions between Li$^+$–Li$^+$ and Na$^+$–Na$^+$, we consider that both surfaces (top/bottom) of $V_4C_3$ MXene acquire reliable binding strength and maximum
Li/Na ion storage. Figure 1c depicts the decreasing binding energy curves with increasing Li/Na concentrations at $x = 2$. A decreasing trend in $E_b$ curves is noticeable due to the $\text{Li}^+−\text{Li}^+$ and $\text{Na}^+−\text{Na}^+$ repulsive forces. A similar pattern was also discerned in other 2D materials upon Li/Na loading [47,48]. The various optimized Li/Na-loaded content structures with front and side views are shown in Figure 2 and Figure S1, respectively. Subsequently, we found the amount of charge transferred from Li/Na to $V_4C_3$ by employing the Bader charge analysis. The amount of charge transfer from Li to $V_4C_3$ and Na to $V_4C_3$ is given in Table 1 [47–49]. A large amount of charge transfer from Li/Na to $V_4C_3$ confirms the binding energy curve (Figure 1c). The decrease in binding energy means there is a repulsion of charge due to Coulomb forces. It could be deduced from these results that there is a charge transfer from Li/Na to the $V_4C_3$ surface [47–49]. This reveals that an electrochemical reaction may occur between Li/Na and $V_4C_3$.

![Figure 1](image_url)

**Figure 1.** (a) Structural model of $V_4C_3$ MXene with top and side views and (b) stable Li/Na sites with their $E_b$ at $x = 0.0625$. (c) $E_b$ with increasing Li/Na content. The numbers 1, 2, 3, and 4 represent the adsorbed four sites site-1, site-2, site-3, and site-4, respectively.
3.2. Safety and Stability of Li/Na-Loaded V₄C₃

Volume alteration of the V₄C₃ monolayer was studied in the in-plane expansion of the V₄C₃ single-layer (Figure S2) upon Li/Na adsorption. The results reveal that the lattice parameters increased with Li/Na adsorption increments in both Li₂ₓV₄C₃ and Na₂ₓV₄C₃, whereas the highest expected lattice expansions were about ~4.31% and 6.20%, respectively. Noticeably, V₄C₃ revealed a lower volume alteration during adsorption/desorption of Li/Na than graphite [50,51]. The energy fluctuation was computed and compared to time duration at 300 K (25 °C) using AIMD simulations to estimate the change in the structure of Li₂ₓV₄C₃ and Na₂ₓV₄C₃ (x = 0.125, 0.25, 0.5, 1, 1.5, and 2) (Figure 3).

The energy fluctuation reduced with increasing Li/Na loading in both Li₂ₓV₄C₃ and Na₂ₓV₄C₃. However, the energy remained stable without any significant change over time,
as illustrated in the straight line (Figure 3). That serves as an indication of the insignificant change in the structures of Li$_2$V$_4$C$_3$ and Na$_2$V$_4$C$_3$ without any deformations during Li/Na intercalation on the time scale of 1 fs to 5000 fs, which is in line with other reports on 2D materials [52–54]. We executed our simulations up to 5 ps (5000 fs) at 300 K. These steps are enough as the structure is retained at the end of 5 ps. It is noticed that the total energy converges right after as the time duration increases. Furthermore, our results show a low energy fluctuation.

### 3.3. Voltage and Li/Na Storage Capacity

To further examine the electrochemical behavior of V$_4$C$_3$ as a Li/Na host for LIBs and SIBs, we calculated the open-circuit voltage (OCV). Here, we discuss the anodic behavior of V$_4$C$_3$ for both LIBs and SIBs. During the lithiation and delithiation processes, the anode reaction is indicated by V$_4$C$_3$ + xLi$^+$ + xe$^-$ ⇌ Li$_x$V$_4$C$_3$. In this reaction, the charges (positive) start the motion between electrolyte and electrodes while the electrons pursue their motion through the external circuit of the cell. Ignoring the impact of temperature, pressure, and entropy, the voltage profile for Li/Na-loaded V$_4$C$_3$ is plotted in Figure 4a. Since the voltage profile depends on the binding energy, it decreases with the increase in Li/Na loading. However, our average voltages are estimated at around 0.38 V and 0.14 V for LIBs and SIBs. The computed voltages are underneath the described voltages of monolayers with Li/Na adsorption, where Li$_x$SnC is 0.44 V, Li$_x$Si$_2$H$_2$ is 0.42 V, Na$_x$Si$_2$H$_2$ is 0.64 V, Na$_x$SnS$_2$ is 1.0 V, and Na$_x$SnSe$_2$ is 0.68 V [17,55,56]. Furthermore, our evaluated average voltages also satisfy the commercial anode materials (i.e., 0.11 V for graphite and 1.5–1.8 V for TiO$_2$) [57,58]. Therefore, the suitable OCV designates the monolayer V$_4$C$_3$ as the superior Li/Na host material for LIBs and SIBs. Additionally, the amount of charge transfer is confirmed by evaluating the charge density difference as shown in Figure 4b, c for Li and Na, respectively. The isosurface marked with yellow exhibits the electron deficit, whilst the blue isosurface indicates the accumulated electrons. The results showed the possible charge transfer from Li/Na to the V$_4$C$_3$ surface and subsequently probable electrochemical reaction may occur between Li/Na and V$_4$C$_3$ [47–49].

![Figure 4](image_url)

**Figure 4.** (a) Voltage plots of Li/Na. Charge density difference with front and side views of (b) Li adsorbed on site-1 and (c) Na loaded on site-1. The yellow color in (b,c) represents the electron deficit, blue is the accumulated electrons, red is V, and brown is C.

The Li/Na storage capacity of 2D V$_4$C$_3$ is computed by employing the formula [59], $C = \frac{xF}{M_{V_4C_3}}$. In this equation, the terms $x$, $F$, and $M_{V_4C_3}$ define the Li/Na content loaded on V$_4$C$_3$, the Faraday constant possesses a noted value of 26,801 mAh mol$^{-1}$, and the
molar mass is per formula unit \( V_4C_3 \), correspondingly. According to the above formula, the Li/Na storage capacity is 223.5 mAhg\(^{-1}\) with a maximum loading of Li/Na content \( (x = 2) \).

3.4. Li/Na Activation Energy Barriers

In an electrochemical cell, the fast transportation of electrons and ions is desirable in a rechargeable battery to reduce the charging and discharging time. It is necessary to diffuse the metal ion at a rapid rate as it depends on the rate capability of the battery. To investigate the energy surface of \( V_4C_3 \) with Li/Na loading, we adopted a technique recognized as the climbing image nudged elastic band (CI-NEB) technique. This method is useful for finding the activation barriers and the corresponding paths. In the case of the monolayer \( V_4C_3 \) (2 × 2 × 1 supercell), we selected three minimum energy paths (MEPs), path-I (1-2-1), path-II (2-3-2), and path-III (1-4-1), for the migration of Li/Na content \( (x = 0.0625) \) as depicted in Figure 5. Five images are incorporated between the final and initial sites for each path. The simulated activation barriers for Li migration along the three pathways are 0.048 eV (path-I), 0.064 eV (path-II), and 0.073 eV (path-III). For Na migration, the computed diffusion energy barriers along the three paths are 0.048 (path-I), 0.023 eV (path-II), and 0.065 eV (path-III). The comparison of the results was made with the prior attempts, such as with Li\(_x\)MoN\(_2\) (0.49 eV), Na\(_x\)MoN\(_2\) (0.56 eV), Li\(_x\)VN\(_2\) (0.237 eV), Na\(_x\)CP\(_3\) (0.356 eV), and Li\(_x\)B\(_3\)S (0.32 eV). The MXene \( (V_4C_3) \) is dominant over other 2D materials due to its high Li/Na charging-discharging rates and low activation barriers. Moreover, we compared the diffusivity and voltages with some well-known anodes, as depicted in Table 2. The simulated results predict low diffusion energy barriers for Li/Na on \( V_4C_3 \) compared to graphitic materials (0.277~0.47 eV) [60,61], illustrating an enhanced rate capability of the host \( (V_4C_3) \) for LIBs and SIBs.

![Figure 5](image_url)  
Figure 5. Activation pathways with their corresponding energy barriers of Na (a) and Li (b). The numbers (1-2-1, 2-3-2, and 1-4-1) represent the energy paths for the migration of Li/Na content \( (x = 0.0625) \).
Table 2. Comparison of voltages and energy barriers with Li$_x$V$_4$C$_3$ and Na$_x$V$_4$C$_3$.

| Material         | Voltage | Diffusion Barrier | Energy   | Reference |
|------------------|---------|-------------------|----------|-----------|
| Na$_x$MoS$_2$    | 0.56 V  | 0.08 eV           | NEB      | [62]      |
| Na$_x$W$_2$C     | 0.43 V  | 0.019 eV          | NEB      | [59]      |
| Na$_x$SiS        | 0.10 V  | 0.18 eV           | CI-NEB   | [63]      |
| Li$_x$WSe$_2$    | 0.67 V  | 0.24 eV           | NEB      | [64]      |
| Li$_x$SiH        | 0.42 V  | 0.18 eV           | CI-NEB   | [56]      |
| 2D K$_x$PC       | 0.69 V  | 0.26 eV           | NEB      | [65]      |
| 2D K$_x$SnC      | 0.41 V  | 0.17 eV           | NEB      | [66]      |
| 3D Li$_x$PBC$_2$ | 0.48 V  | 0.29 eV           | CI-NEB   | [67]      |
| 3D Li$_x$Si$_2$BN| 0.27 V  | 0.44 eV           | NEB      | [68]      |
| Li$_x$V$_4$C$_3$ | 0.38 V  | 0.048 eV          | CI-NEB   | This work |
| Na$_x$V$_4$C$_3$ | 0.14 V  | 0.023 eV          | CI-NEB   | This work |

3.5. Electronic Properties

Besides electronic conductivity, another essential attribute of anode materials is their superior performance. This can be assessed thoroughly to study the electronic structure, such as the density of states (DOS). Therefore, we performed the GGA-PBE calculations to establish the density of states (DOS) and partial density of states (PDOS) of pristine V$_4$C$_3$ MXene and Li/Na ($x = 0.0625$)-loaded V$_4$C$_3$ (Figure 6). Employing the GGA-PBE technique, the DOS of the monolayer V$_4$C$_3$ was expected to be of a possible metallic nature (Figure 6a). The metallic character of the bare V$_4$C$_3$ was further examined by PDOS. The main contributions occur due to the state of V $d$ and C $p$ in the conduction band. However, the other states show small contributions to electronic conductivity. The states, such as V $p$ and C $s$, mainly contribute to the valence band. These results justify the initial efforts made on electronic structures of the V$_4$C$_3$ [46].

The PDOS is depicted in Figure 5b,c after loading the Li/Na content on the supercell of V$_4$C$_3$ at an insignificant amount ($x = 0.0625$). Furthermore, the electronic structures of Li/Na-loaded V$_4$C$_3$ are inspected at $x = 0.0625$. At low Li/Na loading, the metallicity of the material is still maintained (i.e., Li$_s$ or Na$_s$). Thus, the charge carrier transfer to the conduction band is predicted to improve electronic conductivity. The enhanced electronic conductivity suggests the better performance of V$_4$C$_3$ as an outstanding host material for both LIBs and SIBs.
The metallic character of the bare V$_4$C$_3$ was further examined by PDOS. The main contributions occur due to the state of V$_d$ and C$_p$ in the conduction band. However, the other states show small contributions to electronic conductivity. The states, such as V$_p$ and C$_s$, mainly contribute to the valence band. These results justify the initial efforts made on electronic structures of the V$_4$C$_3$ [46].

Figure 6. Density of states of (a) bare V$_4$C$_3$, (b) Li$_{0.0625}$V$_4$C$_3$, and (c) Na$_{0.0625}$V$_4$C$_3$.

4. Conclusions

In summary, a first-principle DFT simulation was utilized to predict the performance of V$_4$C$_3$ MXene as an anode for LIBs and SIBs. To this end, the electronic properties, durability, voltage, storage capacity, and activation barriers of Li/Na-loaded V$_4$C$_3$ were assessed. The results displayed super performances of the Li$_2$V$_4$C$_3$ and Na$_2$V$_4$C$_3$ as anodes for LIBs and SIBs, with an average potential of 0.38 V (for Li) and 0.14 V (for Na), as well as a reasonable Li/Na storage capacity of 223 mAhg$^{-1}$ and good cycle performance. In addition, V$_4$C$_3$ reveals very low diffusion energy barriers of 0.048 eV (for LIBs) and 0.023 eV (for SIBs), indicating the possible fast lithiation/delithiation and sodiation/desodiation processes. As the Li/Na content increased, the voltage decreased from 0.8 to 0.1 V for Li V$_4$C$_3$ and from 0.5 to 0.05 V for NaV$_4$C$_3$. During Li and Na intercalation, the energy fluctuation vs. time duration revealed a straight line, implying structural stability without any apparent deformations. The process also stems from the prompt recovery of V$_4$C$_3$, structure stability during Li/Na, and ion intercalation/extraction. The presented findings may create the opportunity for further usage of V$_4$C$_3$ as an anode material for LIBs and SIBs.
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