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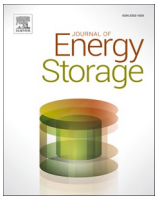

Research papers

Improved rate capability and long cycle life of metal-organic framework derived $TiO_2@V_2O_5$ composite as an efficient cathode for sodium-ion batteries

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ABSTRACT

Vanadium oxide on carbon nanoporous structure (V_2O_5/C) as a potential cathode material for sodium-ion batteries (SIBs) offers significant specific capacities in energy storage systems but suffers from slow ionic diffusivity upon long cycling at higher current rates, thereby generally resulting in substandard electrochemical performance. This study suggests a facile strategy to enhance the electrochemical performance of V_2O_5/C as a cathode in sodium-ion batteries via titanium (Ti) doping using the pre-synthesized Ti-doped vanadium-based metal-organic framework template (V-MIL-101) as the precursor, which can be converted into a sophisticated core-shell type structure in which titania nanoparticle-based shell surrounds the vanadium oxide with a porous carbon-based octahedral core. Structural characterization reveals that Ti-doping forms a protective layer around vanadium based MIL-101 octahedrons that, upon pyrolysis, preserves the octahedral geometry and transforms into a nanoporous core-shell structure. It also greatly enhances the electrochemical performance as a cathode for SIBs. The titania-doped vanadium oxide structures represent higher specific capacities than the undoped vanadium oxide cathode, whereas among all the titania-doped samples, the 3 wt% $TiO_2@V_2O_5$/C exhibited a much higher reversible capacity of 276.2 mAh/g as compared to the other cathode samples at 0.1C current rate and was able to retain a capacity of 250.1 mAh/g with a high coulombic efficiency after 200 cycles. Titanium species induce the formation of oxygen vacancies and V^{+5} species, which enhance the electrode's electric conductivity and ion diffusion—the stable octahedrons with a porous structure and carbon hybridisation in 3 wt% $TiO_2@V_2O_5$/C could facilitate ion/electron transfer through shortened diffusion pathways.

1. Introduction

The significance of energy storage systems (ESS) in addressing the intermittent nature of renewable energy generation is widely acknowledged. The primary emphasis of ongoing research and development efforts is centred on attaining enhanced efficiency and heightened safety in the context of large-scale rechargeable batteries. These batteries are intended for commercial utilization across a wide range of applications [1,2]. The primary challenges associated with attaining these objectives for lithium-ion batteries include elevated production expenses, restricted resource availability, and apprehensions regarding safety [3]. Hence, sodium-ion batteries are seen as a promising option due to their enormous global resources, few safety issues, and cost-effective raw ingredients [4,5]. Sodium ion batteries are inferior to lithium-ion in regards to their energy density due to larger size of sodium ion. Moreover, the reduction potential of sodium is also smaller as compared to that of lithium [6,7]. These challenges can be addressed through meticulous electrode material design that are intentionally engineered to possess a high density of interstitial sites and sufficiently spacious open tunnels, enabling reversible intercalation of sodium ions while accommodating their inherent dimensions [8,9]. Extensive research has been conducted on metal oxides (Na_xMO_2, where M represents 3d-orbital metals) due to their notable capacity for reversible sodium ion uptake, with an average of 0.4 to 1 sodium ion intercalated per unit

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