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Synergistic $NiCo_2S_4$/graphene quantum dot nanosheets for superior electrochemical performance in asymmetric supercapacitors

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HIGHLIGHTS

- GQDs induce hierarchical nanosheet morphology in NCS.
- Synergistic GQDs-NCS interaction boosts surface activity and charge transfer.
- NCS@GQDs-7 achieves a high specific capacitance of 1577 F g^{-1}.
- Hierarchical nanosheet ensures abundant active sites and fast kinetics.
- ASC achieves 29.25 Wh/kg energy density with 91.5 % retention over 10000 cycles.

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ABSTRACT

Nanostructured materials with diversified morphologies have proven their uniqueness in electrochemical energy storage by enhancing the charge storage performance. In particular, transition metal sulfides, known for their rich redox reactions, are extensively explored as promising electrode materials for next-generation supercapacitors. However, severe aggregation often restricts ion-accessible electroactive sites, leading to a decline in capacitance. To address this challenge, the present study synthesizes $NiCo_2S_4$(NCS)@GQDs-x composite nanosheet (NS) structures by integrating GQDs with NCS via hydrothermal method. The hierarchical nanosheet structures of NCS@GQDs-x provide abundant active sites and promote fast electron transfer due to the synergistic effect between GQDs and NCS. Among the synthesized nanocomposites, NCS@GQDs-7 exhibited superior capacitive performance (1577 F g^{-1} @ 0.5 A g^{-1}) owing to its uniformly distributed nanosheet-like morphology, excellent conductivity, and efficient electron and ion-transport pathways. Furthermore, the assembled asymmetric supercapacitor (ASC) device achieves an excellent energy density of 29.25 Wh/kg at a power density of 402 W/kg, with outstanding capacitance retention of 91.5 % even after 10000 charge-discharge cycles. The remarkable electrochemical properties of the NCS@GQDs-7 electrode may testify to one of the potential candidates in capacitive science for the development of next-generation high-performance supercapacitors.

1. Introduction

In recent years, energy storage has become one of the most popular topics of technological research. With the increasing global population, the demand for sustainable and clean energy storage devices is tremendously increasing. To reduce dependency on fossil fuels for energy production and simultaneously mitigate environmental impacts, scientists never stop finding alternative renewable energy sources that can replace conventional energy sources [1–3]. Energy storage technologies such as sodium-ion batteries, lithium-ion batteries, zinc-ion batteries, and supercapacitors (SCs) are gaining significant attention to satisfy the energy demand in the market used every day in various electronic devices [4–6]. Due to the merits of fast charging/discharging, long cycle life, and high-power density, the importance of SCs for practical applications is indispensable. However, the low energy density metrics of SCs compared to other electrochemical energy

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