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Waste silk fiber derived nitrogen doped reduced graphene oxide anchored nickel doped cobalt vanadate for supercapacitor applications

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ABSTRACT

The present study uses Kibisu waste silk fiber as a carbon source to synthesize nitrogen-doped reduced graphene oxide (NRGO). NRGO is anchored with nickel-doped cobalt vanadate (Ni@$Co_3V_2O_8$:Ni@CoV) and forms a stable Ni@CoV/NRGO nanocomposite. A simple solvothermal approach using deep eutectic solvents has been developed for the generation of Ni@CoV/NRGO nanocomposite. X-ray diffraction studies (XRD), Raman spectroscopic, microscopic, energy dispersive spectroscopic (EDS) and X-ray photoelectron spectroscopic (XPS) studies confirm the doping of Ni to CoV, nitrogen to the RGO matrix, and the formation of nanocomposite. Ni@CoV/NRGO showed a significant increase in the specific capacitance (Csp: 434 F g^{-1}) compared to NRGO (275 F g^{-1}) and Ni@CoV (59 F g^{-1}) at a scan rate of 2 mV s^{-1} using the cyclic voltammetry (CV) technique. Enhanced electrochemical performance in Ni@CoV/NRGO could be credited to the combination of faradaic (from Ni@CoV) and electrical double layer capacitance (NRGO) which exhibited pseudocapacitor behavior. In addition, variable oxidation states, and increased conductivity in Ni@CoV/NRGO are responsible for increased electrochemical performance. Even after 5000 cycles, Ni@CoV/NRGO showed good stability and retained 65 %. Asymmetric device (ASD) was fabricated using Ni@CoV/NRGO and activated carbon as the positive and negative electrodes, respectively. ASD showed a Csp of 146 F g^{-1} at a 2 mV s^{-1} scan rate. These findings point to Ni@CoV/NRGO as a suitable candidate for high-performance supercapacitors with a balanced energy density and power density.

1. Introduction

The growing population and evolving lifestyles, along with the widespread availability of modern conveniences, have substantially increased energy demand. This escalation has accelerated the depletion of traditional fossil fuel reserves, which have been utilized for hundreds of years [1,2]. As a result, there is a pressing need to investigate alternative, cleaner, and more sustainable energy sources, such as solar and tidal energy. Nonetheless, the intermittent availability of these renewable energy sources, affected by multiple factors, presents significant challenges. Consequently, it is essential to create efficient energy storage systems capable of reliably storing and delivering energy [3,4]. Among these systems, supercapacitors are particularly favored due to their exceptional cycle life, efficiency, power density, and energy density [5,6]. In an ideal scenario, the desired materials would possess (a) a high surface area and be nonreactive, facilitating energy release through charging at the electrode-electrolyte interface, and (b) redox-active characteristics that enhance pseudocapacitance via rapid, reversible redox reactions involving electrochemically active species [7,8]. Electrical double-layer supercapacitors commonly utilize activated carbon, reduced graphene oxide, and carbon nanotubes. As well, polymers, metal oxides, and perovskites provide pseudocapacitance through redox reactions [9,10].

Metal oxides are among the most frequently utilized pseudocapacitor

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