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Synthesis of New Lithium-Ion Capacitor Using a Composite of NiO and rGO

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Introduction

A lot of research has been done on lithium-ion capacitors (LICs) for energy storage. Achieving a decent energy density, a suitable power density, and a steady cycle life are still difficult to achieve. For this investigation, we created a new LIC using commercial activated carbon (AC) serving as a positive material for energy storage and a NiO-rGO composite serving as a negative material. The NiO-rGO/AC system makes use of uniformly dispersed NiO nanoparticles in rGO to achieve a high specific capacity (with a current density of 0.5 A g1 and a charge capacity of 945.8 mA h g1) and uses AC to provide a sizable specific surface area and adjustable pore structure, achieving excellent electrochemical performance. The NiO-rGO/AC system, which has a mass ratio of 1:3, specifically, can achieve high energy density (98.15 W h kg1), high power density (10.94 kW kg1), and extended cycle life (with 72.1% capacity retention after 10,000 cycles). In this paper, a novel method for producing LIC devices with high energy and high power densities is presented.

Description

Energy storage technologies that operate as middlemen for clean and efficient energy are gaining increasing interest from academics in light of the current energy crisis and global pressure to reduce environmental pollution and climate change. The widespread adoption of energy storage technologies like lithium-ion batteries and supercapacitors is a result of their good electrochemical performance. The high energy density of LIBs (between 150 and 200 W h kg^{-1}) gives them an edge over rival products [1]. Their practical applications are nonetheless limited by their poor cycle life and relatively low power density (less than 100 W h kg^{-1}). The low energy density of SCs (5-10 W h kg kg^{-1}) prevents them from being used as standalone energy storage devices, despite their high power density (10 kW kg1) and outstanding cycle stability. These differences result from the differing ways that these systems store energy [2]. LIBs do this by putting lithium ions into or removing them from most electrodes, whereas SCs do so by having ions adsorb to or desorb from the surface of the electrode. Lithium-ion capacitors (LICs) have undergone extensive research to improve their electrochemical performance. The mismatch in reaction kinetics between the two electrodes is the major factor controlling how well LICs operate, and the electrode material has the biggest impact on this. Finding electrode materials with a suitable specific capacity, amazing rate performance, and great stability has thus emerged as a significant challenge. Carbon-derived materials are thought to be the ideal choice for the positive electrode, including porous carbon generated from metal-organic frameworks (MOF), activated carbon (AC), and graphene, among others. Notably, AC, which has a high specific surface area, is the most commonly used. High-conductivity materials seem like a logical choice for the anode since they match the numerous micropores and the AC positive materials [3]. Graphite and graphene are examples of embedded materials, while Fe_3O_4 is an example of a conversion material. Alloys, such as Si/Cu and SiO_2/C, are another form of anode material. Among these, metal oxides with a high specific capacitance have been employed extensively, but their rate index and stability are constrained by limited conductivity and irreversible structural changes [4]. NiO is regarded as the best transition metal oxide because of its exceptional chemical and physical characteristics, including its high theoretical capacitance and simplicity of production. The synergistic interaction between ultrafine NiO nanoparticles and graphene nanosheets allows the fabrication of materials with improved stability and rate performance in terms of electrochemical characteristics [5]. According to this study, the electrochemical characteristics of NiO-rGO composite showed good cycle stability after 200 cycles at a current density of 0.5 A g1. The capacity retention rate was 95.6% and the coulomb efficiency was 100%. The superior choice of positive material, AC, has a wide specific surface area and tunable pore structure. In order to produce positive and negative materials for LICs, AC has been developed in addition to NiO-rGO [6]. This study used commercial AC as the positive material and a NiO-rGO composite as the negative material to rationally construct a LIC. A NiO-rGO/AC LIC system that has a mass ratio of 1:2 to 1:4 (negative/positive) has also been successfully created. A 1:3 mass ratio LIC produced an energy density of 122 W h kg1, a power density of 32.3 kW kg1, and a capacity retention of 72.1% after 10,000 cycles.

Conclusion

In conclusion, a NiO-rGO composite was successfully used as the negative material in a LIC, and commercial AC was used as the positive material to create a battery with outstanding electrochemical performance. It has been demonstrated that the electrochemical performance in LIC applications can be enhanced by the incorporation of NiO with carbon-based materials. Furthermore, when lithium ions are introduced into or removed from the electrode material, the presence of graphene improves the transport of ions and electrons and successfully inhibits the volume expansion of the metal oxide. The NiO-rGO composite also had a higher specific surface area and a nanoscale ion diffusion channel that made it easier to introduce and remove lithium ions from the material. In addition to having a high reversible capacity at high current densities, the NiO-rGO composite demonstrated good reversible cycling performance at both low and high current densities. Additionally, a synergistically created NiO-rGO/AC LIC system with a mass ratio of 1:2-1:4 (negative/positive) was created. With an energy density of 98.15 W h kg^{-1}, a power density of 10.94 kW kg^{-1}, a respectable level of cycle stability, and a capacity retention of 72.1% after 10,000 cycles, the LIC with a mass ratio of 1:3 demonstrated remarkable electrochemical performance. The NiO-rGO/AC system's thoughtful design offers a lot of fantastic prospects for the creation of high-performance LICs.

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Conflict of Interest

None.

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