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Cobalt-doped tungsten suboxides for supercapacitor applications

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ABSTRACT

A crucial hurdle in developing supercapacitors is the creation of metal oxides with nanoscale structures that possess improved chemically active surfaces, ion/charge transport kinetics, and minimized ion-diffusion pathways. A metal-doping strategy to produce oxygen vacancies and increase electrical conductivity has proven effective for designing high-performance materials for energy storage devices. Herein, cobalt-doped tungsten suboxide (Co-doped $W_{18}O_{49}$) is grown on carbon cloth (CC) using a solvothermal approach and used as an electrode material for supercapacitor applications for the first time. Through this strategy, structurally distorted $W_{18}O_{49}$ is obtained by detecting a more apparent amorphous area caused by forming more oxygen vacancies with the bending of the lattice fringes. Benefiting from the synergy of more oxygen vacancies, increased lattice spacing, a high specific surface area, and accelerated ion diffusion, the Co-doped $W_{18}O_{49}$/CC electrode achieves a specific capacity of 475 C g^{-1} (792 F g^{-1}) at a current density of 1.0 A g^{-1}, which is superior to that of the undoped $W_{18}O_{49}$/CC (259 C g^{-1}, 432 F g^{-1}) and among the highest reported to date. Interestingly, the asymmetric supercapacitor device assembled using Co-doped $W_{18}O_{49}$/CC//AC/CC can provide a high energy density of 35.0 Wh kg^{-1}. This strategy proves that the distortion of the $W_{18}O_{49}$ structure by Co doping improves the ion storage performance and self-discharge behavior. Also, it can enhance the energy storage performance of other electrode materials.

1. Introduction

Efficient and low-cost electrochemical energy storage is urgently needed as the demand for electricity from intermittent renewable resources, such as wind and solar, increases sharply [1]. Recently, supercapacitors (SCs) and batteries have attracted considerable attention owing to their fascinating advances [2]. Energy storage devices have significant room to improve their performance, affordability, and environmental tolerance. Designing and engineering distinct materials is another considerably challenging aim. SCs have attracted the most attention of any energy storage technology. One of the supercapacitors' critical advantages is their high power density, which allows them to deliver much power [3]. This makes them well-suited for applications that require high power output, such as hybrid electric vehicles, regenerative braking systems, and peak power in industrial settings. Besides, they have a long cycle lifespan, meaning they can be charged and discharged many times without significant degradation in their performance. For these reasons, they are superior to other energy storage systems, such as batteries, in terms of durability and dependability. Electric double-layer capacitors (EDLCs) and pseudocapacitors are two types of charge storage in SCs [3,4]. High-surface-area materials, such as carbon nanotubes (CNTs), graphene, or activated carbon (AC), are often used in EDLCs [5]. On the other hand, pseudocapacitors store charges by using fast and stable redox processes at the electrode surface of pseudocapacitive materials, such as MoS_2, Bi_2O_3, and MnO_2, which have a higher energy density than EDLCs [6].

Improving the interface properties between the electrode/electrolyte and current collector/electrode interfaces is crucial for enhancing the electrochemical performance of energy storage systems [7]. They can affect the kinetics of ion and electron transfer, as well as the stability and durability of the device. To enhance the performance of SCs, researchers have been focusing on developing new electrode materials and optimizing the electrode/electrolyte interface. One approach is to modify the surface of the electrode materials to improve their electrochemical

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