Abstract

The thesis, titled **"Nano-material-based Printed Micro-Supercapacitor"**, focuses on the urgent requirement for effective energy storage solutions in the swiftly advancing electronic domain. Fossil fuels, which currently account for 68% of energy use, are confronted with the issues of limited supplies and environmental consequences. Therefore, it is imperative to investigate environmentally beneficial alternatives. Although renewable sources are present, their sporadic availability emphasizes the significance of having energy storage devices to provide on-demand energy supply. Supercapacitors are becoming important competitors due to their high power density, fast charge-discharge rates, lightweight design, and long lifespan.Microscale energy storage is crucial in order to overcome the constraints of traditional batteries and capacitors. Micro-Supercapacitors (MSCs) fill the need by offering high power density, long-lasting cycle life, and fast charging capability. Nevertheless, there are still areas of research that need to be addressed in order to achieve scalable production, planar integration, flexible exploration, and the identification of suitable electrode materials for MSCs.

The present study has undertaken a systematic exploration into the electrochemical potential and practical applications of nickel selenide compounds, with a particular emphasis on Ni_6Se_5 and other stoichiometries within the nickel selenide family. Initially, we investigate a novel one-step hydrothermal synthesis technique utilized for the in-situ development of a binder-free Ni_6Se_5 electrode on nickel foam. The electrochemical performance of the Ni_6Se_5/NF electrode has been demonstrated to be exceptional, as evidenced by its sustained specific capacitance retention of 81% after 20,000 cycles and its high specific capacitance of 473.5 Fg^{-1}at a current density of 4 Ag^{-1}. Furthermore, the Ni_6Se_5/NF/AC ASC device exhibits impressive energy density metrics, registering 97.3 $Whkg^{-1}$, alongside power densities of 2325 Wkg^{-1} and 7750 Wkg^{-1}, even at an energy density of 71 $Whkg^{-1}$. When utilized as an anode material in lithium-ion batteries, Ni_6Se_5

manifests a noteworthy discharge capacity of 939.7 $mAhg^{-1}$ at a current density of 100 mAg^{-1}, retaining 87% of its initial capacity after 30 cycles. Additionally, three electrode materials derived from the nickel-selenide family are synthesized: $NiSe_2$, Ni_3Se_4, and NiSe. NiSe emerges as a standout option, demonstrating exceptional energy storage proficiency, attaining a specific capacity of 93.3 $mAhg^{-1}$ at a current density of 12 Ag^{-1}, and showcasing extraordinary cycling stability, preserving 98% of its capacity over a prolonged 30,000 charge-discharge cycles. Following that, we present screen printing as a material-compatible, scalable, and economical fabrication method for in-plane NiSe-MSC construction. In order to fabricate NiSe-MSC, the rheology of screen-printable NiSe active material ink was optimized and then applied to a flexible PET substrate positioned atop a silver current collector in the interdigitated electrode format design. Flexible symmetric NiSe-MSC shows notable energy density (5.28 mW h cm^{-3}) and power density (822.86 mW cm^{-3}). It has been determined that Nickel Selenide (NiSe) stores positive charge efficiently. Expanding upon this realization, attention is redirected towards the production of an asymmetric micro-supercapacitor. The distinctive configuration of this apparatus features a printed in-plane negative electrode made of $Ti_3C_2T_x$-Mxene and a positive electrode made of NiSe active material. The purpose of strategically incorporating these materials is to augment the energy density, specifically for use in micro-supercapacitor applications. By virtue of this distinctive configuration, energy density is augmented for micro-supercapacitor uses; it exhibits a power density of 1285.7 mW cm^{-3} and an energy density of 117.6 mW h cm^{-3}, both of which are achieved over an extended potential range of 0 to 1.8 V. The NiSe/MXene A-MSC outperforms symmetric alternatives, exhibiting impressive volumetric specific capacity, energy density, and power density. Its remarkable durability, retaining 72% of its initial capacitance after one thousand charging cycles and 81% after 250 bending cycles, underscores its potential as a flexible and enduring energy storage device.

This extensive investigation signifies a notable progress in the development of effective and dependable energy storage methods. In addition to investigating electrode materials, the discoveries provide practical options for micro-supercapacitors and flexible energy storage systems. The applications range from wearable electronics to various industrial and environmental sectors, offering a future in which cost-effective and environmentally friendly energy conversion and storage technologies are of great importance. The study also explores architectural alterations designed to improve the performance of supercapacitors, with a focus on producing in-plane micro-supercapacitors (MSCs) via layer-by-layer screen printing. The

technique, renowned for its economical nature and ease of use, is especially advantageous when combined with a current collector positioned beneath the electrode. Prior to the screen-printing process, ink rheology is carefully optimized, recognizing the crucial influence of rheological properties on the performance of supercapacitors, regardless of the specific active electrode material used.

Keywords: Supercapacitors, pseudocapacitors, nickel selenide, Mxene, flexible micro supercapacitor, micro-supercapacitors, screen printing, ink formulation.